Seventh Edition

HANDBOOK OF CHILD PSYCHOLOGY AND DEVELOPMENTAL SCIENCE

VOLUME 1

Theory and Method

Volume Editors

Willis F. Overton
Peter C. M. Molenaar

Editor-in-Chief

Richard M. Lerner

WILEY

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Cover design: Wiley

This book is printed on acid-free paper. ♾

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
Published simultaneously in Canada.

Library of Congress Cataloging-in-Publication Data:

Handbook of child psychology
Handbook of child psychology and developmental science / Richard M. Lerner, editor-in-chief.—Seventh edition.
1 online resource.
Revision of Handbook of child psychology.
Includes bibliographical references and index.
Description based on print version record and CIP data provided by publisher; resource not viewed.

ISBN 978-1-118-13677-5 (Vol. 1, cloth)
ISBN 978-1-118-13685-0 (set, cloth)
ISBN 978-1-118-95297-9 (pdf)
ISBN 978-1-118-95296-2 (epub)

1. Child psychology. I. Lerner, Richard M., editor of compilation. II. Title.
BF721
155.4—dc23 2014033068

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

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Foreword to the *Handbook of Child Psychology and Developmental Science*, Seventh Edition

WILLIAM DAMON

THE *HANDBOOK*'S DEVELOPING TRADITION

Development is one of life's optimistic ideas. It implies not just change but improvement, progress, forward movement, and some sense of positive direction. What constitutes improvement in any human capacity is an open, important, and fascinating question requiring astute theoretical analysis and sound empirical study. So, too, are questions of what accounts for improvement; what enhances it; and what prevents it when it fails to occur. One of the landmark achievements of this edition of the *Handbook of Child Psychology and Developmental Science* is that a full selection of top scholars in the field of human development have offered us state-of-the-science answers to these essential questions.

Compounding the interest of this edition, the concept of development applies to scholarly fields as well as to individuals, and the *Handbook*'s distinguished history, from its inception more than 80 years ago to the present edition, richly reveals the development of a field. Within the field of human development, the *Handbook* has had a long and notable tradition as the field's leading beacon, organizer, and encyclopedia of what's known. This latest *Handbook* edition, overflowing with insights and information that go well beyond the scientific knowledge available in previous editions, is proof of the substantial progress made by the field of human development during its still-short (by scholarly standards) history.

Indeed, the history of developmental science has been inextricably intertwined with the history of the *Handbook*. Like many influential encyclopedias, the *Handbook* influences the field it reports on. Scholars—especially younger ones—look to it to guide their own work. It serves as an indicator and as a generator, a pool of received findings, and a source for generating new insight.

It is impossible to imagine what the field would look like if Carl Murchison had not assembled a ground-breaking collection of essays on the then-almost-unknown topic of child study in his first *Handbook of Child Psychology*. That was 1931, at the dawn of a scholarly history that, like every developmental narrative, has proceeded with a combination of continuity and change. What does this history tell us about where the field of developmental science has been, what it has learned, and where it is going? What does it tell us about what's changed and what has remained the same in the questions that have been asked, in the methods used, and in the theoretical ideas that have been advanced to understand human development?

The First Two Editions

Carl Murchison was a star scholar/impresario who edited the *Psychological Register*, founded important psychological journals, and wrote books on social psychology, politics, and the criminal mind. He compiled an assortment of handbooks, psychology texts, and autobiographies of renowned psychologists, and even ventured a book on psychic phenomena (Sir Arthur Conan Doyle and Harry Houdini were among the contributors). Murchison's initial *Handbook of Child Psychology* was published by a small university press (Clark University) in 1931, when the field itself was still in its infancy. Murchison wrote:

> Experimental psychology has had a much older scientific and academic status [than child psychology], but at the present time it is probable that much less money is being spent for pure research in the field of experimental psychology than is being

> spent in the field of child psychology. In spite of this obvious fact, many experimental psychologists continue to look upon the field of child psychology as a proper field of research for women and for men whose experimental masculinity is not of the maximum. This attitude of patronage is based almost entirely upon a blissful ignorance of what is going on in the tremendously virile field of child behavior. (Murchison, 1931, p. ix)

Murchison's masculine allusion is from another era; it might supply good material for a social history of gender stereotyping. That aside, Murchison was prescient in the task that he undertook and the way that he went about it. At the time this passage was written, developmental psychology was known only in Europe and in a few forward-looking U.S. labs and universities. Nevertheless, Murchison predicted the field's impending ascent: "The time is not far distant, if it is not already here, when nearly all competent psychologists will recognize that one-half of the whole field of psychology is involved in the problem of how the infant becomes an adult psychologically" (Murchison, 1931, p. x).

For this first 1931 *Handbook*, Murchison looked to Europe and to a handful of American research centers for child study—most prominently, Iowa, Minnesota, University of California at Berkeley, Columbia, Stanford, Yale, and Clark—many of which were at the time called *field stations*. Murchison's Europeans included a young "genetic epistemologist" named Jean Piaget, who, in an essay on "Children's Philosophies," cited data from his interviews with 60 Genevan children between the ages of 4 and 12 years. Piaget's chapter would provide U.S. readers with an introduction to his soon-to-be seminal research program on children's conceptions of the world. Another European, Charlotte Bühler, wrote a chapter on young children's social behavior. In her chapter, which still is fresh today, Bühler described intricate play and communication patterns among toddlers—patterns that developmental scientists would not rediscover until the late 1970s. Bühler also anticipated critiques of Piaget that were to be again launched during the sociolinguistics heyday of the 1970s:

> Piaget, in his studies on children's talk and reasoning, emphasizes that their talk is much more egocentric than social . . . that children from three to seven years accompany all their manipulations with talk which actually is not so much intercourse as monologue . . . [but] the special relationship of the child to each of the different members of the household is distinctly reflected in the respective conversations. (Bühler, 1931, p. 138)

Other Europeans include Anna Freud, who wrote on "The Psychoanalysis of the Child," and Kurt Lewin, who wrote on "Environmental Forces in Child Behavior and Development"—both would gain worldwide renown in coming years.

The Americans that Murchison chose were equally notable. Arnold Gesell wrote a nativistic account of his twin studies—an enterprise that remains familiar to us today—and Stanford's Lewis Terman wrote a comprehensive account of everything known about the "gifted child." Harold Jones described the developmental effects of birth order, Mary Cover Jones wrote about children's emotions, Florence Goodenough wrote about children's drawings, and Dorothea McCarthy wrote about language development. Vernon Jones's chapter on "children's morals" focused on the growth of *character*, a notion that was to become mostly lost to the field during the cognitive-developmental revolution, but that has reemerged in the past decade as a primary concern in the study of moral development.

Murchison's vision of child psychology included an examination of cultural differences as well. His *Handbook* presented to the scholarly world a young anthropologist named Margaret Mead, just back from her tours of Samoa and New Guinea. In this early essay, Mead wrote that her motivation in traveling to the South Seas was to discredit the claims that Piaget, Lévy-Bruhl, and other "structuralists" had made regarding what they called *animism* in young children's thinking. (Interestingly, about a third of Piaget's chapter in the same volume was dedicated to showing how Genevan children took years to outgrow their animism.) Mead reported data that she called "amazing": "In not one of the 32,000 drawings (by young 'primitive' children) was there a single case of personalization of animals, material phenomena, or inanimate objects" (Mead, 1931, p. 400). Mead parlayed these data into a tough-minded critique of Western psychology's ethnocentrism, making the point that animism and other beliefs are more likely to be culturally induced than intrinsic to early cognitive development. This is hardly an unfamiliar theme in contemporary psychology. Mead offered a research guide for developmental field workers in strange cultures, complete with methodological and practical advice, such as the following: (1) translate questions into native linguistic categories; (2) do not do controlled experiments; (3) do not try to do research that requires knowing the ages of subjects, which are usually unknowable; and (4) live next door to the children whom you are studying.

Despite the imposing roster of authors that Murchison had assembled for this original *Handbook of Child Psychology*, his achievement did not satisfy him for long. Barely 2 years later, Murchison put out a second edition, of which he wrote: "Within a period of slightly more than 2 years, this first revision bears scarcely any resemblance to the original *Handbook of Child Psychology*. This is due chiefly to the great expansion in the field during the past 3 years and partly to the improved insight of the editor" (Murchison, 1933, p. vii). The tradition that Murchison had brought to life was already developing.

Murchison saw fit to provide the following warning in his second edition: "There has been no attempt to simplify, condense, or to appeal to the immature mind. This volume is prepared specifically for the scholar, and its form is for his maximum convenience" (Murchison, 1933, p. vii). It is clear that Murchison, despite his impresario urges, was willing to sacrifice accessibility and textbook-level sales for scientific value in this instance.

Murchison exaggerated when he wrote that his second edition bore little resemblance to the first. Almost half of the chapters were virtually the same, with minor additions and updating. (For the record, though, despite Murchison's continued use of masculine phraseology, 10 of the 24 authors in the second edition were women.) Some of the authors whose original chapters were dropped were asked to write about new topics. So, for example, Goodenough wrote about mental testing rather than about children's drawings, and Gesell wrote a general chapter on maturational theory that went well beyond his own twin studies.

But Murchison also made certain abrupt changes. He dropped Anna Freud entirely, prompting the marginalization of psychoanalysis within U.S. academic psychology. Leonard Carmichael, later to play a pivotal role in the *Handbook* tradition, made his appearance as author of a major chapter (by far, the longest in the book) on prenatal and perinatal growth. Three other physiologically oriented chapters were added as well: one on neonatal motor behavior, one on visual–manual functions during the first 2 years of life, and one on physiological "appetites" such as hunger, rest, and sex. Combined with the Goodenough and Gesell shifts in focus, these additions gave the 1933 *Handbook* a more biological thrust, in keeping with Murchison's long-standing desire to display the hard-science backbone of the emerging field.

The Early Wiley Editions

Leonard Carmichael was president of Tufts University when he organized Wiley's first edition of the *Handbook*. The switch from a university press to the long-established commercial firm of John Wiley & Sons was commensurate with Carmichael's well-known ambition; and indeed Carmichael's effort was to become influential beyond anything that Murchison might have anticipated. (The switch to Wiley meant that what was to become known as Wiley's first edition was actually the *Handbook*'s third edition—and that what is now called the seventh edition is really the *Handbook*'s ninth.) Carmichael renamed the volume the *Manual of Child Psychology*, in keeping with Carmichael's intention of producing an "advanced scientific manual to bridge the gap between the excellent and varied elementary textbooks in this field and the scientific periodical literature" (Carmichael, 1946, p. vi).

Despite the small title change, there was significant continuity between the Murchison and Carmichael's editions. Carmichael acknowledged this in the prefaces to both of his editions, the 1946 and 1954 *Manuals*:

> Both as editor of the *Manual* and as the author of a special chapter, the writer is indebted . . . [for] extensive excerpts and the use of other materials previously published in the *Handbook of Child Psychology, Revised Edition*. (Carmichael, 1946, p. vi)
>
> Both the *Handbook of Child Psychology* and the *Handbook of Child Psychology, Revised Edition,* were edited by Dr. Carl Murchison. I wish to express here my profound appreciation for the pioneer work done by Dr. Murchison in producing these handbooks and other advanced books in psychology. The *Manual* owes much in spirit and content to the foresight and editorial skill of Dr. Murchison. (Carmichael, 1954, p. v)

The first quote comes from Carmichael's preface to the 1946 edition, the second from his preface to the 1954 edition. It is not known why Carmichael waited until the 1954 edition to add the personal tribute to Carl Murchison. Perhaps a careless typist dropped the laudatory passage from a handwritten version of the 1946 preface and its omission escaped Carmichael's notice. Or perhaps 8 years of further development increased Carmichael's generosity of spirit. It is also possible that Murchison or his family complained. In any case, Carmichael always acknowledged the roots of his *Manual*, if not always their original editor.

Leonard Carmichael took his 1946 *Manual* in the same direction established by Murchison back in 1931 and 1933. First, Carmichael appropriated five Murchison chapters on biological or experimental topics such as physiological growth, scientific methods, and mental testing. Second, he added three new biologically oriented chapters on animal infancy, on physical growth, and on motor and behavioral maturation (a tour de force by Myrtle McGraw that instantly made Gesell's chapter in the same volume obsolete). Third, he commissioned Wayne Dennis to write a chapter that focused exclusively on physiological changes associated with puberty. Fourth, Carmichael dropped

Piaget and Bühler, who, like Anna Freud years earlier, were becoming out of step with then-current experimental trends in U.S. psychology.

The five Murchison chapters on social and cultural influences in development were the ones Carmichael retained: two chapters on environmental forces on the child (by Kurt Lewin and by Harold Jones), Dorothea McCarthy's chapter on children's language, Vernon Jones's chapter on children's morality (now entitled "Character Development—An Objective Approach"), and Margaret Mead's chapter on "primitive" children (now enhanced by several spectacular photos of mothers and children from exotic cultures around the world). Carmichael also stuck with three other psychologically oriented Murchison topics (emotional development, gifted children, and sex differences), but he selected new authors to cover them.

Carmichael's second and final *Manual* in 1954 was very close in structure and content to his 1946 *Manual*. Carmichael again retained the heart of Murchison's original vision, many of Murchison's original authors and chapter topics, and some of the same material that dated all the way back to the 1931 *Handbook*. Not surprisingly, the chapters that were closest to Carmichael's own interests received the most significant updating. As Murchison had done, Carmichael leaned toward the biological and physiological whenever possible. He clearly favored experimental treatments of psychological processes. Yet Carmichael still retained the social, cultural, and psychological analyses by Lewin, Mead, McCarthy, Terman, Harold Jones, and Vernon Jones, even going so far as to add a new chapter on social development by Harold and Gladys Anderson and a new chapter on emotional development by Arthur Jersild.

In 1946, when Carmichael had finished his first *Manual*, he had complained that "this book has been a difficult and expensive one to produce, especially under wartime conditions" (Carmichael, 1946, p. vii). But the project had been well worth the effort. The *Manual* quickly became the bible of graduate training and scholarly work in the field, available virtually everywhere that human development was studied. Eight years later, now head of the Smithsonian Institution, Carmichael wrote, in the preface to his 1954 edition: "The favorable reception that the first edition received not only in America but all over the world is indicative of the growing importance of the study of the phenomena of the growth and development of the child" (Carmichael, 1954, p. vii).

The Murchison and Carmichael volumes make fascinating reading, even today. The perennial themes of the field were always there: the nature/nurture debate; the generalizations of universalists opposed by the particularizations of contextualists; the alternating emphases on continuities and discontinuities during ontogenesis; and the standard categories of maturation, learning, locomotor activity, perception, cognition, language, emotion, conduct, morality, and culture—all separated for the sake of analysis, yet, as authors throughout each of the volumes acknowledged, all somehow joined in the dynamic mix of human development.

These things have not changed. Yet much in the early *Handbooks*/*Manuals* is now irrevocably dated. Long lists of children's dietary preferences, sleeping patterns, elimination habits, toys, and somatic types look quaint and pointless through today's lenses. The chapters on children's thought and language were done prior to the great contemporary breakthroughs in neurology and brain/behavior research, and they show it. The chapters on social and emotional development were ignorant of the processes of social influence and self-regulation that soon would be revealed through attribution research and other studies in social psychology. Terms such as *cognitive neuroscience*, *neuronal networks*, *behavior genetics*, *social cognition*, *dynamical systems*, *information processing*, and *developmental psychopathology* were unknown. Margaret Mead's rendition of the primitive child stands as a weak straw in comparison to the wealth of cross-cultural knowledge available in today's "cultural psychology."

Most tellingly, the assortments of odd facts and normative trends were tied together by very little theory throughout the Carmichael chapters. It was as if, in the exhilaration of discovery at the frontiers of a new field, all the facts looked interesting in and of themselves. That is what makes so much of the material seem odd and arbitrary. It is hard to know what to make of the lists of facts, where to place them, which ones were worth keeping track of and which ones are expendable. Not surprisingly, the bulk of the data presented in the Carmichael manuals seems not only outdated by today's standards but, worse, irrelevant.

Carmichael's second and final *Manual* had a long life: Not until 1970 did Wiley bring out a third edition. Carmichael was retired by then, but he still had a keen interest in the book. At his insistence, his own name became part of the title of Wiley's third edition: The edition was called, improbably, *Carmichael's Manual of*

Child Psychology, even though it had a new editor and an entirely new cast of authors and advisors.

Mussen's Transformation

Paul Mussen was editor of the 1970 edition; once again the project flourished. Now a two-volume set, the 1970 third edition swept the social sciences, generating widespread interest in developmental psychology and its related disciplines. Rarely had a scholarly compendium become both so dominant in its own field and so familiar in related disciplines. The volumes became essential sources for graduate students and advanced scholars alike. Publishers referred to Mussen's 1970 *Carmichael's Manual* as the standard against which other scientific handbooks were compared.

By 1970, the importance of theory for understanding human development had become apparent. Looking back on Carmichael's last *Manual*, Mussen wrote: "The 1954 edition of this Manual had only one theoretical chapter, and that was concerned with Lewinian theory which, so far as we can see, has not had a significant lasting impact on developmental psychology" (Mussen, 1970, p. x). The intervening years had seen a turning away from the norm of psychological research once fondly referred to as "dust-bowl empiricism."

The 1970 handbook—still called, as noted above, *Carmichael's Manual*—had an entirely new look. The two-volume set carried only one chapter from the earlier books, Carmichael's updated version of his own long chapter on the "Onset and Early Development of Behavior," which had made its appearance under a different title way back in Murchison's 1933 edition. Otherwise, as Mussen wrote in his preface, "It should be clear from the outset . . . that the present volumes are not, in any sense, a *revision* of the earlier editions; this is a completely new *Manual*" (Mussen, 1970, p. x).

And it was. In comparison to Carmichael's last edition 16 years earlier, the scope, variety, and theoretical depth of the Mussen volumes were astonishing. The field had blossomed, and the new *Manual* showcased many of the new bouquets that were being produced. The biological perspective was still strong, grounded by chapters on physical growth (by J. M. Tanner) and physiological development (by Dorothy Eichorn), and by Carmichael's revised chapter (now made more elegant by some excerpts from Greek philosophy and modern poetry). But two other cousins of biology also were represented, in a chapter on ethology by Eckhard Hess, and a chapter on behavior genetics by Gerald McClearn. These chapters were to define the major directions of biological research in the field for at least the next three decades.

As for theory, Mussen's *Handbook* was thoroughly permeated with it. Much of the theorizing was organized around the approaches that, in 1970, were known as the "three grand systems": (1) Piaget's cognitive-developmentalism, (2) psychoanalysis, and (3) learning theory. Piaget was given the most extensive treatment. He himself reappeared in this *Manual*, authoring a comprehensive (some say definitive) statement of his own theory, which now bore little resemblance to his 1931/1933 catalog of children's intriguing verbal expressions. In addition, chapters by John Flavell, by David Berlyne, by Martin Hoffman, and by William Kessen, Marshall Haith, and Philip Salapatek, all gave major treatments to one or another aspect of Piaget's body of work.

Several other theoretical approaches were represented in the 1970 *Manual* as well. Herbert and Anne Pick explicated Gibsonian theory in a chapter on sensation and perception, Jonas Langer wrote a chapter on Werner's organismic theory, David McNeill wrote a Chomskian account of language development, and Robert LeVine wrote an early version of what was to become "culture theory."

With its increased emphasis on theory, the 1970 *Manual* explored in depth a matter that had been all but neglected in the *Manual*'s previous versions: the mechanisms of change that could account for, to use Murchison's old phrase, "the problem of how the infant becomes an adult psychologically." In the process, old questions such as the relative importance of nature versus nurture were revisited, but with far more sophisticated conceptual and methodological tools.

Beyond theory building, the 1970 *Manual* addressed an array of new topics and featured new contributors: peer interaction (Willard Hartup), attachment (Eleanor Maccoby and John Masters), aggression (Seymour Feshbach), individual differences (Jerome Kagan and Nathan Kogan), and creativity (Michael Wallach). All of these areas of interest are still very much with us.

Wiley's fourth edition, published in 1983, was redesignated to become once again the *Handbook of Child Psychology*. By then, Carmichael had passed away. The set of books, now expanded to four volumes, became widely referred to in the field as "the Mussen handbook."

If the 1970 *Manual* reflected a blossoming of the field's plantings, the 1983 *Handbook* reflected a field whose ground cover had spread beyond any boundaries that could have been previously anticipated. New growth had sprouted in literally dozens of separate locations. A French garden, with its overarching designs and tidy compartments, had turned into an English garden, unruly but often glorious in its profusion. Mussen's two-volume *Carmichael's Manual* had now become the four-volume Mussen *Handbook*, with a page-count increase that came close to tripling the 1970 edition.

The grand old theories were breaking down. Piaget was still represented in 1983 by his 1970 piece, but his influence was on the wane throughout other chapters. Learning theory and psychoanalysis were scarcely mentioned. Yet the early theorizing had left its mark, in vestiges that were apparent in new approaches, and in the evident conceptual sophistication with which authors treated their material. There was no return to dust-bowl empiricism. Instead, a variety of classical and innovative ideas were coexisting: ethology, neurobiology, information processing, attribution theory, cultural approaches, communications theory, behavioral genetics, sensory-perception models, psycholinguistics, sociolinguistics, discontinuous stage theories, and continuous memory theories all took their places, with none quite on center stage. Research topics now ranged from children's play to brain lateralization, from children's family life to the influences of school, day care, and disadvantageous risk factors. There also was coverage of the burgeoning attempts to use developmental theory as a basis for clinical and educational interventions. The interventions usually were described at the end of chapters that had discussed the research relevant to the particular intervention efforts, rather than in whole chapters dedicated specifically to issues of practice.

The Fifth and Sixth Editions

There was a long hiatus between the fourth edition in 1983 and the fifth edition, which was not to appear until 1998. The fifth edition fell to me to organize, and this was not at my own initiative. Two Wiley editors—Herb Reich, a legendary figure in academic publishing, and Kelly Franklin, an up-and-coming innovative star—approached me about reviving the project, which they correctly believed had a vital tradition behind it, but that they also believed was in danger of falling by the wayside. I had been editing the Jossey-Bass series that I founded, *New Directions for Child and Adolescent Development*, and the two Wiley editors believed that if we could impart a "new directions" tone to a new *Handbook* edition, the project could regain its past appeal. I agreed, and I proposed that this next edition be organized in an intuitively simple four-volume design: a theory volume, a volume on cognitive and linguistic development, a volume on social and personality development, and a volume on child psychology in practice. When Wiley accepted my proposal, my first action as general editor was to invite an incredibly talented group of volume editors—Nancy Eisenberg, Deanna Kuhn, Richard Lerner, Anne Renninger, Robert Siegler, and Irving Sigel—to collaborate on the selection and editing of chapters. The edition was to become the result of a partnership among all the editors; and the same team collaborated again to produce the sixth edition of the *Handbook* in 2006, with Richard Lerner assuming an added role as my co-editor-in-chief. The 2006 edition closely followed the model of the 1998 edition, with some important additions, such as chapters on the positive youth development approach, on artistic development, and on religiosity and faith in human development.

Our team approached the 1998 and 2006 editions with the same purpose that Murchison, Carmichael, and Mussen before us had shared: "to provide," as Mussen wrote, "a comprehensive and accurate picture of the current state of knowledge—the major systematic thinking and research—in the most important research areas of the psychology of human development" (Mussen, 1983, p. vii). We assumed that the *Handbook* should be aimed "specifically for the scholar," as Murchison declared, and that it should have the character of an "advanced text," as Carmichael defined it. We expected that our readership would be interdisciplinary, given the tendency of scholars in human development to do work across the fields of psychology, cognitive science, neuroscience, history, linguistics, sociology, anthropology, education, and psychiatry. In Volume 4, we hoped that research-oriented practitioners would be among the scholars for whom the *Handbook* had value.

By the time of the 1998 and 2006 editions of the *Handbook*, powerful theoretical models and approaches—not quite unified theories like the "three grand systems" that had marked earlier editions—were again organizing much of the field's research. There was great variety in these models and approaches, and each was drawing together significant clusters of work. Among the powerful models and approaches prominent in the 1998 and 2006 *Handbooks* were the dynamic system theories, life-span and life-course approaches, cognitive science and neural models, the behavior genetics approach, person–context interaction theories, action theories, culture theory, ecological models, and neo-Piagetian and Vygotskian models. Although some of these models and approaches had been in the making for some time, by the end of the 20th century they had fully come into their own: researchers were drawing on them more directly, taking their implied assumptions and hypotheses seriously, using them with specificity and control, and exploiting all of their implications for practice.

The Present

The seventh Wiley edition of the *Handbook* continues and strengthens the trends toward specific theoretical analyses of multiple developmental processes, even highlighting this focus by including the term "processes" in two of the four volume's titles, a designation new to the *Handbook*'s history. The volumes present a rich mix of classic and contemporary theoretical perspectives, but I believe it is fair to say that the dominant views throughout are marked by an emphasis on the dynamic interplay of all relational developmental systems that co-act across the life span, incorporating the range of biological, perceptual, cognitive, linguistic, emotional, social, cultural, and ecological levels of analysis. At the same time, the chapters together consider a vast array of topics and problems, ranging from sexuality and religiosity to law, medicine, war, poverty, and education. The emerging world of digital experience is also given a fuller treatment than in any previous *Handbook* edition, commensurate with our present-day technological revolution. All this gives this seventh edition of the *Handbook* a timely feel.

The present *Handbook*'s combination of theoretical and methodological sophistication and topical timeliness resolves an old tension evident in the *Handbook*'s prior cycling between theoretical-methodological and problem-centered approaches. My impression is that, rather than leaning in one direction or the other, this *Handbook* manages to be *both* more theoretical-methodological *and* more topical than the previous editions. As a developmental phenomenon, this puts the *Handbook* in a class of organisms that develop toward adaptive complexity rather than toward one or another contrasting polar dimension.

I wonder what Carl Murchison would think of the grown-up child that he spawned before the field of human development had become a mainstream endeavor in research and teaching around the world. Murchison's idiosyncratic assortment of fascinating studies bears little resemblance to the imposing compendium of solidly grounded knowledge in the present *Handbook*. Yet each step along the 83-year way followed directly from what had gone before, with only occasional departures or additions that may have seemed more like gradual revisions at the time. Over the long haul, the change in the *Handbook* has been dramatic, but the change process itself has been marked by substantial continuities. If Murchison were to come back to life today, he may be astonished by the size and reach of his child, but I believe he would recognize it—and proudly so.

W. D.
Stanford, California
2014

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Preface

Across its editions, the title of this handbook has changed, now, five times: *A Handbook of Child Psychology*; *Manual of Child Psychology*; *Carmichael's Manual of Child Psychology*; *Handbook of Child Psychology*; and *Handbook of Child Psychology and Developmental Science*. As well, the field of scholarship represented in the *Handbook* has also been labeled differently: child psychology, child development, developmental psychology, and, today, developmental science. The rationales for the use of these labels involve historically changing ontological and epistemological assumptions.

During the latter years of the 19th century and for much of the past two thirds of the 20th century, and perhaps especially in the United States and Western Europe, the study of human development was a visible subfield of psychology (see Cairns & Cairns, 2006, for a review; see also Damon, in the Foreword to this edition of the *Handbook*). In this literature, and its antecedents in philosophy (see Baltes, 1983; Overton, 2006 for reviews), development was envisioned to be a life-span phenomenon (e.g., Erikson, 1959; Hall, 1904, 1922). However, the majority of the scholarship about human development in the United States and Western Europe was focused on the early years of life (infancy and childhood) (e.g., Binet & Simon, 1905a, 1905b; Gesell, 1929; Piaget, 1923; Preyer, 1882; Terman, 1925).

As a consequence, across this historical period, child psychology emerged as a specific subarea of psychology, spurred on by the research of scientists studying this age period; by the founding of several university centers and institutes devoted to the study of children (e.g., in Iowa, involving scholars such as Boyd R. McCandless; and in Minnesota, involving scholars such as Dale B. Harris); and by the work in the field of home economics, which was focused on children (and families), that was occurring within land-grant universities in the United States (Cairns & Cairns, 2006; Lerner & Simon, 1998). At the same time, many of the contributors to child psychology also created a purportedly multidisciplinary instantiation of scholarship devoted to the study of children, that is, child *development*. In 1933, the Society for Research in Child Development (SRCD) was founded to promote such a multidisciplinary approach to the study of children (and to the application of child development research) but, in actuality, SRCD was from its outset and remains today dominated by scholars whose training is in psychology. It is not surprising, then, that, whether labeled child psychology or child development, the study of the early portion of the life span was approached in very similar ways by scholars studying children.

At its inception, the child development (or child psychology) field was framed by Cartesian-split conceptions of change across ontogeny and by reductionist accounts of the bases of human development (Overton, 2013a, 2013b; Overton & Müller, 2013). The core conceptual issues of child development were the nature-nurture, the continuity-discontinuity, and the stability-instability controversies (Lerner, 2002), and "solutions" to these debates involved, for instance, reducing development to being a phenomenon explained by either nature variables (genes or maturation; e.g., Hamburger, 1957) or by operant or respondent stimulus-response connections (e.g., Bijou & Baer, 1961). This split, reductionist ontology about development meant that the epistemological route to learning about the basis of development was to identify the essential (nature *or* nurture) explanatory variable(s). Accordingly, the study of development was also marked by variable-centered analyses, as exemplified by the tables of contents of the editions of this *Handbook* published during this period (e.g., Carmichael, 1946, 1954; Murchison, 1931, 1933; Mussen, 1970, 1983; see also Damon, in the Foreword to this edition), as well as by the tables of contents of other major compendiums published during this period (e.g., Reese & Lipsitt, 1970; Stevenson, 1963).

However, as early as 1970, Mussen, the editor of the third edition of the *Handbook* published by Wiley, pointed to the potential meaning of a growing interest among some scientists to move away from a reductionist approach, involving descriptions of the variables purportedly accounting for ontogenetic structure and function, and toward an approach that viewed development as involving interrelations among variables (from multiple levels of organization). Mussen (1970) said that "the major contemporary empirical and theoretical emphases in the field of developmental psychology . . . seem to be on *explanations* of the psychological changes that occur, the mechanisms and processes accounting for growth and development" (p. vii). By pointing to the interest in change processes, Mussen was implying that we needed something more to explain the process of development, unless we believed that nature or nurture variables explained themselves in structure or function.

That "something more" was already emerging within the study of development—for instance, at a series of conferences held at the University of West Virginia in the late 1960s and early 1970s about the nature and implications of a life-span view of human development (e.g., Baltes & Schaie, 1974; Nesselroade & Reese, 1973; Schaie, 1970). These West Virginia University conferences, the edited books that derived from them, and the associated articles published in both theoretically oriented journals (e.g., *Human Development*, *Developmental Review*) and empirically oriented journals (e.g., *Child Development*, *Developmental Psychology*, *International Journal of Behavioral Development*, and *Journal of Research on Adolescence*) discussed the philosophical, theoretical, and methodological problems associated with split/reductionist accounts of development. In addition, they introduced ideas about the potential for plasticity (i.e., the potential for systematic change) in development across life, and pointed to the role of potentially mutually influential relations between individuals and their normative age- and history-graded experiences and, as well, their non-normative experiences, in instantiating this plasticity. Finally, they underscored the fundamental necessity of studying intraindividual changes (and interindividual differences in intraindividual changes) involved in these individual-context relations in order to describe, explain, and optimize the course of human development. These ideas would act synergistically with growing scholarship in Europe that provided theory and data fostering a "reversal" of focus for developmental inquiry—from variable-centered to person-centered approaches to human development (e.g., Magnusson, 1999). These ideas were also synergistic with work in sociology that demonstrated that the course of life was shaped by historical events that one encountered at particular times and in particular places (Elder, 1974).

When taken together, the dimensions of human development scholarship that crystallized and coalesced between the 1970s and 1990s pointed to the vacuity of split/reductionist models (and their attendant methodologies). In turn, these ideas underscored the importance of time and place, person–context relations, plasticity, and the need for a focus on longitudinal (change-sensitive) methods to study intraindividual change across life and, as well, the diverse life paths of these intraindividual changes. These ideas, when considered together, presented a major challenge to the then-dominant metatheoretical and theoretical ideas in the field. Indeed, the new ideas about human development that found an impetus at the West Virginia University conferences grew in influence across the field and together, across the last three decades of the 20th century, created a Kuhn-like (Kuhn, 1962) paradigm shift (Overton, 2013a, 2013b; Overton & Lerner, 2012).

The shift in conceptual and empirical foci attendant to this paradigm shift was multifaceted. As I noted, Mussen (1970) observed that the field had been primarily descriptive and normative (Mussen, 1970), with the norms usually generated by studying only a small portion of humanity (i.e., European American middle-class children in the main; Hagen, Paul, Gibb, & Wolters, 1990). In addition, the "paradigm" framing this research was as likely (if not more likely) to use cross-sectional research to study development as it was to employ longitudinal methods. The use of cross-sectional designs (and data analysis methods, e.g., R-technique analyses; e.g., see Cattell, 1966, and for more current versions of these ideas see Molenaar & Nesselroade, 2014; Nesselroade & Molenaar, 2010) was predicated on the assumption of the applicability of the ergodic theorem (e.g., Molenaar, 2007; Molenaar & Nesselroade, 2014). The ergodic theorem holds that data sets are marked by: (a) homogeneity across individuals in a three-dimensional matrix that involves persons, variables, and time; and (b) stationarity of individuals' scores on variables across time (Molenaar, 2007).

In contrast, the approach to the study of human development that was evidenced by the life-span and life-course perspectives involved research that documented the presence of systematic variation in trajectories of intraindividual change, both within and across people. As such, the assumptions of homogeneity and stationarity of the ergodic theorem were rejected and developmental scientists placed greater importance on not only person-centered research but, as well, change-sensitive methodologies for both descriptive and explanatory efforts (Molenaar, 2007, 2010). What was distinctive about this research, however, was that it was both derived from and promoted diverse attempts to create theoretical models of human development associated with an emergent, relational paradigm (Overton, 2013a, 2013b; Overton & Müller, 2013), a conception that focused on the individual and on the course of his or her trajectories of reciprocal bidirectional relations with the multiple levels of the ecology of human development (represented as individual ←→ context relations). Examples were the bioecological model of Bronfenbrenner (e.g., 1979), the dialectical model of Riegel (e.g., 1975), the developmental contextual approach of Lerner (1982), the developmental systems concepts of Gottlieb (1997, 1998) and of Ford and Lerner (1992), the model of individual development proposed by Magnusson (1999), and the embodiment model presented by Overton (1994, 1997).

In short, these "strands" of theory merged in the 1970s, 1980s, and 1990s and shifted the predominant developmental "paradigm" away from reductionism, Cartesian-split conceptions, and methods predicated on ergodicity, and created a focus on models emphasizing the mutually influential relations between individuals and their contexts, on person ←→ context relations (Cairns & Cairns, 2006; Lerner, 2006). Such models involved the belief that time and place matter in regard to shaping the course of life (Bronfenbrenner, 2005; Elder, 1998; Elder & Shanahan, 2006), and emphasized that the scientific study of human development needed to study both the individual and the diversity of people in order to understand human development.

In sum, the relational paradigm that framed conceptions of the bases of human development was associated with the generation of several, relational developmental systems models of human development (Lerner, 2006; Lerner & Overton, 2008; Overton, 2013a, 2013b; Overton & Müller, 2013), conceptions that were used to guide the study of individuals, contexts, and their dynamic interrelations across the life span. Table P.1 presents the defining features of such models.

This multilevel and multidisciplinary approach to studying human development was the basis of the view that the field was best represented by the term developmental science. In turn, given this synergistic history of the links among theory, method, and research, it is not surprising that, at this writing, relational developmental systems theories are at the forefront of the study of human development (e.g., Lerner, 2012; Lerner & Benson, 2013a, 2013b; Overton & Lerner, 2012). Indeed, the fifth edition of the Wiley *Handbook* (Damon, 1998) had pointed to the growing prominence of such approaches to the study of human development and, in turn, the sixth edition (Damon & Lerner, 2006) noted that models derived from relational developmental systems thinking, and from a relational meta-model more generally, had become the predominant conceptual lens for the cutting-edge theory and methodological innovations guiding research in human development across the life span.

In the present seventh edition of the Wiley *Handbook,* this pathway of scholarly progression is continued. Key examples of relational developmental systems models are found across all four volumes of this seventh edition of the *Handbook*. Moreover, accompanying the use of these models are new methodologies to study individuals, to therefore capture the nonergodic character of human development and, as well, to study the developmental system within which individual ←→ context relations are embedded. Examples of these methods are also a prominent contribution of chapters in this edition of the *Handbook*.

Another key feature of the chapters in this edition of the *Handbook* is the applied use of relational developmental systems theoretical models. Based on ideas about the relative plasticity of individual ←→ context relations, this use of theory overcomes yet another traditional split within the study of human development—between theory-predicated explanations of human development and applications aimed at enhancing human development (Baltes, Reese, & Nesselroade, 1977; Lerner, 2002, 2012). For instance, to test explanations of developmental change, scholars need to institute or evaluate actions that are aimed at altering the bidirectional relations theoretically expected to produce changes in behavior and development. These actions must necessarily be embedded in the actual ecology of human development in order to have generalizability to the lived experiences of individuals (Lerner & Callina, 2014) and, as such, they constitute intervention (applied) research; at the same time, such research tests basic explanatory processes of human development. As such, in contemporary developmental science any splits between basic and applied research are regarded as anachronistic representations of the reductionist, Cartesian approaches of earlier eras.

TABLE P.1 Defining Features of the Relational Developmental Systems Paradigm

Relational Metatheory
Predicated on a philosophical perspective that transcends Cartesian dualism and atomism, theories derived from the relational developmental systems paradigm are framed by a relational metatheory for human development. This focus includes an emphasis on process and a rejection of all splits between components of the ecology of human development (e.g., between nature- and nurture-based variables, between continuity and discontinuity, and between stability and instability). Holistic syntheses replace dichotomies, as well as reductionist partitions of the developing relational system, through the integration of three relational moments of analysis: the identity of opposites, the opposites of identity, and the syntheses of wholes. Deriving from the relational metatheory, relational developmental systems posit the organism as an inherently active, self-creating, self-organizing, and self-regulating nonlinear complex adaptive system, which develops through embodied activities and actions, as they co-act with a lived world of physical and sociocultural objects.

The Integration of Levels of Organization
Relational thinking, with the rejection of Cartesian splits, is associated with the idea that all levels of organization within the ecology of human development are integrated or fused. These levels range from the biological and physiological through the cultural and historical.

Developmental Regulation Across Ontogeny Involves Mutually Influential Individual ←→ Context Relations
As a consequence of the integration of levels, the regulation of development occurs through mutually influential connections among all levels of the developing relational system, ranging from genes and cell physiology through individual mental and behavioral functioning to society, culture, the designed and natural ecology, and, ultimately, history. These mutually influential relations may be represented generically as Level 1 ←→ Level 2 (e.g., Family ←→ Community), and in the case of ontogeny may be represented as individual ←→ context.

Integrated Actions, Individual ←→ Context Relations, Are the Basic Unit of Analysis Within Human Development

The character of developmental regulation means that the integration of actions—of the individual on the context and of the multiple levels of the context on the individual (individual ←→ context)—constitute the fundamental unit of analysis in the study of the basic process of human development.

Temporality and Plasticity in Human Development
As a consequence of the fusion of the historical level of analysis—and therefore temporality—in the levels of organization comprising the ecology of human development, the developing relational system is characterized by the potential for systematic change, by plasticity. Observed trajectories of intraindividual change may vary across time and place as a consequence of such plasticity.

Relative Plasticity
Developmental regulation may both facilitate and constrain opportunities for change. Thus, change in individual ←→ context relations is not limitless, and the magnitude of plasticity (the probability of change in a developmental trajectory occurring in relation to variation in contextual conditions) may vary across the life span and history. Nevertheless, the potential for plasticity at both individual and contextual levels constitutes a fundamental strength of all human development.

Intraindividual Change, Interindividual Differences in Intraindividual Change, and the Fundamental Substantive Significance of Diversity
The combinations of variables across the integrated levels of organization within the developmental system that provide the basis of the developmental process will vary at least in part across individuals and groups. This diversity is systematic and lawfully produced by idiographic, group differential, and generic (nomothetic) phenomena. The range of interindividual differences in intraindividual change observed at any point in time is evidence of the plasticity of the developmental system, and gives the study of diversity fundamental substantive significance for the description, explanation, and optimization of human development.

Interdisciplinarity and the Need for Change-Sensitive Methodologies
The integrated levels of organization comprising the developmental system require collaborative analyses by scholars from multiple disciplines. Interdisciplinary knowledge is a central goal. The temporal embeddedness and resulting plasticity of the developing system requires that research designs, methods of observation and measurement, and procedures for data analysis be change- and process-sensitive and able to integrate trajectories of change at multiple levels of analysis.

Optimism, the Application of Developmental Science, and the Promotion of Positive Human Development
The potential for and instantiations of plasticity legitimate an optimistic and proactive search for characteristics of individuals and of their ecologies that, together, can be arrayed to promote positive human development across life. Through the application of developmental science in planned attempts (interventions) to enhance (e.g., through social policies or community-based programs) the character of humans' developmental trajectories, the promotion of positive human development may be achieved by aligning the strengths (operationalized as the potentials for positive change) of individuals and contexts.

Source: Based on Lerner (2006) and Overton (2013a, 2013b).

In short, the application of developmental science (optimization) is a co-equal partner with description and explanation within developmental science as it now exists. Once again, the chapters in this edition of the *Handbook* provide rich illustrations of the integrated foci of developmental scholarship on the description, explanation, and optimization of human development across the life span.

Together, the metatheoretical, theoretical, methodological, and applied features of contemporary developmental science that are represented across the four volumes of this seventh edition of the *Handbook* allow this reference work to continue its history of marking the best scholarship in our field and of specifying the key directions for scientific progress. These contributions of the *Handbook* emerge from the intellectual abilities and wisdom of the volume editors and the authors of the chapters involved in this edition. I am enormously indebted to Willis F. Overton and Peter C. M. Molenaar, editors of Volume 1, Lynn S. Liben and Ulrich Müller, editors of Volume 2, Michael E. Lamb, editor of Volume 3, and Marc H. Bornstein and Tama Leventhal, editors of Volume 4, for their broad and deeply erudite scholarship, vision, and leadership. Their knowledge and skills created and shaped the volumes they edited.

The volume editors and I are also profoundly grateful to the authors of the chapters in this edition. Their singular levels of expertise and mastery of their areas of scholarship are richly and compellingly conveyed in this edition. The work of these colleagues represents the best scholarship in developmental science, and we are deeply grateful for their truly field-defining contributions to this edition.

I wish to express particular gratitude to William Damon, for his thoughtful, illuminating, and generous Foreword to this edition of the *Handbook*. Professor Damon was the editor of the fifth and sixth editions of the *Handbook* and, as well, for five decades he has been a visionary intellectual leader of the field that we now term developmental science. He stands as a model of scholarly excellence, erudition, and wisdom, and I am deeply grateful to have his ideas frame the volumes in this edition.

In addition, as scholars contributing to reference works of the scope of the *Handbook* realize, their work cannot be crystallized, completed, or disseminated without the efforts of the professional editors and publishers who work with them. The editors and authors of the seventh edition have been exceedingly fortunate to have had superb support and, as well, collegial guidance, from our editors in the Institute for Applied Research in Youth Development at Tufts and at John Wiley & Sons.

Jarrett M. Lerner, the managing editor in the Institute at Tufts, was involved with the seventh edition since its inception. He has organized and advanced every facet of the editorial and production process. His professionalism, knowledge, organizational capacities, efficiency, commitment, and indefatigable, positive spirit were vital to the existence, and to any archival contributions, of this edition.

In addition, Patricia A. Rossi, the executive editor for psychology at Wiley, was a masterful and wise guide and catalyst for the seventh edition, again from its inception. Her deep knowledge of the scholarly qualities that are required to produce a reference work that will set the standard of excellence for its field, and her enthusiasm and unflagging commitment to enabling editors and authors to attain this standard, were essential contributions to the development and completion of this edition. She and her colleagues at Wiley, who enacted a superbly organized, efficient, and invariantly high-quality production process, have enabled the scholarship of the authors and editors to be superbly presented to our readership.

Across the several years that I have worked on this edition of the *Handbook,* I have been blessed by having support, stimulation, and feedback from my colleagues in the Eliot-Pearson Department of Child Study and Human Development, and from my colleagues, staff, and students at the Institute for Applied Research in Youth Development, both at Tufts University. I am grateful for their inspiration and collaboration. I am also extremely fortunate to have had support for my scholarly work provided by the John Templeton Foundation, the Thrive Foundation for Youth, the Poses Family Foundation, the National 4-H Council, the Altria Group, Inc., the Bertelsmann Foundation, the National Science Foundation, the Gary and Joan Bergstrom family, and several individuals who have made private donations to the Institute to support its research. I thank them for their faith in me and for honoring me with their support. My family has been a vital resource of emotional and intellectual support—encouraging me when things seemed overwhelming and grounding me when, on rare occasions, things seemed to be going exceedingly well. My wife, Jacqueline Lerner, merits special recognition—as my life partner, as my chief scholarly collaborator, and my muse. I would have accomplished nothing in my career or my life without her.

Finally, the volume editors and I want to thank the colleagues and students who will read the chapters in this edition of the *Handbook* and who, we hope, will gain from the work presented across its four volumes. Many of these colleagues will find their contributions to developmental science represented in the pages of this edition. We thank them for these contributions. As well, we are grateful to them for another reason. Many of these colleagues will also be training the next generation of developmental scientists, young scholars whom we hope will be inspired by this edition of the *Handbook* to undertake scholarship that will make subsequent editions even better and more useful.

We wish these younger scientists well in this intellectual journey. As such, with the hope that their scientific aspirations will be realized, we dedicate this seventh edition of the *Handbook of Child Psychology and Developmental Science* to them.

R. M. L.
Medford, Massachusetts
January, 2014

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Volume 1 Preface

The chapters in this volume document conceptual and methodological advances both in theory and in empirical tools of design and analysis that enable developmental processes and the mutually co-acting relations between individual and context to be better understood and better investigated. The chapters also demonstrate that a paradigm shift has occurred within developmental science. The shift has been from a Cartesian-Split-Mechanistic scientific research paradigm to a Process-Relational and Relational-Developmental-Systems scientific research paradigm. The new paradigm forms the conceptual framework for various relational developmental systems models and theories of the development of living organisms broadly and human development specifically. The shift has also opened the path for the construction of important methodological innovations. Indeed, the use of relational developmental systems models in research employing these methodological innovations has advanced knowledge of the holistic, self-creating (enactive), self-organizing, embodied development of the person in individual ←→ context relations, which constitutes the fundamental processes of human development.

We believe that the scholarship within this volume and, as well, across the four volumes of this edition, attest to the fact that we are in the midst of a very exciting period within the development of developmental science. The paradigm shift that we are witnessing involves increasingly greater understanding of how to think about and how to describe, explain, and optimize the course of human life for diverse individuals living within diverse contexts. The years ahead in developmental science hold great promise for profound advances in knowledge about the bases, and evidence for enhancing, human development across the life span.

We are very grateful for the collaborations we have had across the years we have devoted to editing this volume. Most important, we are grateful for the scholarly excellence and unflagging spirit of collegiality of the contributors to this volume. Their commitment to producing the best in developmental science and their goodwill and persistence in accommodating requests for revision enabled us to collaboratively produce a volume that both enhances the seventh edition of this *Handbook* and advances developmental science.

We are also grateful to Richard M. Lerner, the editor-in-chief of this edition and, as well, the remarkably skilled, adept, and productive leader of Rich's editorial staff at Tufts University, Jarrett Lerner. Their work helped transform our goals for this volume into reality.

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CHAPTER 1

Concepts, Theory, and Method in Developmental Science

A View of the Issues

WILLIS F. OVERTON and PETER C. M. MOLENAAR

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The study of the development of living organisms generally, and humans, in particular, has itself developed and significantly so, as compared to past editions of this *Handbook*. For example, across just these early years of the 21st century, scholarship in developmental science has involved several important philosophical, theoretical, and methodological changes and, together, these changes constitute a paradigm shift for the field (Overton & Lerner, 2012).

The outcome of this paradigm shift involves the reanalysis and rethinking of a number of issues in the field, followed by the generation of new data, and new powerful methodological tools. One of the issues affected by the paradigm shift is the hoary nature–nurture debate (i.e., the issue of inheritance). Here, advances in epigenetics and a broader understanding of the genome itself have made the route from genotype to phenotype complex to the point that the classic Cartesian position, which claims that who we are and what we become to be is a simple additive function of gene × environment interactions has become highly untenable (see Bateson, Chapter 6, this *Handbook*, this volume; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume; Overton, Chapter 2, this *Handbook*, this volume). A second broad issue affected by the paradigm shift entails the relation of evolution and ontogenetic development (see Bateson, Chapter 6, this *Handbook*, this volume; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume; Overton, Chapter 2, this *Handbook*, this volume). Here, the field is rapidly moving away from implications of the classic *Modern Synthesis* (i.e., the integration of Mendelian genetics with neo-Darwinian variation and natural selection), which splits evolution off from individual ontogenetic development.

This view of evolution is rapidly being replaced with a position in which individual ontogenetic development is understood to be an integral part of the fabric of evolution. A third issue affected by the paradigm shift concerns cognition and cognitive development. Here the standard Cartesian-framed analysis had held that mental processes are exclusively located in the brain. This position has increasingly been challenged by the view that mental processes extend out into the body as embodied action, and into the technological and cultural worlds (see Marshall, Chapter 7, this *Handbook*, this volume; Mascolo & Fischer, Chapter 4, this *Handbook*, this volume; Overton, Chapter 2, this *Handbook*, this volume). One final example of the impact of the paradigm shift appears in the area of sociocultural development. In this area rethinking has resulted in a distinctive movement away from positions that at one time identified individual development and culture as separate and distinct, if interacting, entities, and toward a position that recognizes their coconstruction, codetermination, and codevelopment (see Mistry & Dutta, Chapter 10, this *Handbook*, this volume).

All the above and other changes that have occurred in developmental science over the past decade or so have been framed by fundamental philosophical and theoretical thinking about the nature of living organisms, the nature of development, and the nature of science, as well as by methodological innovations that have revolutionized the ability of developmental scientists to study developmental change and the mutually influential relations between organism and context that constitute the basic process of intraindividual change across the life span. In regard to the philosophical and theoretical bases of this paradigm shift, it is clear that, whether studying infancy, childhood, adolescence, or the adult and late-adult phases of the life span, contemporary scholarship in developmental science aims to articulate and understand the coacting relational processes that operate between individuals and their contexts (i.e., reciprocally bidirectional, synergistic, or fused relational processes) that serve as the ground for individual action and development. Contemporary developmental scientists focus on systematic and successive alterations in the course of these relations, and focus on the integration of multiple processes of individual functioning (e.g., cognitive, emotional, motivational) and multiple levels of the ecology of human development, ranging from the biological through the sociocultural and historical levels, including designed and natural environments.

Contemporary developmental science recognizes that scientific advances entail the need for new conceptual systems, new theories, and new methods capable of coherently accounting for the highly complex nature of the processes of individual functioning and development. New theories and methods are themselves rooted in novel conceptual systems. Accordingly, the cutting edge of developmental science has increasingly recognized the inadequacies of the classic Cartesian-Split-Mechanistic research paradigm and the theories and methods this paradigm has generated. As an alternative, developmental science has been developing new theories and new methods rooted in an alternative Process-Relational and Relational-Developmental-Systems research paradigm (see Overton, Chapter 2, this *Handbook*, this volume). Lerner, in the Preface to this edition, delineates many features of relational developmental systems theories and their conceptual metatheoretical roots (see Table P.1 in the Preface to this edition of the *Handbook*, and Overton, Chapter 2, this *Handbook*, this volume).

The study of the development of living organisms, including humans, has evolved from a field dominated by dichotomous either/or approaches (e.g., either psychogenic explanation or biogenic explanation) to an interdisciplinary approach to the life span that recognizes the scientific value of integrating multiple perspectives—biological, psychological, sociocultural, historical—into a synthetic, holistic, complex, coactional system. Cartesian reductionistic accounts that treat the complex organism ←→ context system as an additive aggregate of simple elements have been rejected by scientists who approach research within the context of relational developmental systems theories (see, e.g., Lerner, Lerner, Bowers, & Geldhof, Chapter 16, this *Handbook*, this volume; Mascolo & Fischer, Chapter 4, this *Handbook*, this volume; Turiel, Chapter 13, this *Handbook*, this volume). The Cartesian-Split-Mechanistic research paradigm splits as dichotomous competing alternatives perspectives on issues that have traditionally been central to developmental inquiry such as those discussed above. Today, such splits are rejected by developmental scientists who operate within a Process-Relational and Relational-Developmental-Systems research paradigm. The various relational developmental system theories and methods framed by this paradigm convert all such splits into relationally joined integrations of developmental processes as they operate at all levels of organization across the life span. Thus, the conceptual emphasis of various relational developmental systems theories is placed on the nature of mutually coacting relations between individuals and contexts, represented as individual ←→ context relations.

As discussed by Overton (Chapter 2, this *Handbook*, this volume), all levels of the relational developmental system are integrated within relational developmental systems theories, ranging from variables involved in biological/physiological processes, through behavioral and social relationship processes, through physical ecological, cultural, and historical processes. The embeddedness of all levels within history imbues a *temporality* into individual ←→ context relations, and means that there is a potential for *relative plasticity*, for organized and systematic change in these relations, across person, time, and place (see Elder, Shanahan, & Jennings, Chapter 2, this *Handbook*, Volume 4). Accordingly, relational developmental systems theories focus on the "rules," the processes that govern developmental change and exchanges between individuals and their contexts. Brandtstädter (1998) termed these *developmental regulations*, and noted that when developmental regulations involve mutually beneficial individual ←→ context relations, they constitute *adaptive* developmental regulations.

The possibility of adaptive developmental relations between individuals and their contexts and the potential plasticity of human development are the distinctive features of this approach to human development. These features of developmental theory raise, however, important methodological issues. That is, three core features of Relational-Developmental-Systems models provide a rationale for making a set of methodological choices that differ in study design, measurement, sampling, and data analytic techniques, from selections made by researchers using split, dichotomous, or reductionist approaches to developmental science (see Molenaar, Lerner, & Newell, 2014; Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume;

Nesselroade & Molenaar, 2010; Ram & Grimm, Chapter 20, this *Handbook*, this volume; von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume). These three features of relational developmental systems are:

1. The conceptualization of development as the result of multiple coacting influences, which are context sensitive and contingent. This implies that development is inherently subject-specific and stochastic (probabilistic or random).
2. Development is understood to be a constructive process in which nonlinear epigenetic influences play central roles (see Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume). The most successful class of mathematical-biological models explaining such epigenetic influences are the so-called nonlinear reaction-diffusion models. These are nonlinear dynamic models generating emergent qualitative developmental changes that are not caused by genetic or environmental influences but instead are the result of dynamic self-organization. Such nonlinear epigenetic influences create substantial subject-specific variation which reinforces the subject-specific effects due to contingent contextual influences.
3. There is a focus on the potential for change evolving at multiple time scales and at multiple levels. This implies that dynamic systems models inspired will include time-varying parameters located at different levels and changing with different rates.

Along with these methodological implications, the emphasis on how the individual acts within the context, to contribute to the plastic relations with it, fosters an interest in individual agency (see Sokol, Hammond, Kuebli, & Sweetman, Chapter 8, this *Handbook*, this volume) or on intentional self-regulation (see McClelland, Geldhof, Cameron, & Wanless, Chapter 14, this *Handbook*, this volume), and this focus is best instantiated by person-centered (as compared to variable-centered) approaches to the study of human development (see von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume) and thus, to individual difference (diversity) oriented developmental scholarship (Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume).

In addition, the person-centered focus, as well as the emphases on relative plasticity and on mutually influential person ←→ context relations, has resulted in relational-developmental-systems theories being used as a frame for modeling the changing structure of ontogenetic trajectories, and has resulted in the view that developmental science is a nonergodic field (Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume). The ergodic theorem holds that data sets are marked by (a) homogeneity across individuals in a three-dimensional matrix that involves persons, variables, and time and (b) stationarity of individuals' scores on variables across time. Framed by the Process-Relational and Relational-Developmental-Systems research paradigm, however, developmental scientists argue that there is variation across individuals both within time and within individuals across time in their trajectories of individual ←→ context relations (i.e., across time differences). In other words, people differ in their paths across the life span. Because of this, the assumptions of homogeneity and stationarity of the ergodic theorem are rejected in contemporary developmental science. As a consequence of nonergodicity, developmental scientists emphasize the fundamental value of both person-centered and change-sensitive methods.

The chapters in this volume collectively document the paradigm shift to a process-relational and relational-developmental-systems research paradigm that has emerged in developmental science. All chapters focus on the implications for scholarship in different substantive areas of developmental science of process-relational and relational developmental systems thinking. The chapters in this volume also present and discuss contemporary research and new data analytic methods that have emerged within this new paradigm, and reflect the paradigm's focus on concepts of *process and system* with the aim of describing, explaining, and optimizing intraindividual changes and interindividual differences in intraindividual change across the life span (see Lerner, Preface to this edition). The dual and integrated contributions of this volume—to instantiating a paradigm shift by advancing both theory and method in developmental science—are exemplified within the chapters in this volume. A brief summary of each of these chapters describes these contributions.

THE PLAN OF THIS VOLUME

In Chapter 2, Overton compares and contrasts the classic Cartesian-Split-Mechanistic scientific research paradigm with the contemporary process-relational and relational-developmental-systems scientific research paradigm. In this presentation, he discusses the scientific advantages of a holistic approach that treats *endogenous activity, change, becoming, process, necessary organization*, and *relations* as fundamental categories in constructing relational developmental systems theories and research methods. Overton goes on to demonstrate how these fundamental categories lead to a characterization of the organism as an *inherently active, self-creating (autopoetic, enactive), self-organizing, and self-regulating, relatively plastic, nonlinear complex adaptive system*. The system's development occurs through its own *embodied activities and actions* operating *coactively* in a lived world of physical and sociocultural objects, according to the principle of *probabilistic epigenesis*. This development leads, through positive and negative feedback loops created by the system's organized action, to increasing system differentiation, integration, and complexity, directed toward adaptive ends.

In the next chapter, Witherington, explicitly operating within a process-relational context, discusses dynamic systems in developmental science, noting that in its mathematical, methodological, and conceptual grounding, the dynamic systems approach to development offers a unique, relationally focused model for understanding developmental process. Proponents of the dynamic systems approach, however, are metatheoretically divided with respect to what constitutes the very nature of explanation in developmental science, resulting in two distinct ontological frameworks within the approach: a relational inclusive, pluralistic framework, and a split exclusive, monistic framework. The author explains that the purpose of this chapter is to articulate the metatheoretical divide that currently exists within the dynamic systems approach and to address the implications of this divide for realization of the approach's potential as a part of the Process-Relational and Relational-Developmental-Systems paradigm. The chapter begins with an overview of historical influences on the dynamic systems approach to development, specifically targeting the multidisciplinary frameworks of von Bertalanffy's *general systems theory* and *nonlinear dynamical systems theory*. Alternate ways of marrying these multidisciplinary influences are discussed and used to anchor the chapter's delineation of the dynamic systems approach to development through its ontologically distinct variants. The chapter ends by framing metatheoretical division within the dynamic systems approach in terms of the Relational-Developmental-Systems and Cartesian-Split-Mechanistic paradigms.

The following chapter by Mascolo and Fischer represents one the most comprehensive illustrations of a relational developmental systems theory in the contemporary field of developmental science. The theory spans the development of cognitive, affective, and action systems from infancy through adulthood. Flowing from this *dynamic systems* and *skill* theory, along with the associated empirical research the theory has generated, the authors find that qualitatively new abilities emerge naturally in learning and development, transitioning from one form of action or representation to another, and they argue that "humans are self-creating, self-organizing, and self-regulating systems grounded in meaning through the action of our bodies and our cultures." Throughout the chapter, they repeatedly demonstrate empirically that development involves dynamic transformations in the structure-function of behavior.

Relational-Developmental-Systems incorporates a variety of systems perspectives. In their chapter on biology, development, and human systems, Lickliter and Honeycutt take a psychobiological systems perspective, and discuss the interwoven genetic, epigenetic, developmental, ecological, and evolutionary components of contemporary biology as they contribute to our understanding of developmental processes. As is the case with all the sciences, progress in biology depends on advances in theory building, empirical research, and modeling. Development, as one of the central processes of biology, has been the focus of both empirical and theoretical attention for centuries. Research techniques and methods used in biology to study development have evolved dramatically over the past several decades, generating a wealth of detailed empirical data. Metatheoretical frameworks, theories, and modeling have likewise advanced, calling into question established interpretations and assumptions about development, including the relation between genotype and phenotype, the nature and extent of heredity, the links between development and evolution, and the biological bases of behavior and cognition. The authors review the history and current status of biology's perspective on development and discuss the broader implications of this view understanding human development.

In the next chapter, Bateson presents an ethological perspective on how developmental processes become integrated, and he points to the contributions that ethology has made to an understanding of human development and evolution along with how these contributions are being integrated with modern studies of epigenetics. He notes that ethologists have focused on behavior that is characteristic of the species and adapted to its biological requirements. Studies of development have brought ethologists together with those working in many other fields of biology, psychology, psychiatry, and epigenetics. Contemporary ethology maintains a distinctiveness in taking an active view of the organism and focusing on biological function. Bateson points out that the old static view divided behavior into the innate and the acquired and—much in keeping with a Process-Relational and Relational-Developmental-Systems paradigm—the innate versus acquired position has been replaced by a much more dynamic systems view of underlying processes. Attention is now focused on how an individual develops and the interplay between the processes generating the robust features of an individual's behavior and the many processes involved in plasticity. Individuals make choices and control their environment. Their adaptability is crucial. All these activities have an impact on the evolution of their descendants.

Marshall's chapter on neuroscience, embodiment, and development focuses on the problem of the relation of contemporary neuroscience, psychology, and human development. He describes the separatist perspective that neuroscience is unrelated to psychology and human development, and the reductionist view of behavior reduced to brain function. Marshall argues for a more relational understanding based on the concept of *embodied action* and *embodied development*. This concept, Marshall argues, must be an essential feature of any theory of developmental cognitive neuroscience. The argument is made that embodiment has the potential to reframe the ways in which neuroscience data are considered in relation to other kinds of data. However, key developmental features of this reframing are currently underspecified, and Marshall argues that a Relational-Developmental-Systems perspective provides a productive path to integration. The implications of this approach for forging a new biologically grounded perspective for developmental science are profound, and Marshall discusses these in detail.

The chapter by Sokol, Hammond, Kuebli, and Sweetman considers the development of agency as a relational developmental conception that makes clear that the most basic form of agency is already present in the dynamic, self-organizing activities of living systems. The authors discuss how from the earliest point in the development of persons, agency manifests in different forms and grows through the interrelations of various biopsychosocial processes. These processes can be organized into the general levels, including the levels of biophysical agency, psychosocial agency, and sociocultural agency. The authors further describe how the most flexible and richest forms of agency seen in adulthood build from developmental processes evidenced throughout the life span: infants' sensorimotor and perceptual functioning, toddlers' symbolic representational and linguistic functioning, the child's self-regulatory functioning, and adolescents' and young adults' moral functioning.

The dialectic and transactional coactions are constitutive features of the Process-Relational and Relational-Developmental-Systems paradigm. In their chapter, Kuczynski and De Mol employ these concepts to describe contemporary dialectical models of socialization. They argue that dialectics draws attention to ideas of context, change, and nonlinear synthesis, which are best fitted to model the lived experiences of socialization processes. The authors note that despite contemporary acceptance that children are active agents in their own socialization, the influences between parents and children are still often viewed as unidirectional. They argue that a most important advance in the area of socialization has been the move to relationally bidirectional (←→) models and to recognize the complex causal structure of the socialization process. The chapter describes *social relational theory* as a framework for translating four assumptions of a dialectical ontology—*holism, agency, contradiction*, and *synthesis*—to reformulate major transactional processes in parent-child relations and socialization. The chapter concludes with a discussion of applied and methodological implications of social relational theory.

The chapter by Mistry and Dutta discusses conceptual and methodological advances that have been made toward an integration of human development and culture. Beginning as separate and separated fields of inquiry, cross-cultural psychology, cultural psychology, and human development achieved several steps toward integration beginning in the late 20th century and continuing into the 21st century. These are described along with the contemporary trend toward a relational integrative approach. In this analysis the authors point to parallels between contemporary sociohistorical perspectives and relational development science perspectives. In particular, they call attention to four key convergences: (1) the relation of person and culture as embodied or mutually constitutive, (2) the integration of meaning-making as part of context, (3) action and epigenesis as the source and process of developmental change, and (4) the simultaneous focus on both idiographic and nomothetic levels of analysis.

In the next chapter, Lewis discusses the development of emotions and the importance of the emergence of consciousness in the child's emotional development. This discussion begins from the Relational-Developmental-Systems premise that both emotional development and the child's growing knowledge of the world entail the active reciprocal bidirectional (←→) coactions among biological and environmental systems. Lewis argues that the first signs of what will be emotions are found in the newborn's adaptive patterns of action, which developed in utero in the context of an evolutionary background and according to processes of *probabilistic epigenesis*. These action patterns, which have been termed by others as *primary emotions* (anger, contempt, fear, disgust, happiness, sadness, and surprise) engage the child's social and object worlds; shape these worlds, and are shaped by them. However, it is not until the child has the capacity to think and think about him- or herself that these action patterns become *emotions*. Thus, the development of consciousness as self-reflective thought, as evidenced by *self-referential behavior*, becomes a constitutive feature of the development of emotions.

The development of personal and cultural identities is discussed in the next chapter by Chandler and Dunlop. The authors present their chapter in the context of a discussion of dualisms in general and, more particularly, those Cartesian dichotomies of thought that set selves apart from society, and conceptually isolate individuals from their communities. Because these familiar cleavages between persons and collectives can only be understood in the context of centuries of commitments to Cartesian substance dualisms more generally, the chapter begins with an introductory detour through earlier crash sites of contested claims about the alleged vices and virtues of dualistic thought more generally. They explain that it is obviously not enough to simply document common isolationist tactics. Rather, they argue that a promising first step out of this doctrinaire dilemma involves the use of common concepts that already exist at the margins of the problem. The concepts of personal and cultural continuity are offered up as provisional examples of such shared constructs, and are enlisted in the service in a post-Durkheimian account of differential suicide rates in indigenous and nonindigenous cultures.

The chapter by Turiel represents another comprehensive relational developmental systems theory. This chapter, while focusing on moral development presents the author's social domain theory, a *constructivist-relational* approach, which has led to many empirical demonstrations showing that judgments in the moral domain begin at a very early age and are distinct from the formation of other social and personal domains of judgment. A key feature of Turiel's work is the insistence that differentiations that children, adolescents, and adults make among the domains (moral, social, personal) reflect *relational* processes of thought and emotions as well as flexibility of thought. The emphasis throughout is that this relational position means that although thought and emotion can be looked at from one point of view or another, the two processes cannot be dichotomized as separate disconnected processes.

McClelland, Geldhof, Cameron, and Wanless examine the development of self-regulation, especially intentional self-regulation, in the context of the Relational-Developmental-Systems paradigm and action theory, which is a highly prominent theory within the Relational-Developmental-Systems perspective. The authors define the *concept* of self-regulation as referring to taking in information, weighing choices and consequences, and making adaptive choice(s) to attain a particular goal. They note that self-regulation has received heightened attention as a key process, which predicts a variety of developmental outcomes across the life span. However, beyond the general agreed-upon definition, there are a number of debates about the scientific *constructs* that represent self-regulation. The authors discuss the various key conceptual and methodological issues surrounding self-regulation and conclude that the term *self-regulation* is itself an oversimplification. They argue that individuals constantly regulate their behavior in reaction to, and with support from, the opportunities and constraints afforded by their environment. Consequently, optimal self-regulation requires orchestrating a diverse set of self-regulatory skills and abilities. Thus, similar to the conceptual shift away from deficit models, which describe where children are lacking in comparison to other children, is an acknowledgment that people develop the most adaptive regulatory strategies for a given context. The authors say that, in other words, it is not as accurate to say a child "has" or "lacks" self-regulation, but to instead to describe the nature of his or her self-regulatory behaviors and the conditions under which he or she self-regulates in ways that optimize development. The chapter concludes with a discussion of the next steps needed for studying self-regulation in context, improving intervention efforts, and advancing analytical and measurement methods.

In the next chapter, Cummings and Valentino begin their presentation of developmental psychopathology with a consideration of the definition of the field, the gaps it addresses in the study of child psychopathology, theoretical assumptions about the nature of human development, and its relation with other disciplines. The authors demonstrate the close association with a Relational-Developmental-Systems perspective in the key conceptual components of developmental psychopathology they examine. Like relational developmental systems, these components include a holistic approach, an emphasis on plasticity, and a dynamic, process-oriented perspective on both normal development and developmental psychopathology. The notions of developmental pathways, resilience, and the consideration of both risk and protective factors are all important components in the study of developmental psychopathology. In discussing *holism*, Cummings and Valentino introduce the concept of *floating holism* to emphasize the already well-accepted fact that holism does not preclude analysis, but encourages systematic analyses. The authors also emphasize that the evaluation of what is considered disordered or adaptive must take into account the context in which the pattern occurs; for instance, the family and community. The implications for prevention, intervention, diagnosis, and classification are also discussed. The authors close with a consideration of new directions and emerging themes in the field.

Lerner, Lerner, Bowers, and Geldhof's chapter presents a relational developmental systems model of positive youth development. The authors explain that interests in the strengths of youth, the plasticity of human development, and the concept of resilience coalesced in the 1990s to foster the development of the concept of positive youth development (PYD). As discussed by Hamilton (1999), the concept of PYD was understood in at least three interrelated but nevertheless different ways: (1) as a developmental process; (2) as a philosophy or approach to youth programming; and (3) as instances of youth programs and organizations focused on fostering the healthy or positive development of youth. The authors use concepts drawn from the Process-Relational and Relational-Developmental-Systems paradigm and the tripartite conception of PYD suggested by Hamilton as frames to review the literature on (a) the different theoretical models of the PYD developmental process; (b) philosophical ideas about, or conceptual approaches to, the nature of youth programming with a special emphasis on the model of PYD with the most extensive empirical support, the Five Cs Model of PYD; and (c) key instances of programs aimed at promoting PYD. The authors also discuss the conceptual and practical problems in integrating these three facets of PYD scholarship. This chapter concludes by explaining why understanding complex development requires multimethod integration as well as an integration of ideographic and nomothetic perspectives.

Turning to the methodological innovations that have emerged to enable ideas derived from relational-developmental systems theories to be tested, Molenaar and Nesselroade present an overview of new powerful approaches to statistical dynamic systems analysis. They begin their chapter with a heuristic description of a general mathematical theory—ergodic theory—that as mentioned earlier in this introduction implies that the study of developmental processes requires a fundamental change in methodology in which the focus is on analysis of intraindividual variation (time series analysis). A canonical multivariate time series model—the dynamic factor model—is introduced to organize the ensuing presentation of statistical methods for the analysis of intraindividual variation. Special emphasis is given to new methods for inferring valid nomothetic dynamic systems models of heterogeneous developmental processes. The chapter closes with an in-depth description of successful nonlinear dynamic systems approaches to the study of *stagewise* developmental processes.

In the next chapter, on neuroscientific methods with children, de Haan notes that neuroscientific methods can be used to capture the structural and functional changes happening in the human nervous system as it develops throughout infancy, childhood, and adolescence. This chapter provides an introductory overview of the noninvasive neuroscientific methods used in developmental research involving humans. It covers measurement of both the central and the autonomic nervous systems, considers the relative strengths and weaknesses of the methods, and provides examples illustrating their use. Special emphasis is given to general issues in measurement, methods for measuring brain structure and function (in particular an extensive overview of techniques based on magnetic resonance imaging [MRI]), and methods for studying genetics. The chapter concludes with a discussion of challenges that neuroscientific methods with children need to address and the role they will play in future research.

Qualitative and mixed methods models are discussed by Tolan and Deutsch. They note that mixed methods are increasingly recognized as advantageous and particularly informative for developmental science research. Initially and typically referring to the combination of quantitative and qualitative methods within or across studies, the approach can be considered more general than that, referring to the juxtaposition of different analytic methods to increase how informative a study or set of studies can be. This approach recognizes that different methods, within and across quantitative and qualitative types, each have different assumptions and capabilities. Multiple methods help to overcome limitations that occur with any single analytic method and bolster clarity and robustness of understanding. The chapter outlines the theoretical, design, and practical issues in use of mixed methods in developmental science. The key constructs, epistemological framework, theoretical considerations, approaches to different qualitative and quantitative methods and different arrangements in mixing methods are described. Limitations, critical and emerging issues, and exemplars of mixed methods applications are provided.

Ram and Grimm present a review of latent growth curve models and longitudinal factor models and consider how these models can be applied to individual-level and sample-level inquiry to examine intraindividual change and interindividual differences in change. They begin by presenting a taxonomy of change processes, and tether a selection of contemporary models to that taxonomy. Next an extensive list of increasingly complex growth curve models is described, culminating in a number of innovative nonlinear growth curve models (exponential, sigmoid, sinusoidal). This is followed by an insightful theoretical discussion of the relations between growth curve models, latent change models and dynamic systems theory. The chapter continues with the presentation of factor analytic methods, including P-technique, dynamic factor analysis, and latent Markov modeling. Ram and Grimm finish their chapter with emphasizing the need to embrace nonlinearity to capture the intricacies of developmental processes—including the use of differential equations for representing this nonlinearity—as well as the need to measure more frequently (intensive longitudinal designs).

In the next chapter, von Eye, Bergman, and Hsieh discuss person-oriented methodological approaches. They explain that person-oriented approaches to social and behavioral developmental sciences proceed from the fact that aggregate-level descriptions of constancy and change usually fail to represent individuals. Protagonists of a person-oriented approach, including relational developmental systems theories, therefore, have presented tenets stating that development can be person-specific and that psychometric instruments must possess dimensional identity to be applicable over time, and to enable researchers to perform comparisons of individuals or groups of individuals. Protagonists of idiographic psychology have shown that cross-sectional information can be used as substitute for longitudinal information only under conditions that are atypical of developmental processes. In the first part of this chapter, the authors present the main lines of person-oriented and idiographic research, and compare these approaches with differential psychology. In the second part of the chapter, the authors discuss methods of analysis that are suitable for person-oriented research. These methods include, but are not restricted to, hierarchical linear modeling, time series analysis, longitudinal factor analysis, configural frequency analysis (CFA), and item response theory (IRT). Examples with empirical data are given for CFA and IRT. In the discussion, perspectives of the research planner, the data analyst, and the applied developmental scientist are taken.

CONCLUSIONS

As documented by the contributions to this volume, philosophy, theory, and method in developmental science are converging on concepts and empirical tools of design and analysis that enable the mutually influential relations between an individual and his or her context to be better understood and better investigated. The paradigm shift represented by Process-Relational and Relational-Developmental-Systems research paradigm to frame Relational-Developmental-Systems models and theories of human development has advanced sufficiently to enable ideas pertinent to such theories to be aligned with methods elucidating the holistic, embodied development of the individual ←→ context relations constituting the basic process of human development.

The scholarship within this volume and, as well, across the four volumes of this edition, attest to the fact that the field of development of developmental science is in the midst of an exciting period. The paradigm shift involves increasingly greater understanding of how to think about and how to describe, explain, and optimize the course of human life for diverse individuals living within diverse contexts. As documented by the chapters in this volume, the years ahead hold great promise for important, and perhaps profound, advances in knowledge about the bases, and evidence for enhancing, human development across the life span.

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CHAPTER 2

Processes, Relations, and Relational-Developmental-Systems

WILLIS F. OVERTON

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Developmental science is an interdisciplinary scientific field dedicated to understanding and explaining developmental processes, and optimizing the adaptive development of the individual (Lerner, 2012a). The focus of developmental science is on the development of the individual or intraindividual change. Individual differences are explored in the context of this intraindividual change. Like any science, developmental science operates within a broad system of assumptions, principles, or rules. Or stated inversely, developmental science does not operate according to brute induction. The broad system that frames developmental science, as well as any field of science, is usually referred to as a scientific paradigm (Kuhn, 1962, 1970, 1977) or a scientific research program (Lakatos, 1978a,1978b). This chapter will explore paradigmatic issues, some of which are consistent with, and some which are inconsistent with, the aims of developmental science. A good deal of what I present covers territory that represents many years of analysis and reflection on the nature of developmental processes (e.g., Overton, 2013a, 2013b; Reese & Overton, 1970). This chapter represents an extension of earlier chapters that were written for the fifth and sixth editions of the *Handbook of Child Psychology* (Overton, 1998, 2006). The broad aim in this chapter

I would like to express my thanks and appreciation to Rich Lerner for his enormous support during the writing of this chapter and the editing of this volume; to David Witherington for his extremely helpful feedback on the chapter; and to Jen Agans for her outstanding graphic support work on the chapter.

is to work toward bringing greater conceptual clarity to the field. This, in the belief that only through establishing coherent sets of concepts can we continue to move forward toward the goals of describing, explaining, and optimizing human development. The work of conceptual clarification often flies in the face of an earlier description, given by Horgan (2001) of a reality that developmental scientists generally face: "Our training and core practices concern research methods; the discipline is . . . deeply skeptical of . . . [conceptual clarification]. We emphasize methods for the verification of hypotheses and minimize the analysis of the concepts entailed by the hypotheses" (p. 27). However, the work of conceptual clarification is consistent with Horgan's further comment that "All the empiricism in the world can't salvage a bad idea" (p. 27). And, conceptual clarification also stands as an antidote to Wittgenstein's (1958/1953) cynical conclusion that "in psychology there are empirical methods and conceptual confusions" (p. xiv).

Ongoing conceptual work is a necessary feature of any science. In this context it is important to note that since the last edition of this *Handbook* published in 2006, there has been both an increasing recognition of the need for a clearly articulated coherent conceptual system to contextualize our field, and a significant increase in efforts to provide this conceptual framework. Evidence of the accomplished conceptual work is found in each of the chapters of this volume. Evidence of the need for further conceptual reflection is found in several contemporary trends in subareas of developmental science, and here four are presented as examples; these include new understandings of (1) the nature of inheritance (i.e., the old nature-nurture debate), (2) the nature of evolution, and its relation to human development, (3) the nature of cognition and cognitive development, and (4) the relation of culture and individual development.

Concerning the issue of inheritance, advances in epigenetics and a broader understanding of the genome itself have made the route from genotype to phenotype complex to the point that the classic model, asserting that who we are and what we become to be a simple additive function of gene × environment interactions, has become completely untenable (see, e.g., Charney, 2012; Gottlieb, 2000, 2003; Gottlieb, Wahlsten, & Lickliter, 2006; Greenberg, 2011; Ho, 2012; Joseph, 2010; Keller, 2010; Lerner, 2012b; Lickliter & Honeycutt, 2010, Chapter 5, this *Handbook*, this volume; Meaney, 2010; Moore, 2001; Partridge, 2005, 2011; Slavich & Cole, 2013; Wahlsten, 2012).

In her reexamination of this inheritance issue, or nature-nurture debate, Keller (2010) emphasizes the conceptual issues, as she finds a "*morass of linguistic and conceptual vegetation* grown together in ways that seem to defy untangling" (p. 9; emphasis added), and concludes:

> Daily, we are discovering new and extraordinarily ingenious ways in which noncoding DNA sequences participate in the mammoth projects of regulating the spatially and temporally specific transcription of DNA, the construction and translation of messenger RNA and the positioning, conformation, and activity of proteins. Early concepts of the gene were predicated on the assumption of a relatively simple transformation from genotype to phenotype, but now we are beginning to understand just how enormously complex that process is. *Such findings not only require us to rethink basic assumptions in biology, they also create the opportunity for such reconceptualizations*. (p. 78; emphasis added)

Similarly, Charney (2012) expresses the need for conceptual reflection in an exceptionally valuable review and analysis of the significant new empirical findings in genetics and epigenetics. Charney argues that although the new evidence creates virtually insurmountable obstacles for population (quantitative) behavior genetics, and while the evidence moves genetics into a postgenomic era, it does not itself yet constitute a paradigm because, "the post-genomic perspective has *not yet coalesced around a core set of principles or assumptions* characteristic of a paradigm" (2012, p. 332; emphasis added).

With respect to the relation between evolution and individual development and the need for new concepts, in this area of developmental science is rapidly moving away from two related positions. The first, a position held by contemporary evolutionary psychologists, is that "human nature, in the sense of the cognitive and emotional inventory of our species, has been constant over . . . [a] ten-thousand year window . . . a standard assumption in evolutionary psychology" (Pinker, 2011, p. 612). The second retreating position is the now 70-plus-year-old so-called "modern synthesis" (i.e., the integration of Mendelian genetics with neo-Darwinian variation and natural selection). In both cases individual development was taken to be controlled by evolutionary forces, but individual development was understood as playing no constitutive role in evolution. Today overwhelming evidence points to the fact that individual development is an integral part of the fabric of evolution (e.g., Bateson, Chapter 6, this *Handbook*, this volume; Bateson & Gluckman, 2011; Gilbert & Epel, 2009; Gottlieb, 2002; Ho, 2010; Jablonka & Lamb, 2005; Jablonka & Raz, 2009; Laubichler, 2010; Lerner & Overton, 2014; Lickliter & Schneider, 2006; Pigliucci & Müller, 2010b; Robert, 2004; West-Eberhard, 2003).

For present purposes the most important feature of this advance of integrating individual development and evolution is the simultaneous recognition of the need for a new conceptual framework. This sentiment is captured in the title of a chapter—"Rethinking Epigenesis and Evolution in the Light of Developmental Science"—written by Lickliter and Honeycutt (2010). Further, West-Eberhard (2003), one of the major figures in this advance, argues that "the *need for a conceptual framework* for the study of organization lies at the heart of unsolved problems in both ontogeny and phylogeny" (p. 16; emphasis added).

Cognition and cognitive development represents a third example of an area that has increasingly recognized the need for a new coherent conceptual framework. In this area, for example, the standard model, which Rowlands (2010) refers to as "*Cartesian cognitive science*" (p. 2), has involved the claim that mental processes are exclusively located in the brain (e.g., Adams & Aizawa, 2010). This model is increasingly being challenged by "a non-Cartesian vision of mental processes" (Rowlands, 2010, p. 25; see also Carpendale, Atwood, & Kettner, 2013), in which embodied processes, the environment, and culture all enter as constitutive features of mind (see, e.g., Marshall, Chapter 7, this *Handbook*, this volume; Menary, 2010; Mistry & Dutta, Chapter 10, this *Handbook*, this volume; Overton, 2013a; Stewart, Gapenne, & Di Paolo, 2010). However, Rowlands (2010) points to the need for further conceptual reflection on this non-Cartesian vision as he says, it would be "premature to describe this cluster of theories as a new science . . . because the new science, as yet, has *no clear conceptual foundation*" (p. 25).

A final example of an area in which a new conceptual framework is emerging is that of culture and individual development. In this area there appears to be a clear conceptual movement away from positions that treat individual development and culture as separate and distinct, if interacting, entities, and toward concepts that recognize coconstruction, codetermination, and codevelopment of person and culture (e.g., Eckensberger, 2003; Goodnow & Lawrence, Chapter 19, this *Handbook*, Volume 4; Mistry, Contreras, & Dutta, 2012).

The primary thesis of this chapter is that a good deal of the called-for "reconceptualization" and the development of a new conceptual framework—a Process-Relational and Relational-Developmental-Systems paradigm—has already been undertaken in developmental science and elsewhere. Mascolo and Fischer (Chapter 4, this *Handbook*, this volume) note that in recent decades, "there has been what might be called a *relational turn* in many areas of the social sciences" (p. 115). One example of this relational turn in the social sciences is offered by the anthropologist Tim Ingold (2004).

> What I offer is . . . not a recycling of tired preconceptions but a genuinely new way of thinking about human beings and their place in the world, centered on processes of development and the dynamic properties of relational fields, that not only promises a new reintegration of social and biological anthropology, but also sets a radical evolutionary agenda for the twenty-first century. It will, I hope, inaugurate the coming-of-age of anthropology as a *science of engagement in a relational world*. (p. 220)

Other social science examples are found in sociology (Emirbayer, 1997) and cultural psychology (Straub, 2006). This relational turn has not, however, been limited to the social sciences. Gilbert and Epel (2009) in presenting ecological developmental biology (eco-devo) describe several "revolutions" occurring in biology, including a new relational orientation: "Rather than analyzing independent 'things' a new focus of developmental biology concerns '*relationships*.' Nothing, it seems, exists except as part of a network of interactions" (p. xiii; emphasis added).

The theoretical physicist Lee Smolin (1997, 2013) refers to our living in a "relational world" and has sketched the beginning of a relational cosmology in physics, arguing "If we insist on reciprocal action and rule out fixed-background structures, what we are saying is that every entity in the universe evolves dynamically, in interaction with everything else. This is the essence of the philosophy of relationalism" (p. 117). And "In a relational world . . . things are defined by their relationships. Individuals exist . . . but their possibilities are determined by the network of relationships. Individuals encounter and perceive one another through the links that connect them within the network, and the networks are dynamic and ever evolving" (p. xxviii). Smolin terms this "the relational revolution" (p. xxviii).

Latour (1993, 2004), in the field of science studies, contributes to this relational revolution through his detailed proposals of how to move away from the extremes of Cartesian splits to a center or *middle kingdom* position where entities and ideas are represented, not as pure forms of matter, but as forms of process that flow across fuzzy boundaries. This movement is one toward what Latour terms *relationism*, a metatheoretical space where foundations are groundings, not bedrocks of certainty, and analysis is about creating categories, not about cutting nature at its joints.

Like any revolution, the birth of the relational revolution finds its origins deep in the history of humankind's thought about the nature of the universe, nature, and science, and this history includes, among others, centrally, the writings of Heraclitus, Leibniz, Kant, Schelling, Frichte, Hegel, James, Dewey, Pierce, Bergson, and Whitehead. In this chapter I elaborate and analyze in finer detail the central features and historical origins of the contemporary base of the relational turn—the Process-Relational and Relational-Developmental-Systems scientific paradigm.

In broad outline the rethinking leading to the relational turn has entailed reanalyses of the hitherto dominant Cartesian-Split-Mechanistic scientific paradigm along with arguments for the replacement of this paradigm with a Process-Relational[1] scientific paradigm that incorporates Relational-Developmental-Systems as a central component (see, e.g., Lerner, 2006; Lerner & Benson, 2013; Lerner & Overton, 2008, 2014; Overton 1998, 2006, 2010, 2013a, 2013b, 2014; Overton & Lerner, 2012; Overton & Lerner, 2014; Overton & Müller, 2012). In schematic form, the ontological and epistemological categories of this new paradigm include:

- *Holism* (compared to Cartesian *Atomism*).
- The inherent *Activity* of nature (compared to Cartesian *Fixity*).
- *Change* and *Becoming* as features of nature (compared to Cartesian Stasis and Being).
- Nature as *Process* (compared to Cartesian Nature as *Substance*).
- The *Necessary Organization* of nature (compared to Cartesian *Uniformity*).
- A *Pluralistic Universe* (compared to a Cartesian *Dualism*).
- *Constructivism* (compared to Cartesian *Realism*)
- Relational understanding (compared to Cartesian Either/or Split understanding).
- Multiple perspectives (compared to Cartesian Dualistic split Objectivism versus Subjectivism).
- Multiple forms of explanation (compared to Cartesian-Mechanistic Efficient/material causal explanation).

[1]In earlier writings (e.g., Overton, 2013a, 2013b) this paradigm was termed *Relationism*. However, *Process-Relational* better captures the ontological as well as the epistemological groundings of this metatheory.

Deriving from the ontological and epistemological Process-Relational categories, again in broad strokes, Relational-Developmental-Systems characterizes the living organism as an *inherently active, self-creating (autopoetic, enactive), self-organizing, and self-regulating, relatively plastic, nonlinear complex adaptive system*. The system's development takes place through its own *embodied activities and actions* operating *coactively* in a lived world of physical and sociocultural objects, according to the principle of *probabilistic epigenesis*. This development leads, through positive and negative feedback loops created by the system's organized action, to increasing system differentiation, integration, and complexity, directed towards adaptive ends.

In this chapter I first discuss the conceptual context, and how the concepts of any scientific paradigm form a nested system of interrelated concepts. This discussion is followed by a presentation of the nature and history of the Cartesian-Split-Mechanistic paradigm, along with the description of a more circumscribed sets of concepts that are nested within this metatheory, termed *metatheories of a middle range*. At that point in the chapter, attention is turned to a focus on the description and analysis of the Process-Relational paradigm including Relational-Developmental-Systems and closely related metatheories of a middle range.

CONCEPTUAL CONTEXTS

In any area of developmental science, as well as science in general, *context*, whether viewed as constitutive or causal, is a necessary, central, and enduring feature in the understanding of phenomena. For developmental scientists, the living system is the fundamental example, from the molecular, to the cellular, organ, person, and societal level of the functioning and development, each higher level forms the context for all lower levels and, in a relational reciprocal bidirectional fashion (←→), each lower level forms the context for all higher levels. As context, each level operates to both constrain and guide other levels. At this time, particularly in developmental science, there is scarcely anyone who would disagree with this assessment; it is virtually commonplace. What is less often recognized, however, is that the same necessity, centrality, and enduring quality of context extends beyond the empirical target phenomena of scientific investigation to conceptual systems.

Recognition of the nature and role of context in scientific conceptual systems has been hampered by two anachronistic narratives about scientific concepts that continue to exert a shadowy influence on many developmental scientists. In one narrative, that of the early 20th-century neopositivists, scientific concepts were represented as the simple outcome of an entirely bottom-up process, moving through brute induction from pristine particular observations to universal "empirical generalizations." The second shopworn narrative, told by mid-20th-century postpositivists (e.g., Popper, 1959, 1963, 1970), maintained that scientific concepts are merely human conjectures open to refutation via experimental testing. In neither narrative are concepts and conceptual systems considered as contextual in a constitutive sense.

Scientific Research Paradigms and Programs: Metatheory, Theory, Observation

In contemporary scientific epistemology (e.g., Godfrey-Smith, 2003; Lakatos, 1978a, 1978b; Laudan, 1977, 1984) concepts and conceptual systems do function as necessary, central, and enduring contexts for any broad scientific research program (Lakatos 1978a, 1978b) or scientific paradigm (Kuhn 1962, 1970, 1977). Further, and importantly, conceptual systems are understood to be interwoven in a nested fashion. This idea is most clearly described as a hierarchical set. Because all concepts are, by their very nature, abstract, the hierarchy is defined and arranged according to their scope, or the territory each set encompass, and the set's immediacy to everyday experience.

Taken as a whole the conceptual sets constitute the *conceptual framework* of a research paradigm. The most general sets are composed of *background concepts,* which are so termed because, although they establish the framing context for the whole paradigm, they seldom *explicitly* enter into the discourse of any specific set of investigations. These background concepts are generally termed *metatheoretical* or, when described as coherent sets, *metatheories*. They transcend (i.e., *meta*) theoretical concepts and theories in the sense that they constitute the conceptual context within which theoretical concepts and theories are constructed. Metatheories ground, constrain, and sustain theoretical and observational concepts. They perform the same general function with respect to methods, and in this case are termed *metamethods*. *Methodology* is a more familiar term for metamethods, but only when understood in its broad sense as a set of principles that guide the construction of methods (Asendorpf & Valsiner, 1992; Overton, 1998, 2006), and not as methods per se. In general, metatheory and methodology provide a rich source of concepts out of which theories and methods are constructed, and they provide guidelines that assist in avoiding conceptual confusions and inappropriate methods.

The Cycle of Scientific Discourse

An elaboration of the nature and role of metatheory in science, and specific metatheories (including methodology) in developmental science, entails a recognition of the cyclical nature of scientific discourse as it moves between the levels of observational and metatheoretical discourse (see Figure 2.1).

The most immediate and circumscribed area of scientific discourse is the *observational*. This set of concepts is one's current commonsense means of discussing and understanding the nature of objects and events in the world. There is uniform agreement across a wide spectrum of philosophical systems that commonsense observational concepts constitute the base of the structure of scientific discourse (Nagel, 1967, 1979; Pepper, 1942; Wartofsky, 1968; Whitehead, 1925). "The topic of every science is an abstraction from the full concrete happenings of nature" (Whitehead, 1938/1966, p. 143). These commonsense concepts are not the pristine observations of neopositivist methodology; rather they are folk beliefs and distinctions that surround us in everyday life. That "some people are smart" and "other people are more or less smart" is commonsense discourse; "IQ" is not. That "people control their behavior in various ways" is commonsense discourse; "self-regulation" is not. That "people and other animals change over time" is commonsense discourse; "ontogenetic development" is not.

Although the observational, commonsense, or folk set of discourse concepts has a sense of immediacy and

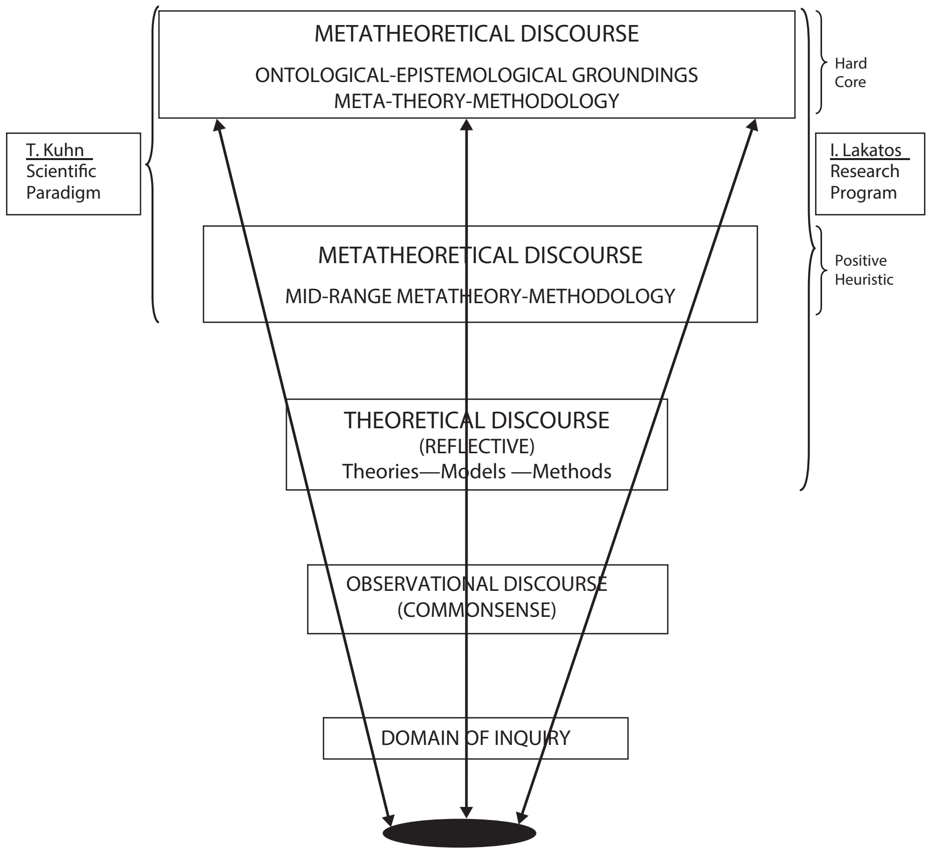

Figure 2.1 Conceptual context of a scientific research paradigm.

concreteness, science—often defined as the reflective criticism of common sense (Wartofsky, 1968)—requires movement to a level of critical reflection on this commonsense understanding. *Reflective* discourse itself entails several increasingly general sets (see Figure 2.1). The first reflective set entails *theoretical* discourse. Here, discourse is about organizing and reformulating observational understandings in a broader and more coherent fashion. At this level, concepts are *about* the observational set of discourse. Theoretical concepts include theories, models, hypotheses, and they range from informal hunches to highly refined concepts concerning the nature of, and relations among, objects and events. For example, classical developmental theories such as Piaget's (1967) and Werner's (1957, 1958; Werner & Kaplan, 1963), as well as contemporary theories such as Mascolo and Fischer's (2010, Chapter 4, this *Handbook*, this volume), Turiel's (Chapter 13, this *Handbook*, this volume) and Witherington's (2011, Chapter 3, this *Handbook*, this volume) contain theoretical principle (e.g., *stage, tier, level of organization*) that represent developmental change as involving both continuous and discontinuous (i.e., transformational) features. Skinnerian, social learning, and information processing theories, on the other hand, all contain theoretical concepts, which represent developmental change as strictly continuous and additive. Each of the theoretical models in turn is, or should be, associated with statistical methods that most faithfully measure the form of change represented by the model. Chapters by Molenaar and Nesselroade (Chapter 17, this *Handbook*, this volume), by Ram and Grimm (Chapter 20, this *Handbook*, this volume), and by von Eye, Bergman, and Hsieh (Chapter 21, this *Handbook*, this volume), all present contemporary methods designed to measure both discontinuous and additive change, while earlier statistical methods, including ANOVA-based methods were limited to the measurement of additive change.

The next more general set of reflective discourse concepts is the metatheoretical (see Figure 2.1). Here discourse is *about* theoretical and observational concepts. A *metatheory* is defined as a coherent set of rules or principles. The rules describe and prescribe what is acceptable and unacceptable, meaningful and meaningless as theory—the means of conceptual exploration of any scientific domain—and these rules place constraints on theoretical and observational discourse. Consider an extremely simple metatheoretical rule: "the living organism is an input-output machine." Such a machine does not *do* anything unless external energy is applied to it. We can invent a theoretical concept *stimulus* for the energy applied as input and a concept *response* for movements of the device constituting output. Then we can "observe" what kinds of things in the world count as stimuli and what kinds of movements of the device would count as responses, and go on to investigate "causal" relations among stimuli and responses. As Searle (1992) points out, we can and do become "captives of a . . . set of verbal categories" (p. 31), to the point, in this example, of believing that the world is actually composed of stimuli and responses. Within this metatheoretical rule we might also come to extend the theory so that stimuli and responses are not simply forces and movements *outside* the device, but *inside* the device as well. In this case, we might consider an outside *S* (Stimulus) producing an inside the device *r* (internal response) leading to an inside *s* (internal stimulus) leading to another *r* and another *s* . . . until an ultimate *R* is produced. And we might then invent a new theoretical terms for the internal sets of *s* and *r* (i.e., *mediators*). One thing is clear; the simple metatheoretical rule has an impact on both the theory and the observations. Now, we can change the metatheoretical rule to another simple one, "the living organism is an inherently active system." With this change *stimulus* becomes not just obsolete, but theoretically meaningless, as does *responses*, because the latter were the product of stimuli. Other theoretical concepts that also immediately become meaningless under this new rule include *mediator, elicit, evoke, reinforce*, and *reinforcement*. Thus, a second thing becomes clear—the metatheoretical rule determines what will be theoretically meaningful and meaningless.

Reflective metatheoretical discourse can be analyzed into subsets according to scope and the character of the metatheoretical principles. At the pinnacle of greatest generality are metatheories that are so broad as to subsume a universe of content. This set is one of *worldviews* (see Figure 2.1). Like other metatheories, worldviews are composed of coherent sets of rules or principles, but in this set the principles are *epistemological* (i.e., pertaining to sources and justification of knowledge) and *ontological* (i.e., pertaining to fundamental categories of Reality) in nature.[2] In essence, a worldview is a framework that presents a vision of the nature of the world (e.g., are stasis or change, substance or process, asserted as the fundamental categories of the world?) and the nature of how we know that world (e.g., is knowledge the reflection of a mind-independent reality, or do minds actively participate in the constitution—construction—of the world as known?).

Nested within worldviews, but more general than theories, discourse involves *metatheories of a middle range* (see Figure 2.1). These conceptual systems are less general than worldviews, and entail principles that are identifiably more specific to the observational domains of interest. For example, nested within one particular worldview a middle-range metatheory represents the human organism as an *active agent* or as a *dynamic system*, while nested within another worldview a middle-range metatheory represents the organism as an *input-output computational recording device*.

The described structure of scientific discourse from commonsense observations to worldviews and back again represents the structure of what Lakatos (1978a, 1978b) referred to as a *scientific research program* (see also Laudan, 1977). The two metatheoretical sets reflect what Lakatos referred to as the program's *hard core* (worldview) and *positive heuristic* (middle-level metatheory), whereas the two metatheoretical sets also reflect Kuhn's (1962, 1970, 1977; see also Overton, 2013a, 2013b) concept of a *scientific paradigm*, (see Figure 2.1; and see Figure 2.2 for levels of discourse with specific examples).

THE CARTESIAN-SPLIT-MECHANISTIC WORLDVIEW AND SPLIT-MECHANISTIC MIDDLE-RANGE METATHEORIES AS SCIENTIFIC PARADIGM

As suggested earlier, the dominant paradigm or scientific research program has been until recently framed by the Cartesian, or, more accurately, the Cartesian-Split-Mechanistic worldview. Lakatos (1978a) has referred to

[2] Putnam (1987) introduced the convention of identifying the ontological Real—defined as that which is not dependent on something else (i.e., that which cannot be reduced to something else)—with a capital "R," thus differentiating it from commonsense reality (i.e., the reality of the manifest world of objects and events). This convention is followed in this chapter.

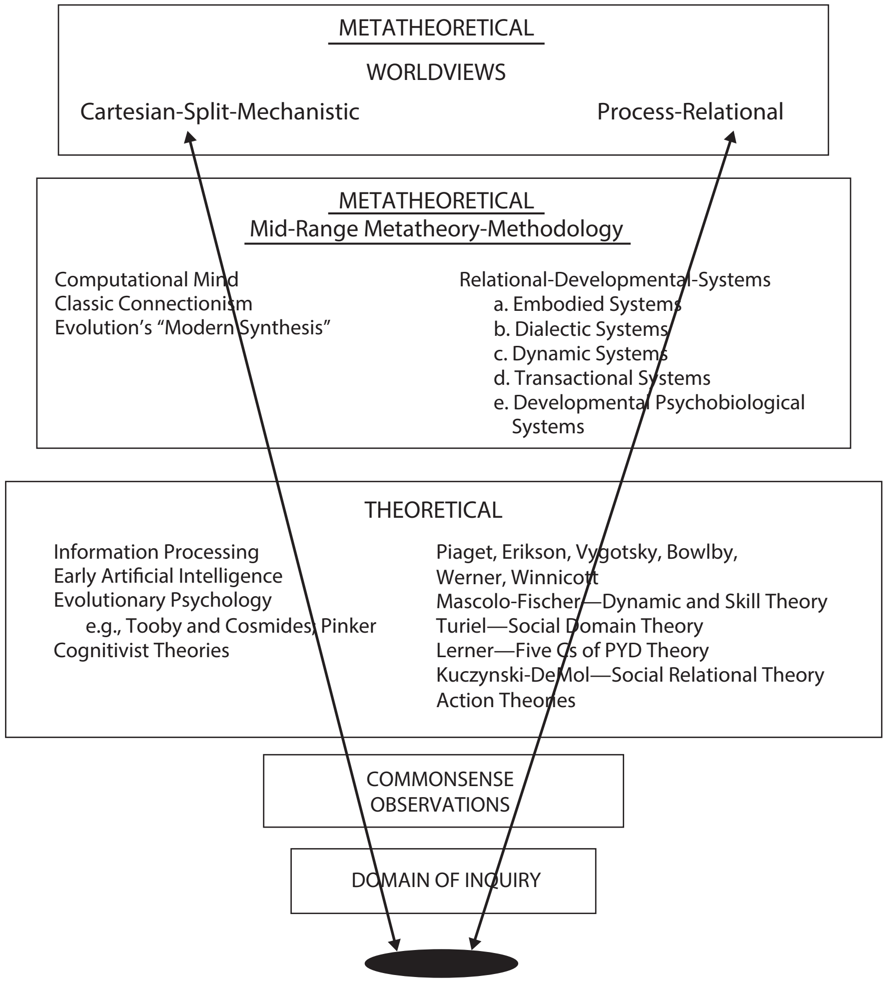

Figure 2.2 Conceptual context of the Cartesian-Split-Mechanistic and the Process-Relational paradigms.

this as the "Cartesian metaphysics, that is, the mechanistic theory of the universe—according to which the universe is a huge clockwork (and system of vortices) with push as the only cause of motion" (p. 47), and in which fundamental features of this world are split into dichotomous independent elements (Bernstein, 1983; Descartes, 1641/1996). A worldview is rarely, if ever, completely developed by any one individual, and this is true of the Cartesian-Split-Mechanistic worldview. Rene Descartes (1596–1650) is the central figure who was to have the greatest impact on the texts and subtext of this grand narrative. Descartes was preceded by Galileo Galilei (1564–1642) whose physics would first *split* the *natural world* from *mind*. Descartes himself elevated *splitting* to a first principle, established *substance* as the ultimate *foundation* of all Reality, and began the path to viewing the world in terms of the categories of the machine. The machine view was later elaborated by Newton (1643–1727) and his admirers, such as John Locke (1632–1704) and Thomas Hobbes (1588–1679), who envisioned both mind and nature in terms of an ontology of mechanically operating *atomistic materialism*.

Cartesian Substance, Splits, Foundationalism, Mechanism, Atomism, and Reductionism

The Renaissance scientific work of Galileo, more than any other person began to formally articulate ontological and epistemological *splitting* (Putnam, 1983, 1987), or a *divide and conquer* strategy (Dennett, 1991; Hundert, 1995) and *materialism*. Looking back to Democritus and anticipating John Locke, Galileo argued that matter and only matter constituted the Real and that all other perceptible qualities were only apparently real:

> The methodological precept "only the mechanical measurable properties of matter are of value in formulating scientific laws" became converted into the metaphysical statement "only the mechanical measurable properties of matter are *real*." And Galileo argued for the reality of these properties and the unreality of all others (colors, tastes, smells, etc.).... These latter properties he concluded were subjective illusions; only the former were objective, real. (Berlin, 1956, p. 47)

Thus, with Galileo, nature became split into an ontological *Real nature* identified with matter—and hence, what later became termed *materialism, naturalism*, or *physicalism*—and *apparent nature* identified with mind. Subject became split from object, with the identification of subject as the apparently real and object as the really real. There was also the anticipation of an epistemological splitting that became increasingly central in the 18th century. Galileo, while recognizing the necessity of both analysis and synthesis, argued a privileged position for analysis. By the 18th century, analysis split off from synthesis (i.e., *reductionism*; see Overton, 2002) would come to constitute the principle method for acquiring knowledge of an ontological *bedrock foundation* of *material elements* (the atoms of *atomism*) whereas synthesis became a distant second.

This analytic process, according to Galileo, is the presupposition of all exact knowledge of nature. The method of formulation of scientific concepts is both analytical and synthetic. It is only by splitting an apparently simple event into its elements and by reconstructing it from these that we can arrive at an understanding of it (Cassirer, 1951, p. 10).

Reductionism itself becomes a central feature of the Cartesian worldview. As Levins and Lewontin (1985) point out in their detailed analysis of Cartesian evolution:

> Cartesian reduction as a method has had enormous success in physics, in chemistry, and in biology ... and this has been taken to mean that the world is like the method. But this confusion of reduction as a tactic with reductionism as an ontological stance is like saying that a square wave is really the sum a large number of sine waves. In actual practice, reduction as a methodology and reductionism as a world view feed on and recreate each other. A reductionist method like the analysis of variance ... assigns weights to the "main effects" and then "first order," "second order," ... and so on—interactions as a matter of tautological bookkeeping.... Having performed this bit of number juggling, the ... scientist then reifies these numerical components as objective forces with actual physical interactions.... The scientist then sets the stage for further analyses by the same method, since, after all, it has already been shown, by the previous analysis, that the main effects exist. (p. 2)

While Galileo was a central figure in setting a framework for the ontological and epistemological presuppositions of what became the Cartesian-Split-Mechanistic worldview, it was the 17th-century philosophical work of Rene Descartes himself that firmly anchored and fleshed out most of this metatheory (Prosch, 1964). Descartes (1641/1996) began this course in his *Meditations* I and II by inventing what would become called *foundationalism*; the idea of a bedrock fixed point of certainty,

> I was convinced that I must once and for all ... build anew from the *foundation* [p. 58; emphasis added] ... Archimedes ... demanded only that one point should be fixed and immovable; in the same way I shall have the right to conceive high hopes if I am happy enough to discover one thing only which is certain and indubitable. (p. 63)

Thus, from the beginning, Descartes would split the world into *independent* parts; one constituting a fixed immovable foundational Reality, the other a derived appearance of reality. This split led Descartes to his second splitting of nature; "the assumption of bodies and minds as independent, individual substances, each existing in its own right apart from any necessary reference to each other" (Whitehead, 1925, p. 194). This is Descartes' well-known *res extensa* and *res cognitans*, an extended substance (body) and an unextended substance (mind):

> I am a thinking thing (or a substance whose whole essence or nature is to think). And ... I possess a body.... On the one side ... as I am only a thinking and unextended thing and as, on the other I possess a distinct idea of body, inasmuch as it is only an extended and unthinking thing. It is certain that this I (that is to say, my soul by which I am what I am) is entirely and absolutely distinct from my body. (Descartes, 1641/1996, Meditation Vi, p. 100)

Having created an ontological dualism by splitting nature into two distinct and independent substances Descartes—and all others who have since accepted the Cartesian categories—was faced with the problem of how to put the individual pieces back together. If there is an absolute foundational bedrock to nature and this bedrock is composed of the atoms of individual independent substances, there must be a glue that can join the pieces into the appearance of wholeness. Descartes favored the solution termed *interactionism*, a solution not unlike interactionist positions today, which split the living organism into elements such as nature-nurture, subject-object, brain-mind, body-brain, person-culture, and proposes that the whole organism is formed through the additive combination of those elements. As Descartes stated (1641/1996), the "body is by nature always divisible" (p. 105).

Substance dualism had other implications, as the philosopher Alfred North Whitehead (1925) pointed out. Descartes'

> fundamental principles are so set out as to presuppose independently existing substances with simple location in the community of temporal durations, and in the case of bodies, with simple location in the community of spatial extensions. Those principles lead straight to the theory of a materialistic, mechanistic nature, surveyed by cogitating minds. (p. 145)

And in the 18th century the British empiricist movement —as discussed later in this chapter—dismantled the cogitating mind.

The final feature of the Cartesian worldview was Descartes' use of the machine metaphor, thus ensuring the establishment of mechanistic framework (see Garber, 2002; Müller & Newman, 2008; Wright & Bechtel, 2007).

> I have described this earth and indeed the whole universe as if it were a machine: I have considered only the various shapes and movements of its parts. [Descartes, 1644, IV, Para. 188]. (quoted in Wright & Bechtel, 2007, p. 32)
>
> And as a clock is composed of wheels and counterweights . . . I consider the human body as being a sort of machine, so built and composed of bones, nerves, muscles, veins, blood, and skin. (Descartes, 1641/1996, Meditation VI, p. 104)
>
> The mechanisms familiar to Descartes (e.g., clocks . . .), typically produced their effects because of the shape, motion, and contact between their parts. So, if natural . . . [things] are mechanical they could likewise be rendered explicable by appealing to the shape and motion of their parts. (Wright & Bechtel, 2007, p. 32)

In this summary of Descartes' work we see that a nascent worldview had been established, which was fleshed out over the 18th and 19th centuries and came to dominate science, or at least the natural sciences, for three centuries. A key feature of this worldview, not yet made explicit, is its quality of "nothingbutness." Splitting yields "either/or" propositions, and the selection of one or the other of a forced choice necessarily means having nothing but this selection. Thus, knowledge arises according to the categories of materialism or idealism, subjectivism or objectivism, body (e.g., brain) or mind, and so on. Whichever category is chosen becomes the foundational Real, while the other becomes the peripheral, epiphenomenal, appearance, the *explanandum*, rather than the *explanans*. Searle (1992) captures the contemporary impact of this metatheory generally, and the impact of splitting specifically:

> Along with the Cartesian tradition we have inherited a vocabulary, and with the vocabulary a certain set of categories, within which we are historically conditioned to think about these problems. The vocabulary is not innocent, because implicit in the vocabulary are a surprising number of theoretical claims. . . . The vocabulary includes a series of apparent oppositions: "physical"; versus "mental," "body" versus "mind," "materialism" versus "mentalism," "matter" versus "spirit." Implicit in these oppositions is the thesis that the same phenomenon under the same aspects cannot literally satisfy both terms. (p. 14)

In the context of this "nothingbutness," Descartes' ontological categories can be summarized as (a) inert *substance* or matter forms an atomistic bedrock *foundation*, excluding any role for *process*; (b) inert substance does not itself change, thus, *being* or stasis (i.e., lack of change) is the natural state of things, excluding *becoming*; (c) substance is the ultimate indivisible particles or atoms, hence *atomism* (also termed *elementarism*), excluding *holism*; (d) atoms are identical, yielding a *uniform universe*, excluding a *pluralistic universe*, and excluding *necessary organization*; (e) *splitting*, both vertically (appearance-foundation) and horizontally (body-mind), excluding *relational* analysis and *multiple perspectives*; and (f) *interaction* as the additive combining of elements, excluding *coaction* of *parts and wholes*.

To flesh out the Cartesian-Split-Mechanistic worldview, the following section will briefly examine the period termed *Modernity*, and particularly the *empiricist* line of Modernity that emerged in the 18th century, an era termed the *Enlightenment*.

The Modern Period, the Enlightenment, and Rise of Radical Empiricism

Although there is some disagreement about the date, the modern period began around 1600 to 1650 (Toulmin, 1990). *Modernity* was defined both by a quest for absolute certainty of knowledge and by an effort to expand individual freedom, especially freedom of thought. Building knowledge on rational and reasoned grounds, rather than on the grounds of authority and dogma was understood as the key to each of these goals. The works of the early protagonists—Galileo, Descartes, Hobbes—have already been discussed. Building on these came the Newtonian (1643–1727) contribution (publishing *Principia* in 1687), the 18th-century *Enlightenment*, and the 19th-century *Utilitarian* movement.

Newton and the Mechanistic Split Tradition

The thought of the English Enlightenment emerged from the background of the earlier advances of the physical sciences, particularly the work of Newton. Building on Descartes' categories, Newton's major contribution was the scientific redefinition of the nature of matter in a way that conceived of all bodies as fundamentally *inactive*. Prior to Newton, scientifically, matter was understood as *inherently active*. Matter was thought of in terms of the *relation* of *being* (static, fixed) and *becoming* (active, changing). Newton, however, through his concept of *inertia*, split activity and matter and redefined matter as inactivity. For Newton,

> "Being" seemed to be simply the power, or "force," of inactivity, the passive power of remaining in motion in a straight line, unless acted upon by another force, and the passive power of remaining at rest unless and until acted upon by another force. "Being" and (active) "force" were thus separated. (Prosch, 1964, p. 52; see also, Schelling, 1803/1988, p. 154)

The redefinition of bodies as inert matter, and the assumption of the *atomicity of matter*, (i.e., following Descartes, bodies were thought of as ultimately composed of some *elementary substance that is uniform in nature*, and in combination, yields the things of the world), were basic for Newton's formulation of his laws of motion. These ideas were also ones that a later generation, working from the Cartesian categories, generalized into a metaphysics that identified the nature of the Real as fixed inert matter and *only* fixed inert matter. This view has been called the *billiard ball* notion of the universe, "the notion that basically everything . . . was made up of small, solid particles, in themselves inert, but always in motion and elasticitly rebounding from each other, . . . and operating mechanically" (Prosch, 1964, p. 66).

The impact of this extension of Descartes categories as a *billiard ball* or *clockwork* or *mechanistic* universe was, and continues to be, several-fold. First, the reduction of the subject to the object meant that the object approach was to be the only legitimate scientific approach to knowing. Given the split of subject (Spirit) from object (Matter), and given that the Real was understood to reside in the object, it was not possible to entertain the subject *point of view* as a legitimate perspective for scientific inquiry. In fact, there is no possibility of entertaining even the notion of *point of view* within this universe, because, within a mechanistic ontological-epistemological framework, there is only the truth of object, or the falsity of error.

Because fixity and uniformity constituted the Real, a second impact of the Newtonian tradition (Matson, 1964) was that change, other than random movement (a split-off notion of Aristotle's *alternation* or variational change), came necessarily to be treated as Appearance. The notion of developmental change as *transformational change* (see Ram & Grimm, Chapter 20, this *Handbook*, this volume) along with its allied concepts of *sequence, discontinuity, emergence, nonlinearity, novelty, direction*, and *irreversibility* became problems, not solutions. Similarly, the idea of *complex organization* presented a problem not a solution. These problems could not be solved until they were reduced to unchanging laws of the motion of the fixed and uniform smallest possible elements of matter, the atom (i.e., *atomism*). Whether the atoms of inquiry were the material *particles* of the early physicist, the *genes and DNA* of later day molecular biologist, the *neurons* of the neurophysiologist, the *elements of consciousness* of the early structuralist psychologists, the *responses* of the later behavioral psychologists, or the *output* of contemporary cognitive psychologists, these were the bedrock material elements that, interacting in linear combination with causal forces, generated the illusion of transformational change and complex organization. In this framework observable change was represented by the metaphor of the *Cycle of Time*, according to which seemingly transformational change is ultimately reduced to contingently determined and totally reversible movement (Coveney & Highfield, 1990; Gould, 1987; Nisbet, 1969; Overton, 1994a; Valsiner, 1994). And complex organization is treated as a *complicated* network, that can be analyzed into simple elements with sufficient reductive efforts.

The impact of the Newtonian mechanistic-split categories was not limited to ontological issues. The epistemological legacy of this tradition also reflects the assumptions of inert matter and atomism. From the Reality of the split-off object there grew the doctrine of *objectivism* or *scientific realism*, or what the American philosopher Hilary Putnam (1990) has called the *God's eye view*. According to this doctrine of objectivism there is a mind-independent fixed Real, and this Real forms the essential absolute foundation for all knowing; hence the Newtonian version of *foundationalism*. If the flux of the manifest world constituted the illusion of Appearance, then the task of knowing was the task of analysis down to the level of the Real mind-independent fixed base, and the detection of forces acting on these elements. Further, analysis and detection were to take the form of closer and closer observations until the "laws of nature would stand forth"—not as subjectively generated hypotheses, or suppositions drawn deductively from some higher-order premises ("Hypotheses non fingo," "I make no hypotheses," said Newton)—but as "observed correlations" or "empirical generalizations" *inductively* generated from these same observations (Wartofsky, 1968, pp. 183–184). Thus, the epistemological legacy of the Newtonian tradition was a nascent thoroughgoing radical empiricism and realism, driven by the primacy of an *analytic ideal* of complete *reductionism***,** and a synthetic method of a mind-independent *induction* (i.e., the form of logical reasoning that moves, via generalization and only generalization, from the particular to the universal). This view is summarized in the three steps of what came to be known as Newtonian "mechanical explanation" (Prosch, 1964, p. 77):

1. Take the subject matter (i.e., the commonsense understanding of some domain), and *reduce* it through analysis to its smallest invariant stable part, its atom (e.g., the atom of physics, the element of chemistry, the genes of biology, the neuron of neuroscience, the response of psychology).
2. Find, *through direct observation*, the forces, (i.e., *efficient or material causes*) that operate upon the atom (e.g., the stimulus, material or efficient, that determines the response in psychology).
3. *Induce* the laws (i.e., the observed regularities).

Locke, Hume, and the British Enlightenment

In an important sense, the 18th-century Enlightenment was a reaction against Descartes (Cassirer, 1951). In the context of a Process-Relational worldview (to be discussed later in this chapter), that traces back to the pre-Socratic Greeks and forward to Leibniz and Spinoza, to Hegel, James, Dewey, Whitehead, and Bergson, among others, an opposition arose to Descartes' inert substance, foundationalism, splitting, atomism, and mechanization. However, the line of thought that was to be known as the *English Enlightenment* or *British Empiricism*, accepted Cartesian inert substance, foundationalism, splitting, atomism, and mechanization. The British movement, founded on the ontological-epistemological implications of Newton's work, and advanced initially by philosophers John Locke (1632–1704), Bishop George Berkeley (1685–1753), and David Hume (1711–1776), continued to operate within the Cartesian categories (Searle, 1992), and introduced one additional category (i.e., the limitation of explanation to efficient and material causes and/or correlational *associations*). The British reaction against Descartes occurred on two fronts, (1) until the 18th century the primary method of both philosophy and science had been *deductive* in nature; the 18th century rejected this, and substituted *induction* as the primary method in virtually all disciplines of knowledge; (2) Descartes' "thinking substance" (mind) was to be suppressed.

Dualism had split the universe into two dichotomous elements, extended (body) and unextended (mind) substance, and the 18th-century empiricist reaction was to pursue the advocacy of a *monism* according to which the two would be reduced to a single Real. However, the ultimate *one* continued to be based on a dichotomous choice according to which *either* matter (materialism or idealism) must constitute the absolute bedrock foundational Real. The empiricist solution was to choose inert matter as the foundational Real. The difficulty with this solution, as the philosopher Charles Taylor (1991) pointed out, is that in the context of "either/or" a monism merely suppresses one of the terms of the split; it does not reject the split itself. Or, as neuroscientist Gerald Edelman (1992) has phrased it, "apparently monistic behaviorism is simply dualism reduced by a denial of the mind as a scientific object, and therefore left with one end hanging" (p. 11).

The British Enlightenment can best be understood as a progressive pacification and emptying of mind, until mind itself disappears as Appearance; something to be explained, not something that explains. Beginning with an active mind—a necessary feature of human agency—containing what Descartes' termed *innate ideas*, the mind would step-by-step be reduced from active to passive and then disappear completely. The primary tool designed to accomplish this task was the epistemological doctrine of *radical empiricism; the doctrine that all knowledge arises inductively from the senses (pristine observation) and only from the senses*.[3] John Locke, a great admirer of

[3]Some texts (e.g., Benjamin, 2009; Brennan, 2003; Goodwin, 2005) will define *empiricism* as acquiring knowledge through "*experience*." However, on closer reading it will be discovered that the author is referring to "direct *sensory* experience" or "sensation."

Newton's work, began this historical march by accepting the split Cartesian categories, and—following Galileo's lead—dividing nature into *primary* and *secondary* qualities. Primary qualities were features of Newtonian dead matter and constituted the Real.

Secondary qualities were features of mind and constituted Appearance. Locke's image of the mind of the child as a *tabula rasa* (Blank Slate) was part of this movement, as was his famous slogan that became the rallying cry for future generations of radical empiricists: *There is nothing in the intellect which is not first in the senses* (to which the relationally oriented Leibniz replied, *Nothing but the intellect itself*) (Brennan, 2003). If Locke's slogan was taken completely seriously then there are no active powers of mind; no active faculties of reflection, judging, willing, comparing; all this and more would be mere Appearance requiring explanation in terms of the ultimate atomistic foundation. In this program, mind would ultimately disappear as subject and reappear as object (Matson, 1964); in the 20th century even the objective mind would fade into objective behavior with the advent of behaviorism.

Locke's reductionism to a passive, empty mind was, however, incomplete. He advanced the empiricist program by eliminating Descartes' innate ideas, and by proclaiming the tabula rasa, and the *sensationist* thesis. The advance was based on a distinction between *complex ideas* (all universals, including *beauty, gratitude, man, woman*) and *simple ideas* (*sensations*). Simple ideas were to generate complex ideas via combinations and associations, and here Locke began what would become the school of psychological *associationism* (Heidbreder, 1933). However, Locke came to recognize the impossibility of generating the manifest world from the atomistic base of simple ideas and associations. As a consequence, he faltered at this point and allowed mind one central active power, that of *reflection*, which was comprised of the set of activities of judging, willing, and comparing.

Bishop George Berkeley, himself an idealist in matters of ontology, accepted the sensationistic thesis. He advanced the empiricist program a step beyond Locke by denying that reflection constituted an inherent central activity of mind, and by redefining ideas as particularistic images. If he had stopped there, mind would be some kind of simple storage space where particularistic images floated unconnected each to the other. Recognizing the problem, Berkeley gave a broader meaning to *perception*, beyond simple passive sensation. Perception was to include the *activity of representation*. However this activity was no longer a central power of mind, rather it was the activity of each particular sense organ; a particularistic and peripheralistic activity. To get from there to an idea (image) Berkeley argued that every sense impression becomes re-presented to consciousness and every re-presentation causes all other sense impressions it is *associated* with (contiguity in space and time). However, even this move failed to account for the experience of a world of universal order and organization (e.g., the experience of a uniform space). It was at this point that Berkeley stopped being an empiricist and appealed to God, and argued that the order, consistency, and stability of objects that are found in common sense reside in the perceiving mind of God and each individual mind is a particular of the mind of God.

Although Berkeley destroyed any central power of mind, it was left to David Hume to destroy the very notion of mind itself. Hume did this in a most direct fashion; he took the sensationist thesis seriously, and asked where in pure sensations do we find *mind, soul, self, personal identity,* or any such *universal concept*. His answer is that we do not find them in sensation, and because all knowledge must come through the senses, mind and all universal concepts are mere illusions.

> Thus, under Hume's criticism, the world collapsed into an aggregate of ideas, supported by no substance and connected by no necessity. The world as Hume saw it was a drift of [simple] ideas without connection, without permanence, without unity, without meaning, simply present and passing. (Heidbreder, 1933, pp. 48–49)

At the end of Hume's argument all the complex or abstract ideas that had constituted categories of knowing—*space, time, order, relations, necessity, universality*—were nothing but particular images called *ideas*, contingently gathered together according to principles of Association.

This position led to Hume's well-known skepticism about the possibility of valid (i.e., universal and necessary) knowledge. For Hume, all knowledge became contingent and particular. It was the more relationally oriented Kant who, while agreeing with Hume that neither necessity nor universality (i.e., valid knowledge) are found in sensations, argued that they are nonetheless critical components for understanding the world and, consequently must be found in another source (i.e., an active mind).

To this point the categories of the Cartesian-Split-Mechanistic metatheoretical worldview were complete and well formed. Hume represented the zenith of this category system with respect to knowledge, but Hume's skepticism about valid knowledge did not dampen the influence of splitting, foundationism, atomism, and mechanism on future generations in philosophy and the sciences. As precursors to the emergence of psychology, in the 19th century the Utilitarian philosophy of Jeremy Bentham, passed down through James and John Stuart Mill, and Alexander Baine, sought to apply the Cartesian paradigm, not to knowing, but to the explanation of actions, values, morals, and politics (Halevy, 1955). And then with the emergence of psychology, the *experimental* psychologies of Wundt and Titchener grew from this ground, followed in the 20th century by the functionalist approaches of Angell, Carr, Woodworth, and, ultimately, behaviorism and multiple forms of neobehaviorism, including learning and social learning theories of development.

As the 20th century progressed, the Cartesian tradition continued operating as a metatheory for various domains of inquiry, including developmental inquiry. In philosophy, the tradition extended its influence in the articulation of Anglo-American analytic philosophy, which took what has been called a *linguistic turn*. Analytic philosophy was, in one sense, a general reaction against the dominance of metaphysical systems or worldviews, including the worldview that describes the Cartesian tradition. In another sense, analytic philosophy simply drove the Cartesian worldview underground, where it continued to exert a strong contextual influence. As the name suggests, analytic philosophy has continued to maintain the Cartesian split categories, and, to the present day, in various surrogate forms, it pursues the analytic ideal of finding the *atoms*, or absolute bedrock foundational elements of knowing (Rorty, 1979). The British line of this approach located its foundationalism in the analysis of *ordinary language*. The American line pursued the same goal in the *neutral data language* and *observation sentences* of logical or neopositivism, elaborated in the writings of Moritz Schlick, Roudolf Carnap, Gustav Bergmann, Herbert Feigl, Carl Hempel, A. J. Ayer, and the "earlier" Ludwig Wittgenstein (of the *Tractatus Logico-Philosophicus*).

Contemporary Cartesian Middle-Range Metatheories

As mentioned earlier, nested within a worldview, are metatheories *of a middle range* (see Figure 2.1). These conceptual systems are consistent with but less general than worldviews and consistent with but broader than the concepts of specific theories, and they entail principles that are identifiably more specific to the observational domains of interest. Cartesian middle-range psychological metatheories characterize organisms as *inherently stable, fixed*, and *unchanging*. Both movement (behavior) and development are understood to be a result of extrinsic (whether internal biological or external environmental) *forces* (efficient and material causes), often termed *mechanisms*, and methodologically referred to as *antecedent* or *independent variables*. The Cartesian organism is complicated, but not complex. When the term *complex* is used within this framework it connotes "capable of being analyzed into simple elements"; that is, *complicated*. Because the organism is complicated, it is described as independent pieces. Biology is a piece, culture is a piece, cognition, motivation, and affect are pieces. Pieces combine (add together, interact) to form a whole that is no different than the sum of its pieces. There can be no novelty, as any apparent novelty must be reduced to the pieces. There can be no discontinuity to development, as this would constitute novelty. There can be no emergence in development for the same reason. The Cartesian organism is linear, both with respect to behavior and development (prenatal and postnatal); inputs are strictly proportional to outputs. Because of this linearity, the behavior and development of the organism is *deterministic* and, hence, in principle completely *predictable*. There is an initial uniformity or lack of organization with respect to psychological organization or psychological structure. In sum, the organism at whatever level chosen for investigation—from the biological to the psychological to the cultural—operates as an input-output device.

Beyond this general characterization, the following constitute some examples of Cartesian Middle-Range Metatheories.

Cartesian Inheritance

In classic genetics, the gene was introduced as an analog to the chemical element as the foundational biological element (Keller, 2010). The gene was conceptualized as the "master molecule" that "causes" the production of proteins. A linear additive, unidirectional causal path was asserted to operate from DNA to RNA to protein as defined by the *central dogma of molecular biology* (Gottlieb, 2000). With respect to population (quantitative) genetics, within this metatheory, the relation of genes to environment was conceptualized according to a completely additive (Lewontin, 1974; Overton & Reese, 1973) model, and statistical gene × environment interactions are themselves completely decomposable into strictly additive elements. As Turkheimer (2011) points out, this assumption of additivity is "the foundation of modern quantitative genetics" (p. 228). Partridge (2005, 2011), supporting Turkheimer's point, goes on to describe how advances in the Fisher–Wright ANOVA model, such as extensions to multivariate and latent variable models and multilevel models, adhere to the same additive structure as the original Fisher model.

Cartesian Evolution

Depew and Weber (1995) present an extensive and detailed analysis demonstrating that Darwin himself,

> Had a genuine, indeed a burning, desire to find a theory of organic origins that conformed as far as possible to Newtonian canons . . . Darwin tried systematically to operate within the prescribed Newtonian framework, where real forces impinge on real populations and organisms, rather than positing an internal developmental dynamic that is awakened, steered, or thwarted by external stimuli. (p. 110)

Levins and Lewontin (1985), in turn, analyze the continuity of this approach exhibited in the Cartesian nature of the 20th century understanding of evolution. The evolutionary *Modern Synthesis*, which in the 1930s and 1940s integrated Mendelian genetics with neo-Darwinian variation and natural selection, split phylogenesis and ontogenesis, and discarded the latter as irrelevant (see, e.g., Lickliter & Honeycutt, 2010, Chapter 5, this *Handbook*, this volume). Further, an internal is split-off from an external, yielding an isolated internalism of gene-centrism (i.e., gene as the sole unit of variation), and an isolated externalism of change (i.e., emphasis on natural selection as the virtually sole mechanism [cause] of change) (see, e.g., Pigliucci & Müller, 2010a). But change itself is restricted to a specific type. As Lewontin (2000) points out, "development is a *transformational* theory of change. . . . In contrast, the [Modern Systhesis] theory of organic evolution is based on a *variational* model of change" (p. 9). Evolutionary change, thus, becomes defined in terms of *variation* in gene frequencies *and only variation* in gene frequencies. Finally, the Modern Synthesis entails commitment to evolutionary *gradualism* (i.e., additive continuity) that derives from the same additive mathematical formalism that applies to inheritance. Pigliucci and Müller (2010a) refer to this formalism as the *backbone* of population genetics, and, hence, the backbone of the Modern Synthesis.

Present day evolutionary psychology is itself based on this Cartesian metatheory (see, e.g., Belsky, 2012; Belsky, Steinberg, & Draper, 1991; Draper & Harpending, 1982, 1988; Ellis, Schlomer, Tilley, & Butler, 2012; Richardson, 2007). Pinker (2011) emphasizes this Cartesian orientation in describing the "distinctive mechanistic" (p. 613) natural selection, and the assumption that:

> Human nature, in the sense of the cognitive and emotional inventory of our species, has been constant over . . . [a] ten-thousand year window . . . , and . . . all differences in behavior among societies have strictly environmental causes. That is a standard assumption in evolutionary psychology. (p. 612)

As an example of this standard assumption being put into a theoretical context, consider what evolutionary psychologists term *paternal investment theory*. A central component of this theory is the "assumption . . . that natural selection has designed boys' and girls' brains to detect and encode information about their fathers' social behavior and role in the family as the basis for calibrating sociosexual development in gender-specific ways" (Ellis et al., 2012, p. 329).

Cartesian Cognition

Cognition science and cognitive developmental psychology have frequently and explicitly acknowledged their roots in Cartesian metatheory. (e.g., Copeland & Proudfoot, 2007; Edelman, 1992; Marshall, 2009; Müller & Newman, 2008; Rowlands, 2010; Varela, Thompson, & Rosch, 1991; Wright & Bechtel, 2007). As the study of cognition emerged in the late 1950s, in a period known as the *cognitive revolution* (Bruner, 1990; Miller, 2003), its dominant form came to be termed *cognitivism*. This approach to thinking and other cognitive functions was contextualized by the metatheory of the *computational model of mind*. Not only did this metatheory strictly follow the dictates of the Cartesian worldview by splitting mind from body, it also explicitly framed itself within the worldview's basic category system, the machine.

As described by Marshall (2009),

> The ascent of cognitivism depended on making the mind more transparent by using computers to model mental processes. . . . The Cartesian foundation of this approach has inspired a rising tide of criticism over the last three decades, mainly centered around the problem that the computational mind of cognitivism lacks a brain, a body, and a culture. (p. 120)

Later, as Rowlands (2010) points out, "from the mid-1980s on, this [computer model of mind] emphasis gradually gave way to a renewed emphasis on 'hardware' in the form of connectionist or neural network approaches" (p. 2). These approaches—connectionism is also known as

"Neuron-like computing" (Copeland & Proudfoot, 2007, p. 440)—attempt a mechanical modeling of cognition that, although perhaps more neurobiologically realistic (see, however, Edelman, 1992, for a neurobiological critique), continue to adhere to Cartesian dictates, thereby leaving mental events locked in the brain, split-off from the full functioning of the body and from culture. This Cartesian position is clearly articulated by Adams and Aizawa (2010) in their argument that "There are processes that (1) are recognizably cognitive, (2) take place in the brain, (3) do not take place outside of the brain, and (4) do not cross from the brain into the external world" (p. 69). In the end, as Goode (2007) notes, "on the cognitivist view . . . the starting point is the solitary Cartesian subject detached from the world and its objects (including other people). Thus, the cognitivist has to account for the way the knower 'hooks on to' the world and to other people in it" (p. 272).

Earlier in this chapter Thomas Hobbes, a contemporary of Descartes, was mentioned as a central figure in the development of the Cartesian worldview. Hobbes' contribution was to argue that, along with the body, mind also operated as a machine. Mind and thought and other human activity were all reducible to motions of the animal organism. "Influenced by Galileo's conception of motion, Hobbes held that everything that happens is matter in motion, mental activities are motions of the nervous system arising as reactions to motions in the external world" (Watson & Evans, 1991). For Hobbes, thought or reasoning entailed motions, which he referred to as "computing" (Hobbes, 1655/1981) and, thus, he was an important precursor to the computational model of mind.

The idea discussed earlier in this chapter of the Cartesian organism being represented as an input-output device does not change in any essential way when the computational model of mind takes mind or brain to be an *informational processing system* and thinking becomes a form of *computation*. The insertion between input and output of a computing mechanism or neural network is merely an updating of Descartes cogs and wheels, yielding a more complicated relation between input and output; from a push-pull machine or a wind-up clock to the telegraph system, telephone switchboard, hydraulic pump, and the digital computer, this idea has been constant.

Following the work of the early behaviorists who insisted on a strict S-R model, the space between S and R began to fill with Cartesian mechanisms. With the learning theories of Hull (1943) and Spence (1956), as well as the social learning theories of Dollard and Miller (1950) and Sears, Maccoby, and Levin (1957), the space between input and output began to be filled with internal responses and internal stimuli that formed chains linking the external Stimulus with overt Response. The chains, thus mediated antecedent conditions and instrumental behaviors and were termed *mediating responses*. These internal mediating "events" were understood to have the same theoretical status as overt stimuli and responses. Thus, the meditational responses were subject to the same laws of composition and decomposition as their observable counterparts. And further, the internal mediators were understood to have originated from the antecedents and consequents according to traditional learning principles of *reinforcement* and *imitation*. As this meditational tradition expanded, particularly into clinical psychological cognitive and cognitive-behavioral approaches, the mediating responses came to be referred to as *symbols, representations, thoughts*, and *cognitions* (see, e.g., Foster, Kendall, & Guevremont, 1988).

With the rise of artificial intelligence and information processing the digital computer became the machine of choice. This machine receives sensations from the external world and transduces them into signals termed *information* or "messages" that the machine can operate on. The signals constitute the content of representations or symbols, while the mind is equipped with syntactic symbol structures and computational procedures that act as symbolic vehicles that carry the content (Eliasmith, 2007, p. 316). The procedures manipulate the symbols "in prescribed ways: it lists, orders, combines, compares . . . " (Bruner, 1990, p. 4). Is this still a Cartesian machine? According to Copeland and Proudfoot (2007) it is, given that

> The item's [computer] operation can be accounted for in monistic, materialist terms and in a manner analogous to that in which the operation of an artifact, such as a clockwork figure or church organ, is explained in terms of the nature and arrangement of its components. (p. 457)

Cartesian Culture

Inquiry into the field of culture and development has not been as enmeshed in the Cartesian metatheory as have the studies of inheritance, evolution, cognition, and cognitive development. Nevertheless, the tracks of Cartesian categories are found in several areas where individual and culture have been viewed, at least until recently as split-off independent entities. Mistry, Contreras, and Dutta (2012) describe this splitting with respect to work on cross-culture and child development investigations at the beginning of the present century.

> On the issue of how culture should be conceptualized, cross-cultural psychologists tended to view culture as an independent variable that influenced human behavior. Some cross-cultural psychologists suggested that culture should be operationalized as a set of conditions (Poortinga, 1992, 1997; Segall, 1984). For example, Poortinga (1997) defined the cross-cultural approach as: "there is a tendency to take cultural context, including ecological as well as sociocultural variables, as a set of antecedent conditions, while behavior phenomena, including attitudes and meanings as well as observed behaviors as outcomes or consequents (p. 350)." (p. 267)

In a similar vein, in the present volume Mistry and Dutta (Chapter 10, this *Handbook*, this volume) argue that in Bronfenbrenner's (1979; Bronfenbrenner & Morris, 2006) developmental bioecological model,

> Culture is represented as the outermost layer of context or macro-system. Although this model has conceptually focused on the interplay among the various layers of the context (i.e., psychological, biological, cultural, historical, institutional), empirically, the specific layers have been treated as split-off independent variables that influence behavior and development as efficient causes. Thus, culture is conceptualized as a feature of environmental or ecological context that exists independent of the person. (p. 370)

It is also the case that some who take a sociohistoric-cultural perspective (e.g., Cole, 1996; Rogoff, 2003; Wertsch, 1991), along with social constructivists (e.g., Gergen, 1994) who generally reject the Cartesian worldview, nevertheless at times become captured by the categories of foundationalism and splitting, This step occurs primarily through an allegiance to Marxism, which itself has promoted the broader split between ideas and matter, claiming a bedrock foundational primacy for material sociocultural objects; hence Marxism as dialectical *materialism*. Wertsch (1991) acknowledges the Marxist contribution and frames his own work within the person-sociocultural split and the foundationalism of "social forces," endorsing both a split interpretation of Vygotsky (i.e., "In pursuing a line of reasoning that reflected their concern with Marxist claims about the *primacy of social forces* Vygotsky and his colleagues . . . contended that many of the design features of mediational means *originated in social life*.") (p. 33; emphasis added), and a split interpretation of Luria.

> As stated by Luria (1981), "in order to explain the highly complex forms of human consciousness one must go beyond the human organism. One must seek the origins of conscious activity and "categorical" behavior *not in* the recesses of the human brain or in the depths of the spirit, *but in* the external conditions of life. Above all, this means that one must *seek these origins in the external processes of social life*, [emphasis added] in the social and historical forms of human existence (p. 25)." (Wertsch, 1991, p. 34)

At times the splitting of sociohistorical-cultural-developmental theorists and social constructivists becomes more subtle. For example, Cole and Wertsch (1996) begin one article by acknowledging, on the basis of several direct Piagetian quotes, that Piaget—a traditional villain of both sociohistorical-cultural-developmentalists and social constructivists—who is often inaccurately accused of privileging the person—"did not deny the co-equal role of the social world in the construction of knowledge" (p. 251). However, these authors then switch the ground of the issue from the social world specifically to culture mediation entailed by the social world and argue, both in headings (i.e., "The Primacy of Cultural Mediation," p. 251) and in text, that culture is to be the privileged split-off foundation.

> Social origins take on a special importance in Vygotsky's theories that is less symmetrical than Piaget's notion of social equilibration. . . . *For Vygotsky and cultural-historical theorists more generally, the social world does have primacy over the individual* in a very special sense. Society is the bearer of the cultural heritage. (p. 353; emphasis added)

To summarize the chapter to this point, the initial discussion argued for the centrality of a conceptual analysis, and the idea that any rich scientific research paradigm necessarily entails a conceptual framework. This framework consists of sets of nested concepts that are coherently related and range from the broadest in scope —worldviews—through more scope-limited metatheories of the middle range, and to the least general specific theories and hypotheses.

The discussion of a conceptual framework was followed by the analysis of the scientific research paradigm that held dominance in science for 300 years—the Cartesian-Split-Mechanistic worldview—along with worldview consistent metatheories of a middle range that are particularly relevant to developmental science; inheritance, evolution, cognition, culture. Criticisms of the Cartesian worldview as an adequate scientific paradigm for developmental science have come from many sources and many fields beyond those described in the present analysis. The criticisms arise from biology and neuroscience (e.g., Damasio, 1994; Edelman, 2006; Gallese & Lakoff, 2005; Gilbert & Epel, 2009; Mayr, 1982, 1988), philosophy (Bennett & Hacker, 2003; Gallagher, 2005; Taylor, 1995), anthropology (Ingold, 2000; Sheets-Johnstone, 1990), and psychology (Good, 2007; Hobson, 2002; Santostefano, 2010; Wheeler, 2005).

The reanalysis of the Cartesian paradigm represents, and its critiques constitute, one component of the thesis of this chapter. The second component of the thesis begins from the acknowledgment that, as Kuhn (1962) first suggested, regardless of the amount of counterevidence, empirical and conceptual, a scientific paradigm remains functional until another paradigm is available to take its place. Thus, the second component feature of the thesis of this chapter is that there is potential replacement paradigm available, one that (a) better accommodates the new data from several fields of developmental science; (b) overcomes the conceptual problems of the Cartesian-Split-Mechanistic metatheory and its subsumed middle-range metatheories; and (c) generates novel and empirically productive predictions for the field of developmental science. This scientific paradigm is defined by a Process-Relational worldview metatheory and Relational-Developmental-Systems (as middle-range metatheory) paradigm, which is the topic of the following sections.

THE PROCESS-RELATIONAL WORLDVIEW AND RELATIONAL-DEVELOPMENTAL-SYSTEMS AS SCIENTIFIC PARADIGM

The Process-Relational[4] worldview derives from a coherent synthesis of what Steven Pepper (1942) referred to as the world hypotheses *Organicism* and *Contextualism*. This metatheory counters the "nothingbutness" of the Cartesian paradigm with an inclusiveness attained by converting the Cartesian split dichotomies into coequal indissocible complementary processes. The metatheory also entails a rejection of Cartesian atomism and bedrock foundationism. As Alfred North Whitehead (1861–1947) said concerning his own *philosophy of organism*, or what is now termed *process philosophy*.

> There persists . . . the fixed scientific cosmology which presupposes the ultimate fact of an irreducible brute matter or material. . . . It just does what it does, following a fixed routine imposed by external relations which do not spring from the nature of its being. It is this assumption that I call "scientific materialism." Also it is an assumption which I shall challenge as being entirely unsuited to the scientific situation at which we have arrived. (Whitehead, 1925, p. 12)

In Pepper's (1942) work, the description of each of several worldviews begins from a basic or *root* metaphor and the categories of the worldview are generated upon this metaphor. In contrast to the Mechanistic worldview, which takes the machine as its root metaphor, the root metaphor of Contextualism is the "historical event" (p. 232); not the past event, but rather "the event alive in its present . . . in its actuality, . . . when it is going on *now*. . . . This event might be called an *act* so long as it is not thought of as an isolated act, but an act in and with its settings, an act in context." (p. 232)

This world is composed, not of dead Cartesian substance, but of these events or acts, which "are all intrinsically complex, composed of interconnected activities with continuously changing patterns. . . . Contextualism holds tight to the changing present event" (p. 233).

Pepper rejects *organism* as the root metaphor for the Organicism worldview because he judges it too loaded with biological connotations, and too static, and he finds *integration* only a bit better. He argues that, in fact, Contextualism's *historical event* is as good an approximation as possible (p. 280), and "the root metaphor of organicism always does appear as a *process*" (p. 281; emphasis added). In fact, because they share the same basic metaphor, Pepper points out that it is tempting "to regard these two theories as species of the same theory, one being dispersive [Contextualism] and the other integrative [Organicism]" (p. 280). But here the rub enters; Pepper argues that the opposition between the dispersive (spread out) and integrative (organized) is so basic that it leads to implications that constitute a "flat categorical contradiction and something that cannot be interpreted as a difference of emphasis" (p. 281).[5]

[4]As mentioned in footnote 1, in earlier writings (e.g., Overton, 2013a, 2013b) this worldview was termed *Relationism*. However, *Process-Relational* better captures the ontological as well as the epistemological groundings of this metatheory.

[5]Pepper makes a critical error of interpretation at this point in arguing that Organicism does not take time seriously and consequently does not include time and change in its fundamental categories. This position rests on a misinterpretation of Hegel's concept of the *Absolute*. Although the whole argument is too complex to present here, Pepper's basic mistake is to interpret Hegel's Absolute as a final *state* (p. 313), whereas a more reasonable interpretation is that the Absolute is a *horizon concept* (i.e., movement is toward an end that can never be reached) (Gadamer, 1960/1989). As Beiser (2006) points out, "No less than Kant, then, Schelling

The Relational Synthesis of Organicism and Contextualism

Let us suppose, however, that dispersion and integration are treated not as an oppositional dichotomous split, but rather, a relational two sides of the same coin, an indissociable complementarity—a relation. In fact, if dispersion and integration are considered in a relational context, then dispersion rather than being a random spread becomes the differentiation of parts or part processes. As a consequence the term *dispersion* will be dropped from this point forward and the discussion will entail on the one hand, *differentiation*, and on the other hand, *integration*.

To explore this relational approach consider the famous face-vase illusion (see Figure 2.3), and place *differentiation* on the black (faces) areas, and *integration* on the white (vase) area. Is the picture *either* faces (differentiation) *or* is it a vase (integration)? In this context that is no longer a meaningful question because there is a relation; the faces constitute and are constituted by the vase and the vase constitutes and is constituted by the faces. Remove either the white area or the black area and there are neither faces nor a vase. The famous ink sketch by M. C. Escher titled *Drawing Hands* gives an even more vivid visual illustration of this relational transformation. In this sketch a left and a right hand assume a relational posture according to which each is simultaneously drawing and being drawn by the other

Figure 2.3 The Face-Vase Illusion.

and Hegel warn against the fallacy of hypostasis, which treats the Absolute as if it were only a specific thing" (p. 5). Extending this error, Pepper also misinterprets the Absolute as excluding finitude (p. 314). In fact, Hegel rejected Schelling's Absolute, which did exclude finitude, and replaced it with an understanding that "it is necessary to conceive of the absolute as the *whole* of substance *and* its modes, as the *unity* of the infinite *and* finite" (Beiser, 2006, p. 7). *Change* is a basic category in both Organicism and Contextualism.

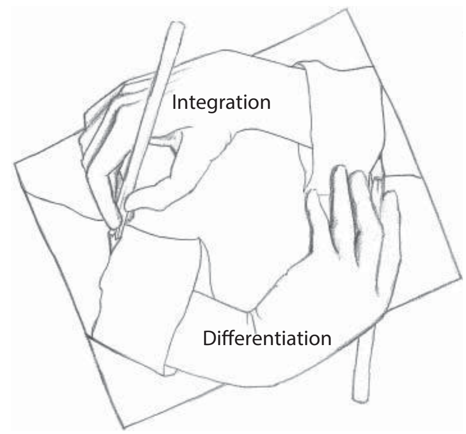

Figure 2.4 A schematic sketch of two hands drawing and being drawn by each other constituting a relational identity of opposites. With the term *integration* on one hand and *differentiation* on the other hand there results a pictorial illustration of a constitutive relation.

(a schematic outline figure rather than Escher's drawing is shown in Figure 2.4). On one hand *differentiation* is written and on the other hand *integration* is written: This figure should illustrate pictorially how these concepts can stand in a constitutive relation.

The effect of moving differentiation-integration from a Cartesian split frame to a relational frame is that Organicism and Contextualism *do* become "species of the same theory" and this is the *Process-Relational* metatheoretical worldview. Because Organicism is sometimes said to have a vertical cosmology and "contextualism is sometimes said to have a horizontal cosmology" (Pepper 1942, p. 251), the Process-Relational synthesis of the two can be represented pictorially by an intersection of a vertical and horizontal plane of a differentiated and integrated figure (see Figure 2.5). Although this is a worldview representing all of nature, we can simplify for present purposes by using the living organism as our primary model. The horizontal axis then represents the external act of the organism, and the vertical axis represents the organism performing the acting. Along with *activity* and *change* (*time-duration*), Contextualism and Organicism share *holism* and *dialectic processes* as basic categories. However, both holism and the dialectic take a different form on each plane.

Two Dimensions of Holism

First, consider *holism*, the assertion, to be repeated several times in this chapter, that the identities (meanings) of entities and events derive from the context in which they are

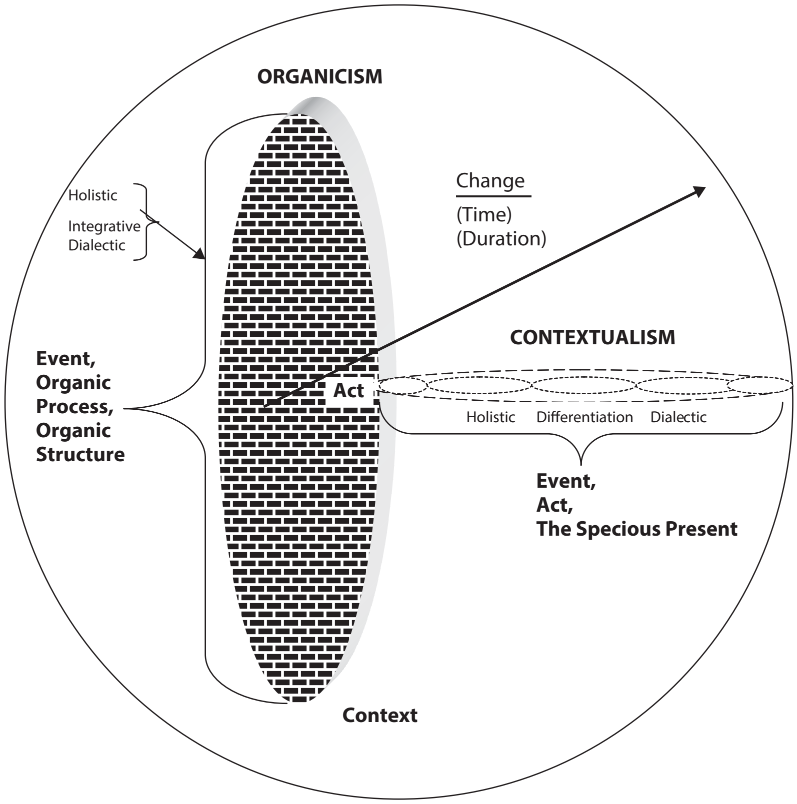

Figure 2.5 The Synthesis of Organicism (vertical plane) and Contextualism (horizontal plane) into a Process-Relational metatheoretical worldview.

embedded. The whole is not an aggregate of discrete elements, but an organization of parts, each part being defined by its relations to other parts and to the whole. The whole, in turn, through its organization has systemic features that are not features of any part. Thus, the whole is not greater than, it is *different from*, the sum of its parts.

Differentiated Holism. Along the differentiation horizontal plane of the Process-Relational metatheory shown in Figure 2.5, an *event* is an *act* composed of a series of part-acts occurring *in the here-and-now*. For example, walking to the store to buy a newspaper constitutes an event, and writing this sentence constitutes an event. The event has a beginning, middle, and end, thus a spread or a *specious present*. The holism on this plane is defined in terms of the structure of this event including its *quality* (i.e., the event's wholeness), *texture* (i.e., parts), *strands* (parts of parts) and *context*. Pepper (1942) emphasized that quality and texture are not separable, and the whole act is presumed to be different than the sum of its parts. Further, with respect to context (e.g., the physical and sociocultural environment) "the quality [wholeness] of an event is the fused quality of its strands [parts], and the qualities of the strands come partly out of its context" (p. 249). Thus, context is not causal, but constitutive, an irreducible feature or part of the event as a holistic system.

Integrative Holism. Turning to holism along the integrative vertical plane of the Process-Relational worldview (see Figure 2.5), every event in the specious present is a reflection of and reflected in an underlying (inferred) organized and organizing activity of the organism. Holism on this dimension entails the integrated quality (wholeness) of this dynamic organization. This quality is an *organic* whole in which every part "implies every other and an alteration of any . . . [part] would alter every other . . . [part] or destroy the system" (Pepper, 1942, p. 300). Two features of this dynamic organization (e.g., the organism as a dynamic system) are that (1) its relation to the horizontal plane is such that acts as external events emerge from it, and feed back to it; (2) there are *degrees* of organization, whose three main criteria are: "(1) degrees of inclusiveness, (2) degrees of determinateness, and (3) degrees of . . . [wholeness]" (Pepper, 1942, pp. 298–299). Take, as an example of both of these features the infant's act of grasping an object (actual event). Grasping emerges from a sensorimotor bodily organization and feeds back to this organization. Early grasping is global and poorly articulated; it is imprecise and limited. Its partial wholeness is indicated by the fact that, at a later time, grasping will become more finely differentiated and precise; will entail the potential of a wide variety of part-acts (e.g., one handed, two handed; with the feet); and will become a part of a broader organized system of conscious thought.

Two Dimensions of the Dialectical Process

The issue of degrees of wholeness leads to a consideration of the dialectic as it functions on each plane of the Process-Relational metatheory. Each plane affirms the centrality of the dialectical process, and each begins from the basic identification of the dialectic as a process entailing the working through of contradictions (i.e., affirmations and their negations). There are, however, as with holism two forms of dialectics, one differentiation, the other integrative.

Differentiated Dialectics. The horizontal plane (overt act, event) of the Process-Relational approach is characterized by the differentiated form of dialectics. This form has its roots in the Socratic dialogue, with "origins in living conversation in ordinary language" (Kainz, 1988, p. 31) in which contradictions appear and are resolved through dialogue. Kainz, points out that "Richard Rorty (1979) recognizing the importance of such ordinary dialectical encounter for philosophy, . . . characterizes philosophy itself as essentially 'conversations' writ large" (Kainz, 1988, p. 58). As Rorty (1979), says with respect to this differentiated form of dialectic,

> A "voice in the conversation of mankind," . . . which centers on one topic rather than another at some given time not by dialectic necessity [the integrative form of dialectic] but as a result of various things happening elsewhere in the conversation. (p. 264)

For Rorty, the differentiated form of the dialectic resulted in what has been called *edifying philosophy*, "the sort of philosophy found in the work of Kierkegaard, William James, Dewey, the later Wittgenstein, and the later Heidegger" (Kainz, 1988, p. 58), whose aim was merely to "keep the conversation going" in opposition to systematizing.

This differentiated form of dialectics operates on the horizontal plane of the Process-Relational metatheory with respect to what Pepper termed *references* and *blocking* of events. The part acts of any event along with the total event have goals (references), which have a "point of *initiation*, a transitive *direction*, and achieves an ending or *satisfaction*" (p. 252). These acts may be stopped or blocked. The goal of the event or part-event is the affirmation, while the blocking is the negation or contradiction of the act. As in the earlier given example, I may have a general goal of walking to the store to buy a newspaper. Prior to my leaving the house a downfall of rain may occur, hence "the walking to" has been blocked. Or I may walk to the store only to find they are sold out of newspapers. In this case the event itself is blocked.

The differentiated contradiction (goal and blocking of an act) leads to a form—again a differentiated form—of *novelty*, which is the resolution of the dialectic contradiction. Thus, if it is raining and I cannot walk to the store, I may decide to drive and if the store is out of newspapers I may buy a magazine. If there is a total blocking, then what Pepper refers to as *emergent novelties* may occur, as would be the case if I fell down, sprained my ankle, could not go to the store at all, and so, sat and watched TV. Novelties and emergent novelties at the level of the act taking place in the specious present are important, but they should not be confused with emergent novelties that occur on the vertical plane of the Process-Relational synthesis. The new acts of the horizontal plane generally represent *variations* of the original (e.g., news or entertainment may be achieve through both newspapers and TV) rather than the *transformations* of the vertical plane.

It might be helpful to give a developmental example here. Consider again the infant's act of grasping an object (actual event). When that event is blocked, to the extent that the infant continues, a number of variations of the form of grasping may arise, one of which attains the object. Thus, from the differentiated perspective, there are several emergent behaviors. At the same time, the blocked event feeds back to the organization of the integrative system resulting in system change, which leads to the novel actions.

Integrative Dialectics. The vertical plane of the Process-Relational approach is characterized by an integrative or *systematic* dialectics. This form has its roots in Plato's "systematic 'testing' of . . . [his] own point of view against the views of contemporaries and predecessors" (Kainz, 1988, p. 61). Aristotle's dialectic, in turn was "a continuation of the 'upward path' of the explicit dialectic in Plato, but as a systematic endeavor connotes primarily a conscientious and methodical sifting of common or influential opinions pro and con on a given controversial topic" (Kainz, 1988, p. 62). However, the most immediate precursor to the *systematic* integrative dialectics articulated by the 19th-century philosopher G. W. F. Hegel (1770–1831) is found in the works of Kant, Frichte, and Schelling (see Beiser, 2006; Schelling, 1803/1988). In Hegel's system, historical and—by extension—developmental change of the organism is a dynamic expressive/transformational process of growth, represented and defined by the dialectic.

Central to Hegel's dialectic is the idea of a *process* through which concepts or fundamental features of a dynamic system *differentiate* and move toward *integration*. Any initial concept or any basic feature of a dynamic system—called a *thesis* or an *affirmation*—contains implicit within itself an inherent *contradiction* that through action of the system in the world, becomes differentiated into a second concept or feature—the *antithesis* or *negation* of the thesis (e.g., the thesis *being* leads to its negation *nothing*). As a consequence, even in the single unity of thesis there is the implicit or potential contradictory relation of thesis/antithesis, just as in the unity of the single organic cell there is the implicit or potential differentiation into the unity of multiple cells.

The polarity of opposites that emerges from the unity of the one, as thesis leads to antithesis, does not constitute cut-off (split) contradictory categories that absolutely exclude each other. Having grown from the same soil as it were, the two, although standing in a contradictory relation of opposites also share an identity. Hegel, in fact, referred to this relation as the *identity of opposites* (Stace, 1955) and illustrated it in his famous example of the master and slave. In this example Hegel demonstrated that it is impossible to define or understand the freedom of the master (thesis) without reference to the constraints of slavery (antithesis); and consequently impossible to define the constraints of slavery without the reference to the freedom of the master. Freedom thus contains the idea of constraint as constraint contains the idea of freedom, and in this situation we see the identity of the opposites, freedom and constraint.

Through the differentiation of a polarity of opposites—a potential space between them is generated, and this space becomes the ground for the *coordination* of the two. The coordination that emerges—again through the action of the system—constitutes a novel unity or integration, called the *synthesis*. The synthesis is not some combination of thesis and antithesis, but an emergent coordinating synthesis that is itself a new system, which exhibits *novel systemic properties* while subsuming the original systems (e.g., the synthesis of *being* and *nothing* is the process *becoming*, which coordinates the two). Thus, a new dynamic matrix composed of three interconnected realms—*thesis-antithesis-synthesis*—is formed. The integration that emerges from the differentiation, like all integrations, is incomplete. The synthesis represents a new dynamic action system—a new thesis; and, thus, begins a new developmental cycle of differentiation and integration always moving toward, but never reaching the *Absolute* (the complete Whole).

Instantiations of this integrative dialectic on the vertical (organismic) plane of the Process-Relational metatheory are readily found in classic developmental theories such as those of Erikson (1968), Piaget (1970c), and Werner (1958) and in contemporary developmental theories and middle-level metatheories that view the organism as a dynamic open system operating far from equilibrium (e.g., Mascolo & Fischer, 2010, Chapter 4, this *Handbook*, this volume; Witherington, 2011, Chapter 3, this *Handbook*, this volume). Werner's *orthogenetic principle*, for example states that "development . . . proceeds from an initial state of relative globality and lack of differentiation to a state of increasing differentiation, articulation, and hierarchic integration" (1957, p. 126). Another example is found in Mascolo and Fischer (2010) description of *skill theory*: "The levels and tiers specified by skill theory reflect increasingly levels of differentiation and hierarchical integration of skill components" (p. 168). And Mascolo and Fischer (Chapter 4, this *Handbook*, this volume) elaborate by stating that "to understand psychological development, it is necessary to examine how integrative structures of thinking, feeling, needing, and acting undergo differentiation and integration as products of multiply nested coactions that operate throughout the person ←→ environment system" (p. 120).

Ontological Features of the Process-Relational Worldview (Metatheory)

With the Process-Relational worldview as a synthesis of Organicism and Contextualism it remains to detail the particular ontological and epistemological categories of this new worldview. Despite Pepper's objection that the concept *organism* can have too many biological connotations, if the reader can ignore these, *organism*, as metaphor, captures better than others the sense of this worldview. This idea is particularly true as the Process-Relational worldview aligns itself closely to Alfred North Whitehead's (1925) *philosophy of organism*.

Ontology is the domain of metaphysics concerned with question of what constitutes the *Real* (Putnam, 1987). Operating within the framework of a thorough going *holism,* it is *activity, process, change,* and *necessary organization* that constitute the Process-Relational ontological categories. As these concepts are intricately interwoven among themselves and with epistemological concepts, overlaps in their description are unavoidable.

Activity

The idea of inherent activity as a basic ontological category goes back to the pre-Socratic Greek period when Anaximander rejected Thales's assertion that a fixed substance was the basis of all things, and instead proposed that Reality was to be found in an *indeterminate stuff* that was *self-activity*. For Anaximander, any fixed elements or fixed substance grew out of this activity (Wartofsky, 1968). Heraclitus further continued this position by arguing that ceaseless flux or change constituted the ontological Real.

The ontological Reality of activity later became prominent in the German Enlightenment beginning with the work of Gottfried Wilhelm Leibniz (1646–1716). Activity and ceaseless change were fundamental to the nature of the Real. Leibniz, a contemporary of Locke, maintained against Descartes' extended substance and Newton's atom, that the fundamental unit of the Real is the *monad*. As Leibniz said, "The nature of the monad consists in being fruitful and in giving birth to ever new variety" (quoted in Toulmin & Goodfield, 1965, p. 267). The monad:

> "Is" only in so far as it is *active*, and its activity consists in a continuous transition from one new state to another as it produces these states out of itself in unceasing succession. . . . Never is one of these elements just like another; never can it be resolved into the same sum of purely static qualities. (Cassirer, 1951, p. 29)

> In Leibniz's philosophy an inalienable prerogative is first gained for the individual entity. The individual no longer functions as a special case, as an example; it now expresses something essential in itself. . . . Every individual substance [monad] is not only a fragment of the universe, it is the universe itself *seen from a particular viewpoint*. (pp. 32–33; emphasis added)

The Leibnizian tradition is relational, and it emerged, as Cassirer (1951) suggests, from an organic understanding of the nature of events. Thus, it was within an emerging organic frame that specific ontological features of the Process-Relational worldview came to be articulated.

Although it was much later, with the discovery of subatomic particles and the formulation quantum mechanics, that a notion of such fundamental activity could be taken seriously in physics, this idea continued to form the basis for the German Enlightenment's theories of mind and nature. Immanual Kant's (1724–1804) faculties of mind were the active powers that stood between the sensory aspect of experience and categories of understanding: (a) *intuition*, the faculty of receiving and organizing impressions; (b) *imagination*, the faculty of organizing (i.e., the power of analysis and synthesis) perceptions (Intuitions); (c) *understanding*, the faculty of producing rules or concepts; (d) *judgment*: faculty of determining whether a rule or concept is subsumed under other rules or concepts; and (e) *reason*, the highest faculty, which produces principles.

F. W. J. Schelling (1775–1854), a onetime philosophical ally of Hegel, presented an organic rather than a mechanical view of nature, and believed it necessary that "rather than regarding matter as static, so that it acts only upon external impulse, . . . to see it as active, as generating and organizing itself" (Beiser, 2006, p. 6; see also Schelling, 1803/1988, pp. 137–138). Hegel, in turn, inherited Schelling's organic conception with its inherent activity, including that found within the tensions of the dialectic itself. As Hegel (1830/1975) comments on the circle of the dialectical thesis-antithesis, "If we look at the distinction between the two characteristics in this unity, it realizes the concrete totality of the form, the immediate self-translation of inner into outer, and of outer into inner. This self-movement of the form is **Activity**" (p. 208; bold in original).

When early psychologists and philosophers of psychology are included along with philosophers of nature and the mind, one of the early commitments to the basic category of inherent activity is found in Franz Brentano's (1838–1917) *act psychology* in which he called for a focus on mental activity and defined psychology in terms of the study of psychic phenomena expressed as acts and process (Brentano, 1874/1995). Less commonly recognized, because of the historical impact of Titchener's (1908) later mechanistic interpretation, Wundt was an advocate of the fundamental centrality of activity; "volitional activities are the type in terms of which all other psychological phenomena are to be construed (Wundt, 1908, Vol. 3, p. 152)" (quoted in Blumenthal, 1975, p. 1083).

William James (1890/1950) argued both against the elementaristic view of mind and for the centrality of intentional acts or *functions*. James' *functionalism* was largely guided by the principle that "*The pursuance of future ends and the choice of means for their attainment are . . . the mark and criterion of the presence of mentality* in a phenomenon" (James,1890/1950, p. 8; italics in original) and stated slightly differently "*no actions but such as are done for an end, and show a choice of means can be called indubitable expressions of Mind* (p. 11). John Dewey's (1916/1966) *transactional* approach followed on from James and focused on an understanding of experience as a relational acting upon and being acted upon. "When we experience something we act upon it, we do something with it, then we suffer or undergo the consequences" (Dewey, 1916/1966 p, 139). As Alexander (1987) points out, "activity, for Dewey, is in the world before it is either subjective or objective" (p. 9). Or as Dewey (1925/1958) said himself, "Life denotes a function, a comprehensive activity, in which organism and environment are included. Only upon reflective analysis does it break up into external conditions . . . and internal structures" (p. 9).

Process

Activity, action, acts, become *process* when holistically located in a temporal order of duration. The works of Heraclitus, Leibniz, Kant, Frichte, Schelling, Hegel, James, George Herbert Mead, C. S. Pierce, Dewey, and Henri Bergson, among others, can all be counted as making significant contributions to understanding the nature and role of process. It is, however, in the writings of Alfred North Whitehead (1861–1947) (Whitehead, 1920/2004, 1925, 1929/1978, 1938/1966) and Charles Hartshorne (1897–2000) (Hartshorne, 1972, 1979, 1984) that there emerges a fully systematic *philosophy of process*—which, as mentioned earlier, Whitehead termed a *philosophy of organism*—(see also Bickhard, 2008; Rescher, 1996, 2000; Seibt, 2013).

Because of Whitehead's central contributions to a Process-Relational worldview, and because he is likely less familiar to developmental scientists than other central contributors, a brief biography is in order. Whitehead was a British mathematician, logician, and philosopher. He is well known for his work in mathematical logic as the coauthor with Bertrand Russell of the groundbreaking three-volume *Principia Mathematica* (Whitehead & Russell, 1910, 1912, 1913/1927). He was also intimately familiar with the physics of his day, including Einstein's relativity, as well as early quantum theory. In this context, he produced his own theory of relativity (Whitehead, 1922, 1929/1978; see also Desmet, 2009; Seaman, 1955). As a philosopher, he focused on the philosophy of science (Whitehead, 1925), but his central contribution was, as stated earlier, as the original pioneer of what today is known as the *process philosophy*.

Whitehead's (1925) discussion of process begins with the challenge, quoted earlier, to the idea of an ontology of fixed substance; an idea that had been foundational in philosophical and scientific thought from Aristotle to Descartes through the history of the doctrine of *materialism*:

> There persists . . . the fixed scientific cosmology which presupposes the ultimate fact of an irreducible brute matter, or material, spread throughout space in a flux of configurations. In itself such a material is senseless, valueless, purposeless. It just does what it does do, following a fixed routine imposed by external relations, which do not spring from the nature of its being. It is this assumption that I call "scientific materialism." Also it is an assumption which I shall challenge as being entirely unsuitable to the scientific situation. (p. 18)

Whitehead (1938/1966) extends this challenge to the epistemology associated with materialism in stating that, "my quarrel with modern epistemology concerns its exclusive stress upon sense perception for the provision of data respecting nature. Sense perception does not provide the data in terms of which we interpret it" (p. 133).

As illustrated in the title of his philosophical system, Whitehead argues that the world is organic rather than materialistic. Activity, process, and change "are the matter of fact" (p. 146). And as a broad overview of his position he states,

> At an instant there is nothing. Each instant is only a way of grouping matters of fact. Thus since there are no instants, conceived as simple primary entities, there is no nature at an instant. Thus all the interrelations of matters of fact must involve transition in their essence. All realizations [*actual entities*, see below] involves implication in the creative advance. (p. 146)

A key concept in Whitehead's philosophy is the *actual entity* or *actual occasion*. These "are the final real things of which the world is made" (Whitehead, 1929/1978, p. 18). They may be subatomic particles or electrons, and they may also be a tree, house, the person or the act of the person. "There is no going behind actual entities to anything more real" (p. 18). "Each actual entity is conceived as an *act* of experience" (p. 40; emphasis added). Also, while actual entities may differ from each other, their commonality is that they are all "drops of experience, complex and interdependent" (p. 18).

An actual entity, as well as all of nature, is considered a process and consequently, "is not describable in terms of the morphology of a 'stuff'" (p. 41). The actual world, composed of actual entities,

> Is a *process* and that *process* is the *becoming of* actual entities. . . . In the becoming of an actual entity, the potential unity of many entities . . . —actual and non-actual—acquires the real unity of the one actual entity; so that the actual entity is the real . . . [process of unifying] of many potentials. (p. 22; emphasis added)

As a consequence, the

> "Substance-quality" concept is avoided, and that morphological description is replaced by description of *dynamic process* [a growing together, becoming] . . . The process . . . of any one actual entity involves the other actual entities among its components. In this way the obvious solidarity of the world receives its explanation. (p. 7; emphasis added)

Whitehead introduces the term *event* in a fashion consistent with Pepper's (1942) Contextualist *event* (i.e., "an *act* . . . But . . . not an act conceived as alone or cut off; it is an act in and with its setting, an act in its context" (p. 232) and Dewey's (1925/1958) *event* (i.e., "nature is viewed as consisting of events rather than substances, it is characterized by *histories*, that is, by continuity of change proceeding from beginnings to endings" [p. xii]). For Whitehead, the process of becoming (*realization*) an actual entity is an event. "Nature is a structure of evolving processes. The reality is the process. The realities of nature are . . . the events in nature" (1925, p. 74). And further, activity is central as each "event is an individual matter of fact issuing from an individualization of the substrate activity" (1925, p. 71). There is an essential unity to an event, a pattern; it is not the mere assembly of ingredients. "Space-time is nothing else than a system of pulling together of assemblеages into unities. But the word *event* just means one of these spatio-temporal unities" (1925, p. 74).

An event (process of becoming), whether we are addressing the horizontal dimension of an external act, or the vertical dimension of person, has a past, present, and future. The past entails the necessary (not sufficient) conditions of the present, and the present entails anticipations of the future. A *moment* in the event is an actual occasion in the "life-histories of enduring non-living objects, enduring living objects, and enduring objects with conscious knowledge" (Whitehead, 1929/1978, p. 177). A *duration* is "a complete locus of actual occasions in 'unison of becoming.' It is the old fashioned 'present state of the world'" (Whitehead, 1929/1978, p. 320). Both Henri Bergson (1911) and William James (1890/1950) employ highly similar concepts of *duration*. The durational present James terms—like Pepper (1942)—the *specious present* and describes this situation as "no knife-edge [Newton's instant], but a saddle-back, with a certain breadth of its own . . . with a bow and a stern, as it were—a rearward- and a forward-looking end" (James 1890/1950, p. 613).

As a broad summary of his position, Whitehead argues that, "nature is a process. . . . It is an exhibition of the process of nature that each duration happens and passes. The process of nature can also be termed the passage of nature" (1920/2004, p. 29). Whitehead's philosophical system is obviously complex, and it is also counterintuitive for those raised on a diet of mechanistic materialism. These few paragraphs can do little more than hint at the breadth and complexity of the complete system, and of the implications for developmental science of taking process seriously. Three of these implications, however, require at least brief mention.

First, because actual entities constitute the Real, and they are in process of becoming and passing away, as both Leibniz and Whitehead argue, the universe is not monistic, nor dualistic, but *pluralistic* (see also Smolin, 1997). Or as Hartshorne (1979) expresses it, "It is not one entity different at different times, but different entities or single events, one after another" (p. 254). With respect to methodology, in the Cartesian universe, understanding is achieved by reducing the many appearances to the one Real. In the Process-Relational universe reductionism becomes meaningless, and understanding is achieved through the rational discovery (i.e., abductive inference; Overton, 2014) of patterns of activity and transitions among patterns. The focus of understanding is, therefore, not on things but on the *relation*s among things. Thus, unity is found in multiplicity and not by reducing the many to the one.

A second implication of taking process seriously is also methodological. This is the need to ensure that process is the center of attention, and part and parcel of the methodology of developmental science. The work of two contemporary developmental methodologists, Nesselroade and Molenaar (Molenaar & Nesselorade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2010), is illustrative of this implication of taking process seriously. In fact the Nesselroade and Molenaar

(2010) methodological understanding of the nature of development and process, is a precise reflection of the Process-Relational metatheoretical concepts:

> Development includes many processes occurring simultaneously. . . . We subscribe enthusiastically to the value of going beyond basic notions of change to focus on more highly structured temporal organizations, which is what we believe researchers are trying to convey with the use of the term *process* and the application of a variety of approaches, including "person-centered" ones and various systems theoretic ideas. (p. 32)

A third implication of taking process seriously follows from the fact that the pluralistic universe is also a holistic universe. Because, as every monad in Leibniz's system, and actual entity in Whitehead's, is related to every other one, no single entity is merely a "fragment of the universe, it is the universe itself seen from a particular viewpoint and only the totality of these unique points of view gives us the truth of Reality" (Cassirer, 1951, pp. 32–33). This unity of the whole yields a *perspectivist* position, which is not relativistic, but entails a coherence theory of truth and within the scientific arena encourages interdisciplinary approaches to research.

Change

Just as activity blends into process so also does process blend into a third ontological category of the Process-Relational worldview, *change*. If "the process of nature . . . [is] the passage of nature" (Whitehead,1920/2004, p. 29), then change is categorical, or, as Whitehead says, "for the modern view process, activity, and change are the matter of fact" (1938/1966, p. 146). Considerations of change necessarily involve a discussion of the concept of time. In a book titled *Time Reborn* (2013), Smolin—the theoretical physicist mentioned earlier—has developed the argument that philosophers and physicists alike—from Plato to Newton to Einstein—have held fast to the claim that time is ultimately an illusion; replaceable by immutable, absolute, timeless laws. Smolin's thesis is that solutions to the current conundrums in theoretical physics and cosmology can only be found by taking time seriously, by thinking in time, which he terms "a form of relationism" (p. xvi). He further argues that the physics of the 20th century represented a "partial triumph of the relational view over the older Newtonian conception nature" (Smolin, 1997, p. 19), but even today this triumph is only partial.

In Newton's system, space and time are taken as absolutes. Matter is conceived of as inert bodies occupying a spatial location at a particular instant. Time is conceived of as simply a series of instances. Bergson (1960), James (1890/1950), Smolin (1997, 2013) and Whitehead (1938/1966) have all objected to this conception, particularly as it spacializes time, reducing it to a simple juxtaposition of instances. And, as stated earlier, "at an instance there is nothing . . . there is no nature at an instant" (Whitehead, 1938/1966, p. 146). Time, to the contrary, has moments, durations, events, transitions. Time is filled with nature, as activity, process, and change.

Change as the active process of becoming, moving from phase to phase, from potential to actuality, rather than split-off static being moved about by external forces, is the central theme that pervades the works of the advocates of a Process-Relational worldview. "All things change, the activities and their interrelations" (Whitehead, 1938/1966, p. 146). Yet, concurrently there is no denying of a relational *being*. This perspective is captured in the opening pages of Whitehead's *Process and Reality* (1929/1978) in his assertion that the lectures the text is based on are "concerned with the becoming, the being, and the relatedness of 'actual entities'" (p. xiii). And this theme is repeated throughout Whitehead's writings: "Every scheme for the analysis of nature has to face these two facts, *change and endurance*" (1938/1966, p. 88; emphasis added). "There are two principles inherent in the very nature of things, recurring in . . . whatever field—the spirit of change, and the spirit of conservation. There can be nothing real without both. Mere change without conservation is a passage from nothing to nothing. . . . Mere conservation without change cannot conserve" (1938/1966, p. 201). In the Process-Relational worldview, relational Being is found in Becoming and this attitude has come to be termed the *Becoming* tradition to distinguish it from the split off Cartesian-Newtonian-Mechanistic "nothingbutness" *Being* tradition.

Becoming. Heraclites is credited with the initiating the Becoming tradition in his claim that not fixed substance, but change was the fundamental underlying Real. As he wrote: "Everything flows and nothing abides; everything gives way and nothing stays fixed. You cannot step twice into the same river, for other waters and yet others, go flowing on" (quoted in Savitt, 2013). If this is so, then the stable objects we experience are phases in the process of change. With change or becoming as fundamental *being or endurance* is somewhat akin to a photographic snapshot that captures a moving object in a single stopped frame. From the becoming perspective there are no causal forces that lead to the composition of a "new" object. Change is imminent and necessary. A new seemingly stable object is a moment—that has endurance, duration—in the coming into being and passing away of process. Hence, *Being* is found in *Becoming*, *Constancy* is found in *Change*.

Before proceeding, it may be helpful to clarify what exactly is meant by the Process-Relational assertion that change is *necessary*. The distinction between the *necessary* and *accidental* was first articulated by Aristotle in his *Physics* (Book II, Chapter 9). Change that is accidental is change that arises in association with fortuitous or contingent events. Necessary change qua change is free from external causal forces and is natural to the entity being considered. For example, a plant goes through a sequence of changes that are as necessary to the essence of the plant as are any other intrinsic features. That is, the changes must occur or the plant would be something other than itself. On the other hand, the plant has a history during which accidental conditions such as favorable or unfavorable nutrients or good or bad weather may occur. These accidental conditions are not features of the plant qua plant, but they may be conditions closely associated with changes in the rate or ultimate level of the plant's growth. From this example it should be clear that the Cartesian-Newtonian-Mechanistic position's acceptance of a "nothingbut" Being assumption entails the proposition that there are no necessary changes. Indeed, as mentioned earlier, it was Newton who first split-off Being from Becoming. From the Process-Relational perspective change is necessary, hence categorical.

The traditions of Becoming were further elaborated across the centuries (see Allport, 1955; Nisbet, 1969). Plato's and Aristotle's positions are ambiguous, but important. Plato as the father of the search for *essences* of nature and, thus, what has been called *essentialism* (see Mayr, 1982; Overton, 2006) was taking an ultimate position of natural fixity. However, Plato himself also specifically stated that "*only* the divine is changeless; that the world of man and society is an incessant process of becoming" (Nisbet, 1969, p. 308). Aristotle has been criticized for his advocacy of primary substances as the fundamental entities in his ontology (Whitehead, 1929/1978, p. xiii) and for his static classificatory system of logic (Whitehead, 1920/2004, p. 10). On the other hand, a Becoming orientation is expressed in his relational concepts of the *potentiality* and *actuality* of individual entities (*Physics*, Book III). The actuality of an object of inquiry (i.e., what the object is at a given moment) points to its being. The passage from potentiality to actuality points to the becoming of the object (Ross, 1959, p. 176). Coming into being (i.e., becoming) constituted Aristotle's conceptualization of developmental change and—as in a definition of development to be elaborated later in this chapter—he emphasized both the transformational and variational nature of change as critical relational features of becoming. Aristotle referred to *transformational change* as *generation and destruction*, and he termed *variational change alteration* (Ross, 1959, pp. 101–102).

In the 17th century Leibniz further expanded the Becoming position through his, earlier discussed, concept of the *monad*. The monad was considered to be the basic irreducible feature of all substance. It differed from the atom, however, in that it was thought of as inherently active and continuously changing. Because of the existence of constant change, knowledge of the world could not be obtained by attempting to reduce the events of experience down to some stable and fixed feature. The approach to be taken was to discover, by a rational, logical method, according to his *principle of sufficient reason*, the rules according to which the change operated. The concept of the monad served to establish the basic idea and set the stage for the 18th-century expansion of the idea to an understanding of man, society, and nature.

In 1725 Giambattista Vico attacked the static view of human nature and proposed the changes of society to be the reflection of the imminent and necessary development of the human mind. In his *General History of Nature and Theory of the Heavens*, Immanuel Kant (1755) (cited in Toulmin & Goodfield, 1965, p. 130) applied this idea to the material world and maintained that the world was continuously evolving in a systematic and ordered fashion. And from 1784 on, in a series of four volumes, Johann Gottfried Herder (1744–1803) extended the idea of *Becoming* to include all nature, animal species and human society alike (Toulmin & Goodfield, 1965).

In the late 18th and early 19th centuries Hegel was the most influential figure to advance the Becoming tradition. For Hegel, history was a necessary, dynamic process of change. The nature of this change was defined by the integrative dialectic, which, as discussed earlier, is the process through which concepts or fundamental features of a system *differentiate* and move toward *integration*. This process, in fact, suggests a grounding for understanding developmental change as directional. Within the dialectical process, the dichotomy of thesis and antithesis (i.e., a differentiation) is resolved through the emergent synthesis (integration), which itself then becomes the new thesis and the process continues and thus represents a cycle. However, the cycle is never closed, as they would be in a circle. When a circle is opened a bit, it does not return precisely to its starting point. As a consequence, with the continuation of activity, the open cycle forms a spiral (the synthesis or integration). With the repetition of spirals, a direction is formed (see Overton 1994a, 1994b) and cycles of time (durations) become the Arrow of Time (see Figure 2.6) (Coveney & Highfield, 1990; Gould, 1987; Nisbet, 1969; Overton, 1994a). The integrative dialectic also provides the ontological background for the relational continuity-discontinuity and emergence within the developmental processes. Hegel expresses this most clearly in his introduction to the *Phenomenology of Spirit*:

> The bud disappears in the bursting-forth of the blossom, and one might say that the former is refuted by the latter; similarly, when the fruit appears, the blossom is shown up in its turn as a false manifestation of the plant, and the fruit now emerges as the truth instead. These forms are not just distinguished from one another, they also supplant one another as mutually incompatible. Yet at the same time their fluid nature makes them moments of an organic unity in which they not only do not conflict, but in which each is as necessary as the other; and this mutual necessity alone constitutes the life of the whole. (Hegel, 1807, p. 2)

In the 19th century the Becoming tradition flourished in the works of social theorists such as Comte, Marx, and Spencer and in the writings of biologists such as Wolff, Goethe, and von Baer. And later into the 20th century, figures who contributed to the ontology of becoming included, along with Nietzsche and Heidegger, the various process philosophers mentioned earlier, especially Whitehead. It should be noted, however, that, in general, the process philosophers tended to focus their attention on the differentiation dialectic.

In the late 19th century and into the 20th and 21st centuries, the Becoming tradition, along with the other ontological features of the Process-Relational worldview, became background assumptions of the grand developmental theories of James Mark Baldwin (1895, 1897/1973, 1902/1976), Jean Piaget (1967, 1970), Heinz Werner (1957, 1958), and Lev Vygotsky (1978). Baldwin was the first to formulate a developmental psychology specifically in terms of integrative dialectical categories. As Broughton (1981) points out, "his [Baldwin's] . . . orientation came to be tempered with a Hegelian view of dialectical progress through qualitatively distinct levels of consciousness" (p. 399) (see also Freeman-Moir, 1982).

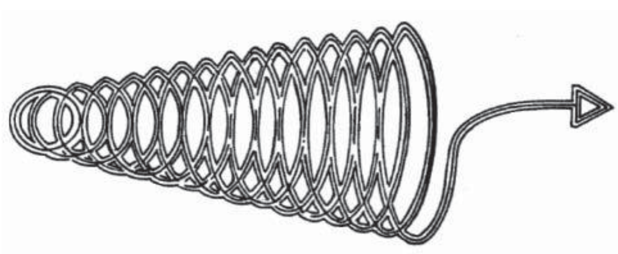

Figure 2.6 Spirals of time transform into an arrow of time.

Werner (1957, 1958) drew his own theoretical approach from the systematic dialectical feature of Becoming. In this context, he proposed the orthogenetic (normal development) principle as a universal explanatory principle, or law, of transformational change. As mentioned earlier in this chapter, the *orthogenetic principle* asserts that development proceeds from an initial relative globality and lack of differentiation to increasing differentiation, articulation, and hierarchic integration. Piaget draws from the same Becoming tradition in laying out the metatheoretical grounding for his *equilibration* explanation of human transformational change: "These global transformations . . . gradually denote a sort of law of evolution which can be phrased as follows: assimilation and accommodation proceed from a state of chaotic undifferentiation to a state of differentiation with correlative coordination" (Piaget, 1954, p. 352). Similarly, Vygotsky (1978) maintains that development is best characterized as "a complex dialectical process characterized by periodicity, unevenness in the development of different functions, metamorphosis or qualitative transformation of one form into another" (p. 73).

It is significant also that the three major developmentalists of the last half of the 20th century—Piaget (Piaget & Garcia, 1991), Werner (Werner & Kaplan, 1963) and Vygotsky (1978)—all considered development to be change entailing a spirality that emerges from cycles and yields direction (see Figure 2.6). As Vygotsky noted specifically with respect to higher psychological functions, "Development, as often happens, proceeds here not in a circle but in a spiral, passing through the same point at each new revolution while advancing to a higher level" (p. 56).

Along with the classical developmental theorists Werner, Piaget, and Vygotsky, dynamic theorists, both from the British object-relations school (e.g., Fairbairn 1952; Winnicott, 1965) and the ego psychology school (e.g., Erikson, 1968) found the core systematic dialectical Becoming, along with concepts of *process*, *differentiation*, and *integration* central to an understanding both normal and pathological human ontogenesis (Overton & Horowitz, 1991).

Necessary Organization

Organization enters the blend of the Process-Relational ideas of activity, process, and change as a final ontological category. *Organization*, and its synonyms *pattern, structure,* and *system*, is about the form or pattern of an actual entity—both the horizontal dimension of the overt act and the vertical dimension of the individual organism. The categorical nature of this concept in a Process-Relational worldview is acknowledged by Whitehead in his statement, "Pattern involves the concept of different modes of togetherness. This is obviously a fundamental concept which we ought to have thought of as soon as we started with the notion of various types of fundamental things" (1938/1966, p. 143). And as to its blending with other categories Whitehead says further,

> In the place of the Aristotelian notion of the procession of forms ... [there is] substituted the notion of the *forms of process* .... The study of the *internal relations within a complex state of activity*. This complex state is in one sense a unity. There is the whole universe of physical action extending to the remotest star cluster. In another sense it is divisible into parts. We can trace interrelations within a selected group of activities and ignore all other activities. (1938/1966, p. 140)

Organization or form as an ontological category was first proposed in the pre-Socratic Greek period by Anaxagoras, who rejected the reductionism of the many manifest qualities to the one Real (i.e., termed the problem of the *one and the many*) (Wartofsky, 1968). Anaxagoras postulated an indefinite number of real qualities and argued that their essence was in their form. Plato later argued that forms (also termed *ideas*), nonmaterial entities that do not exist in the world of sense perception, but underlie it (Wartofsky, 1968, p. 86), constituted the ultimate Reality. Although Aristotle argued that Plato's ideal forms do not exist apart from things themselves, his major contribution is found in his relational dialectic understanding that things are composed of matter and form and "form is not separable from the thing itself" (*Physics*, Book II, Chapter 1). Aristotle further argued that the form is what is unique to the entity in question; what makes it what it is and makes it distinctive from other entities. For example, if we did not understand the form of a statue then it would have no meaning as a statue, but would be merely a piece of marble. Further, if we did not understand the form of marble it would have no meaning as marble but would be merely stone and if we did not understand the form of stone, and so on. Finally, for Aristotle, form ("the form or pattern") was one of the four (efficient, material, formal, final) types of explanation (*Physics*, Book II, 3) that were required for a complete explanation of any phenomenon.

In the early 17th century, Schelling (1803/1988) elaborated on the centrality of necessary organization of the organic world, arguing that the organism

> Organizes itself.... It could not organize itself without already being organized. The plant nourishes itself and subsists through assimilation of external matter, but it can assimilate nothing to itself unless it is already organized.... Thus organization constructs itself out of organization. (p. 31)

The concept of necessary *organization*, (*pattern*, *structure*, *system*) within the modern Process-Relational worldview is the ontological face of the principle of *holism*. A whole, unity, or system is a relational set of processes, such that the whole determines the nature of the part processes and the part processes determine the nature of the unity. The unity exhibits systemic qualities that are different than any single part process or the sum of the part processes. Thus, these systemic qualities are *emergent novelties*. Consider the simple example of vision and the visual system: cornea, pupil, iris, lens, retina, optic nerve, lateral geniculate nucleus, optic radiation, primary visual cortex, and associative visual cortex: Where is vision? Vision does not reside in any of the part processes, nor is vision found in the aggregate sum of the parts. Vision is an emergent function of the whole organization; the pattern of coacting part processes.

Structure-Function Relations. Within the Process-Relational worldview, structure (organization, pattern; Aristotle's "formal" explanation) and process constitute a necessary indissociable relation; there can be no process without structure and no structure without process. This relation is generally referred to as a *structure-function* relation. Within the Cartesian worldview, this relation is one that is split off with organization being treated as trivial, epiphenomenal, or the outcome of causal forces. An early example of the splitting of structure-function in the field of psychology occurred when Titchener (1898) first coined the term "functional psychology" (p. 451) to describe the theoretical approach of James, and Dewey, and to contrast it to his and Wundt's "structural psychology" (p. 449). The split and contrast was explicit in his reference to the Wundt/Titchener paradigm as "experimental" and functional psychology as "descriptive" (p. 452). In fact, the Wundt/Titchener approach was irrelevant to the current use of the term structure, as it was a reductionistic approach to bedrock "elements of mind, their number and nature" (p. 455). The important point here, however, is the splitting of structure and function. A related point is that, whereas Titchener was exhibiting this "nothingbutness" of the Cartesian worldview, the holism of structure-function (organization-process) was, in fact, a primary characteristic of James's philosophy (Putnam, 1995). Ironically, in the hands of the later American functionalists James Rowland Angell, Harvey A. Carr, and Robert S. Woodworth, function became increasingly detached from structure to the point that the categorical nature of organization was lost and the appearance of organization was reduced to a Reality of stimuli, responses, and drives (i.e., motivational forces). And contemporary "functionalists" maintain this Cartesian split (for examples, see Overton & Horowitz, 1991).

A contemporary developmental example of the splitting of structure-function is found in a variant of *dynamic systems* developed by Thelen and Smith (1998, 2006) and, Spencer (Spencer, Perone, & Buss, 2011; Spencer, Perone, & Johnson, 2009). As Witherington (2011; Chapter 3, this *Handbook*, this volume) demonstrates in detail, these authors deny the ontological status of structure and argue that structure is itself generated solely by the activity entailed in the process of self-organization. As Witherington (2014; Chapter 3, this *Handbook*, this volume) further demonstrates, arguing that sensorimotor activity (function) in and of itself generates mental structures opens this variant of dynamic systems to a new type of reductionism. Other dynamic system models such as those of Lewis (1997, 2011), van der Maas (1995; van der Maas & Raijmakers, 2009), van Geert (2003; van Geert & Steenbeek, 2005) and Witherington (2011, 2014; Chapter 3, this *Handbook*, this volume) recognize the unity of structure and function and, hence, recognize the fact that regardless of level of analysis some organization is never lacking.

Although present in the developmental theories of Baldwin, Stern (1938), Vygotsky, and Werner, the most clearly defined systematic articulation of the necessary joining of structure-function is found in Piaget's developmental theory. In fact, Piaget's theory is a paradigmatic example of a Process-Relationally derived developmental theory. However, in the vast majority of Piaget's writings the Process-Relational details are embedded in his empirical, methodological, and theoretical concerns about the specific nature of knowing and development. Given this fact, Piaget is often read in a Cartesian framework and this reading, in turn, has generated serious misunderstandings (see Lourenço & Machado, 1996, for examples) about Piaget's theory itself and empirical findings concerning the nature and development of mind, and human functioning generally.

With respect specifically to structure-function, Piaget explicitly asserts, "structures are inseparable from performance, from functions" (Piaget, 1970a, p. 69). The simple fact of the matter is that structures function and functions have structure. Within Piaget's theory, structure-function is frequently translated into the concepts *organization* and *adaptation*, and again at this level, Piaget is insistent that that there can be no Cartesian split between them.

> Organization is inseparable from adaptation: . . . The first being the internal aspect of the cycle of which adaptation constitutes the external aspect. (Piaget, 1952, p. 7)
>
> The "accord of thought with things" and the "accord of thought with itself" expresses this dual functional invariant of adaptation and organization. These two aspects of thought are indissociable: It is by adapting to things that thought organizes itself and it is by organizing itself that it structures things. (p. 8)
>
> The organism and the environment form an indissoluble entity, . . . there are adaptional variations simultaneously involving a structuring of the organism and an action of the environment, the two being inseparable from each other. (p. 16)

Further Piaget offers numerous testimonials to the theory's commitment to necessary organization or ontological holism:

> Wholes do not result from putting together a bunch of parts; parts result from differentiation of the whole. This means that autoconservative properties of the whole provide a cohesive force that distinguishes the whole from inorganic psychochemical totalities. (Piaget, 1985, p. 20)
>
> Wholeness is a defining mark of structures . . . all structuralists . . . are at one in recognizing as fundamental the contrast between *structures* and *aggregates*, the former being wholes, the latter composites formed of elements that are independent of the complexes into which they enter. To insist on this distinction is not to deny that structures have . . . [parts], but the [parts] of a structure are subordinated to laws, and it is in terms of their laws that the structure *qua* whole or system is defined. Moreover, the laws governing a structure's composition are not reducible to cumulative one-by-one associations of its elements: they confer on the whole, as such, over-all

> properties distinct from the properties of its [parts]. (Piaget, 1970a, pp. 6–7)

Structure is a totality; that is, it is a system governed by laws that apply to the system as such, and not only to one or another element in the system (Piaget, 1970b, p. 22).

> The concept of totality expresses the interdependence inherent in every organization. . . . The correlative of the idea of totality is . . . the idea of *relationship*. Every totality is a system of relationships just as every relationship is a segment of totality. (Piaget, 1952, p. 10)

In the living organism, the reflexes form organized totalities and not juxtaposed mechanisms (Piaget, 1952).

Summary

To this point, the ontology of Process-Relational metatheory has been described both in terms of its synthesis of Organicism and Contextualism, and in terms of its essential ontological commitments of this synthesis to the necessary inherent activity of nature, the necessary inherent nature of change and becoming, of process, and of organization. As a consequence of this presentation most of the promises shown in bullet points early in the chapter have been fulfilled: *Holism* has replaced Cartesian *Atomism,* the *Activity* of nature has replaced Cartesian *Fixity*, *Change* and *Becoming* have replaced Cartesian *Stasis and Being*, Nature as *Process* has replaced Cartesian *Substance*, the *Necessary Organization* of nature has replaced Cartesian *Uniformity*, and a *Pluralistic Universe* has replaced the Cartesian *Dualistic* or *Monistic Universe*. What remains to be discussed are the epistemological commitments of the Process-Relational paradigm including Relational Understanding, and the multiple perspectives and multiple forms of explanation it entails.

Epistemological Features of the Process-Relational Worldview (Metatheory)

As ontology is the domain of metaphysics concerned with the question of what constitutes the "Real" (Putnam, 1987), epistemology is about knowing, and its primary question concerns the validity of what and how we know. Understood relationally, epistemology is a narrative about *how* we know what is Real, and ontology is a narrative about the *Real* as we know it. Classically, the fundamental questions of epistemology have concerned the relation of the knower to the known, or the question of the source of knowledge. And once the Cartesian paradigm had split the world, the question became do we know the world through *pristine* observation *or* reason? The relational answer to this question is *both*.

The epistemology of the Process-Relational paradigm is, first and foremost, a *relatively inclusive* epistemology, involving both knowing and known as equal and indissociable complementary processes in the construction, acquisition, and growth of knowledge. It is *relatively* inclusive, because *inclusion* itself—much like Hegel's master-slave dialectic—can be grasped only in relation to its complement *exclusion*. Thus, just as *freedom* must be identified in the context of *constraint*, *inclusion* must be identified in the context of *exclusion*. Relational epistemology specifically excludes Cartesian dualistic ways of knowing because Cartesian epistemology trades on exclusivity; it constitutes an epistemology of "nothingbutness." For the same reason, the Relational-Process paradigm rejects both the Mechanistic worldview and a strict contextualist interpretation of the Contextualist worldview (Overton, 2007; Witherington, 2007, 2011, 2014).

Epistemologically, the Process-Relational position begins by clearing the "nothingbutness" of splitting from the field of play. Splitting was described earlier. It originates from the original Cartesian splits of mind and body, subject and object, appearance and foundation, and it consists of the formation of a *conceptual dichotomy*, a separation of components of a whole into *mutually exclusive* pure forms or elements. In splitting, these ostensibly pure forms are cast into an exclusive *either/or* logical framework that forces them to be understood as contradictions in the sense that one category *absolutely* excludes the other (i.e., following an Aristotelian classificatory logic as the *law of contradiction* according to which it is never the case that A = Not A). When splitting is combined with the idea of there being an absolute bedrock foundation, a one certain Real, then one of the alternatives becomes privileged over the other and this idea leads to theoretical and methodological wars over which alternative constitutes the "legitimate" or "significant" or "meaningful" approach to inquiry. Nature and Nurture, Idealism and Materialism, Reason and Observation, Subject and Object, Constancy and Change, Biology and Culture, among others (see Table 2.1 for a list of common antinomies that can be converted into relational complementarities) and under the influence of Cartesian epistemology are presented as split-off competing alternatives. Choose one concept as the foundational "Real" and

TABLE 2.1 Fundamental categories: Interpreted in the Cartesian-Split-Mechanistic paradigm as dichotomous antinomies. Interpreted in the Process-Relational and Relational-Developmental-Systems paradigm as coequal indissociable complementarities.

Fundamental Categories	
Subject	**Object**
Mind	Body
Form	Matter
Differentiation	Integration
Stability	Change
Universal	Particular
Transcendent	Immanent
Analysis	Synthesis
Unity	Diversity
Certainty	Doubt
Absolute	Relative
Expressive	Instrumental
Variation	Transformation
Intrapsychic	Interpersonal
Reason	Emotion
Biology	Culture
Person	Biology
Culture	Person
Nature	Nurture
Interpretation	Observation

it follows, under a split epistemology, that the other is mere Appearance or epiphenomenal.

In place of the rejected splitting and foundationalism, the Process-Relational metatheory installs *holism* as the over-arching epistemological first principle. Building from the base of holism, Process-Relationism moves to specific principles that define the relations among parts and the relations of parts to wholes. In other words, relational metatheory articulates principles of analysis and synthesis necessary for any scientific inquiry. These principles are (a) *The Identity of Opposites*, (b) *The Opposites of Identity*, and (c) *The Synthesis of Wholes*.

Holism

Holism has already been discussed with respect to the Process-Relational synthesis of Organicism and Contextualism and, more specifically with respect to ontological face of holism. Now holism is presented, as mentioned above, as the epistemological first principle. To repeat, holism is the principle that the identities of objects and events derive from the relational context in which they are embedded. Wholes define parts and parts define wholes. The classic example is the relation of components of a sentence. Patterns of letters form words and particular organizations of words form sentences. Clearly, the meaning of the sentence depends on its individual words (parts define whole). At the same time, the meaning of words is often defined by the meaning of the sentence (wholes define parts). Consider the word meanings in the following sentences: (a) The *party leaders* were *split* on the *platform*; (b) The *disc jockey* discovered a *black rock star*; and (c) The *pitcher* was *driven home* on a *sacrifice fly*. The meaning of the sentence is obviously determined by the meaning of the words, but the meaning of each *italicized* word is determined by context of the sentence it is in. Parts determine wholes, and wholes determine their parts (Gilbert & Sarkar, 2000).

Holistically, the whole is not an aggregate of discrete elements subject to a reduction to an ultimate foundation, but an organized system of parts, each part being defined by its relations to other parts and to the whole. Complexity in this context is *organized complexity* (Luhmann, 1995; Nicolis & Prigogine, 1989; von Bertalanffy, 1968a, 1968b), in that the whole is not decomposable into elements arranged in additive sequences of mechanistic cause–effect relations (Overton & Reese, 1973). In the context of holism, principles of splitting, foundationalism, and atomism are, by definition, rejected as meaningless approaches to analysis, and fundamental antimonies are similarly rejected as false dichotomies (see Table 2.1). In an effort to avoid *standard* (i.e., neopositivistic and conventionalist) misunderstandings here, it must be strongly emphasized that *nondecomposability does not mean that analysis itself is rejected*. It means that *analysis of parts must occur in the context of the parts' functioning in the whole*. It is difficult to overemphasize this point, as the most shopworn and illegitimate criticism of holism, repeated again and again, is the notion that if one accepts holism then one is committed to examine everything simultaneously. This assumption is simply false and it has always been false.

What is true is that the *context-free specifications* of any object, event, or process—whether it be a DNA, molecule, cell, neuron, evolution, the architecture of mind, or culture—is illegitimate within a holistic system (see, e.g., Ingold, 2000, 2004). Bunge (2003) nicely captures both the problem of reductionism and the issue of holism in the following:

> At first sight, the discovery that genetic material is composed of DNA molecules proves that genetics has been reduced to chemistry.... However, chemistry only accounts for DNA chemistry: it tells us nothing about the biological functions of DNA—for instance that it controls morphogenesis and protein synthesis. In other words, DNA does not perform

> any such functions when outside a cell, anymore than a stray screw holds anything together. Besides, DNA does nothing by itself: it is at the mercy of the enzymes and RNAs that determine which genes are to be expressed or silenced. In other words, the genetic code is not the prime motor it was once believed to be. This is what epigenesis is all about. (p. 138)

Although holism is central to the Process-Relational paradigm, holism does not, in itself, offer a detailed program for resolving the many dualisms that have framed scientific knowing and knowledge. A complete relational epistemological program requires principles according to which the individual identity of each concept of a formerly dichotomous pair is maintained, while simultaneously it is affirmed that each concept constitutes, and is constituted by, the other. This understanding is accomplished by considering identity and differences as two *moments of analysis*. The first moment is based on the principle of the *identity* of opposites; the second moment is based on the principle of the *opposites* of identity.

Identity of Opposites

The principle of the identity of opposites establishes the *identity among parts* of a whole by casting them not as exclusive contradictions as in the split epistemology but as differentiated polarities (i.e., coequals) of a unified (i.e., indissociable) inclusive matrix—as a *relation*. As differentiations, each pole is defined recursively; each pole defines and is defined by its opposite. In this identity moment of analysis, the law of contradiction is suspended and each category contains and, in fact, *is* its opposite. Further—and centrally—as a differentiation, this moment pertains to character, origin, and outcomes. The character of any contemporary behavior, for example, is 100% nature because it is 100% nurture; 100% biology because it is 100% culture. There is no origin to this behavior that was some other percentage—regardless of whether we climb back into the womb, back into the cell, or back into the DNA—nor can there be a later behavior that will be a different percentage.

There are a number of ways to illustrate this principle; as discussed earlier in this chapter, a particularly clear illustration is shown in the schematic sketch of hands drawing hands (see Figure 2.4). As a reminder, this sketch shows a left and a right hand assuming a relational posture according to which each is simultaneously drawing and being drawn by the other. In this matrix, there is a sense in which each hand is different (opposite left and right hand) and a sense in which the hands are identical (each is drawing and being drawn). It is in the latter analytic *Identity of Opposites* moment, that the hands are identical (i.e., A = Not A), and thus they are coequal and indissociable. This moment of analysis is one in which the law of contradiction (i.e., not the case that A = Not A) is relaxed and identity (i.e., A = Not A) reigns. In this identity moment of analysis, pure forms or the notion of *natural kinds* collapse and categories flow into each other. Here, each category contains, and is, its opposite. As a consequence, there is a broad inclusivity established among categories.

The justification for the claim that a law of logic—for example, the law of contradiction—can reasonably both be applied and relaxed depending on the context of inquiry requires a recognition that the laws of logic themselves are not immutable and not immune to background ideas. In some metatheoretical background traditions (i.e., epistemological Realism), the laws of logic are understood as immutable realities given either by a world cut off from the human mind or by a prewired mind cut off from the world. However, in the background tradition currently under discussion (i.e., epistemological Constructivism) the traditional laws of logic are themselves ideas that have been constructed through the reciprocal action of human minds and world. The "laws of logic" are simply pictures that have been drawn or stories that have been told. They may be good pictures or good stories in the sense of bringing a certain quality of order into our lives, but, nevertheless, they are still pictures or stories, and it is possible that other pictures will serve us even better. Whitehead (e.g., 1922/1978) often complained that we have become prisoners of Aristotelian classificatory logic. Wittgenstein, whose later works focused on the importance of background or what we are calling *metatheoretical ideas*, made this point quite clearly when he discussed another law of logic—the law of the excluded middle—as being one possible *picture* of the world among many possible pictures.

> The law of the excluded middle says here: It must either look like this, or like that. So it really . . . says nothing at all, but gives us a picture. . . . And this picture *seems* to determine what we have to do and how—but it does not do so. . . . Here saying "There is no third possibility" . . . expresses our inability to turn our eyes away from this picture: a picture which looks as if it must already contain both the problem and its solution, while all the time we *feel* that it is not so. (1953, para. 352)

Within the identity moment of analysis, it is often a useful exercise to write on each hand one of the bipolar terms of

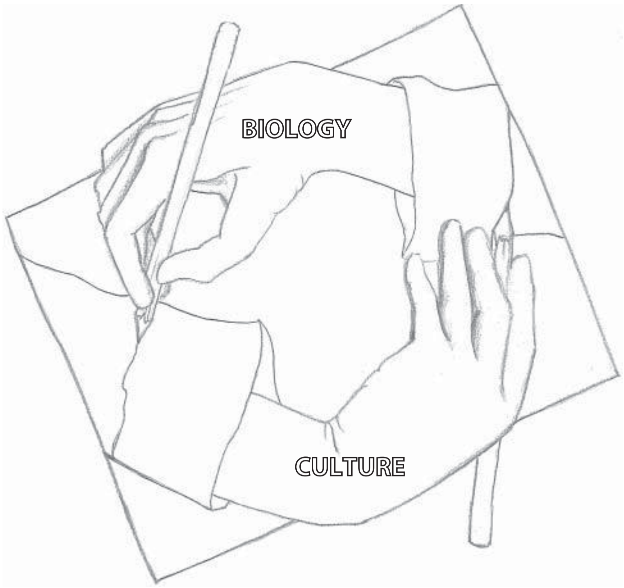

Figure 2.7 A schematic sketch of hands drawing hands demonstrating the indissociable relation between biology and culture. An *Identity of Opposites*.

the Cartesian split dualisms (mentioned earlier were *differentiation* and *integration;* others include, e.g., *genotype* and *phenotype*; *development* and *evolution*; *subject* and *object*; *biology* and *culture*) and to explore the resulting effect (see, for example, Figure 2.7). This exercise is quite different than an illustration of a familiar bidirectionality of mechanical cause and effects. This exercise makes tangible a central tenet of the relational metatheory; seemingly dichotomous ideas often thought of as competing alternatives (see Table 2.1) can, in fact, enter into inquiry as coequal and indissociable. This exercise also concretizes the meaning of *causality* as used within the Process-Relational framework. In this framework, the concepts of *reciprocal determination* (Overton & Reese, 1973), *coaction* (Gottlieb et al., 2006), *fusion* (Greenberg, 2011; Partridge, 2011), as well as *relational bidirectional* (←→) *causality* (Lerner, 2006), *relational causality* (Gottlieb, 2003), and *circular and downward causality* (Witherington, 2011), are relatively similar terms used to differentiate the positive and negative feedback loops of the Process-Relational worldview from additive (even bidirectionally additive) efficient causality of the Cartesian-Split-Mechanistic worldview.

The principle of the Identity of Opposites imposes theoretical and methodological constraints on any field of inquiry—biological, evolutionary, individual, and cultural—just as other metatheories impose constraints on any field of inquiry. The primary constraints within the Process-Relational metatheory are that (a) splits are not permitted (e.g., the split of genotype and phenotype in genetics, the split of internalism and externalism in the Modern Synthesis, the split of brain, body, and culture in cognitivism, and the cultural split of individual and culture) and (b) phenomena cannot be thought of as being decomposable into independent and additive pure forms (e.g., the Fisher–Wright AVOVA model in genetics and in the Modern Synthesis).[6]

If the principle of the Identity of Opposites introduces constraints, it also opens possibilities. One of these is the recognition that—to paraphrase Searle (1992)—the fact that a behavior implicates activity of the biological system does not imply that it does not implicate activity of the cultural system, and the fact that the behavior implicates activity of the cultural system does not imply that it does not implicate activity of the biological system. In other words, the Identity of Opposites establishes the metatheoretical rationale for the theoretical position that biology, person, and culture operate in a truly *interpenetrating relational* manner.

Opposites of Identity

Although the Identity of Opposites sets constraints and opens possibilities, it does not in itself set a positive agenda for empirical scientific inquiry. The limitation of the identity moment of analysis is that, in establishing a flow of categories of one into the other, a stable base for inquiry that was provided by bedrock material *atoms* of the Cartesian-Split-Mechanistic metatheory is eliminated. In the split approach, no relativity entered the picture; all was absolute. Reestablishing a *stable base*—not an absolute fixity, nor an absolute relativity, but a *relative relativity* (Latour, 1993)—within Process Relational metatheory requires moving to a second moment of analysis. This is the *oppositional moment where the figure of identity and the ground of opposites reverses, and opposites become figure*. This moment—the Opposites of Identity—becomes dominated by a *relational exclusivity*.

[6]West-Eberhard's (2003) evolutionary work provides a biological example of the identity of opposites in her resolution of the conflict between the quantitative genetics of continuous variation and the developmental biology of discrete traits. This resolution is "a theory of the phenotype based on the *complementarity* of continuous and discrete variation" (p. 13; emphasis added). All antimonies are best viewed as complementaries. The Process-Relational metatheory articulates the meaning of *complementarity*.

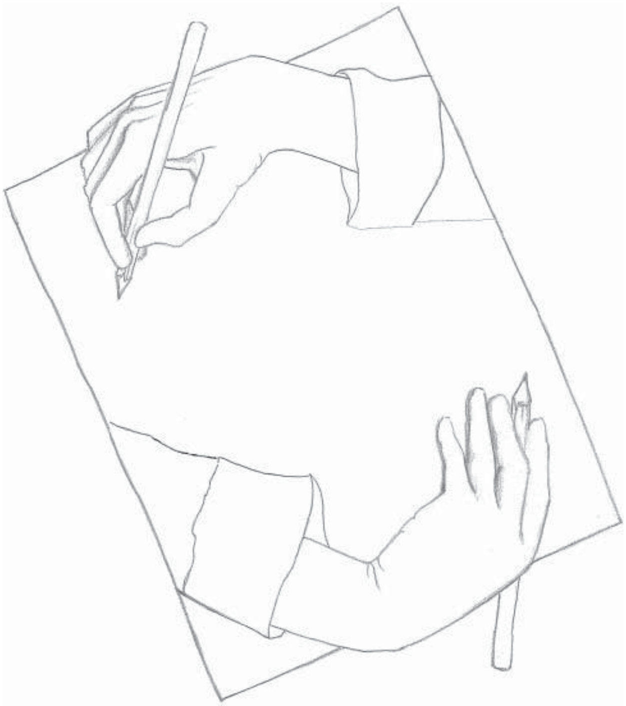

Figure 2.8 A schematic sketch drawing hands separated. *Opposites of Identity*—constituting standpoints, points-of-view, lines-of-sight.

Thus, in this oppositional moment of analysis, it becomes clear that despite the earlier identity, the hand sketch does illustrate both a *right* hand and a *left* hand (see Figure 2.8). In this moment of opposition, the law of contradiction is reasserted and categories again exclude each other. As a consequence of this exclusion, parts exhibit *unique* identities that differentiate each from the other. These unique differential qualities are stable within any holistic system and, thus, may form relatively stable platforms for empirical inquiry. The platforms created according to the principle of the Opposites of Identity become *standpoints, points-of-view,* or *lines-of-sight,* in recognition that they do not reflect absolute foundations (Latour, 1993, 2004) but perspectives in a *multiperspective world*. See Figure 2.8.

Again, looking back to the hand sketch designating the relational Biology-Culture (see Figure 2.7), when left hand as left hand and right as right are in relation but separately the focus of attention, it then becomes quite clear that, were they large enough, one could stand at either hand and examine the structures and functions of that location, as well as its relation to the other location (i.e., the *coactions* of parts). Thus, to return to the example of nature–nurture, although explicitly recognizing that any behavior is both 100% biology and 100% culture, alternative points of view permit the scientist to analyze the acts of the person from a *biological* or from a *cultural standpoint*. Biology and culture no longer constitute competing alternative explanations; rather, they are two points of view on an object of inquiry that has been created by, and will be fully understood only through, multiple viewpoints. More generally, *the unity that constitutes nature, the organism, and development becomes discovered only in the diversity of multiple interrelated lines of sight*.

Synthesis of Wholes

Engaging fundamental bipolar concepts as relatively stable standpoints opens the way, and takes an important first step toward establishing a broad stable base for empirical inquiry within Process-Relational Metatheory. However, this solution is incomplete as it omits a key relational component, the relation of parts to the whole. The oppositional quality of the bipolar pairs reminds us that their contradictory nature still remains, and still requires a resolution. Further, as discussed, the resolution of this tension cannot be found in the Cartesian-Split-Mechanistic approach of reduction to a bedrock absolute Real. Rather, the Process-Relational approach to a resolution is to move away from the extremes to the center and above the conflict, and there discover a novel system that will *coordinate* the two conflicting systems. This principle is the *Synthesis of Wholes*, and the synthesis that emerges itself becomes yet another standpoint in this multiperspective mode of understanding.

The synthesis of interest for the general metatheory would begin from a system of opposites that would constitute the most universal bipolarity that can be imagined. Arguably, there are several candidates for this level of generality, but the polarity between the *physical*, on the one hand, and *society*, on the other, is sufficient for present purposes (Latour, 1993). The physical and society represent systems that stand in an Identity of Opposites. To say that an object is a social or cultural object in no way denies that it is physical; to say that an object is physical in no way denies that it is social or cultural. And further, the object can be analyzed from either a social-cultural or a physical standpoint. The question for synthesis becomes the question of *what new system will coordinate these two systems*. Arguably, the answer is that it is *life* or living systems that represent the coordination of the physical and sociocultural. Because our specific focus

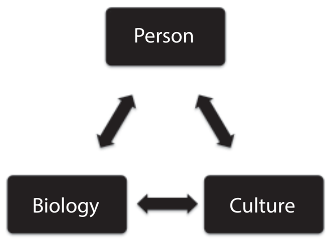

Figure 2.9 *Synthesis of Wholes*. Three of multiple possible standpoints.

of inquiry is the psychological subject, we can reframe this physical-societal polarity back into a nature–nurture polarity of *biology* (physical) and *culture*. If we again write *biology* on one, and *culture* on the other drawing hands schematic (see Figure 2.7), and question what system represents the coordination of these systems, it is life, the living organism, the *person* (see Figure 2.9). That is, within a psychological perspective, the person is the relational synthesis of biological and sociocultural processes.

At the synthesis, then, a standpoint coordinates and resolves the tension between the other two components of the relation. This particular synthesis provides a broad and stable base for launching empirical inquiry. A *person standpoint* opens the way for the empirical investigation of universal dimensions of psychological structure–function relations (e.g., processes of perception, thought, emotions, values), the particular variations associated with these wholes, their individual differences, and their development across the life span. Because universal and particular are themselves relational concepts, no question can arise here about whether the focus on universal processes excludes the particular; it clearly does not as we already know from the earlier discussion of relations. The fact that a process is viewed from a universal standpoint in no way suggests that it is not situated and contextualized; the fact that it is viewed from an individual standpoint in no way denies its universality.

It is extremely important to recognize that one standpoint of synthesis is relative to other synthesis standpoints. *Life and Society* are coordinated by the *Physical*. As a consequence, if we are broadly considering the scientific field of psychology, *biology* represents a standpoint as the synthesis of person and culture (see Figure 2.9). The implication of this idea is that a relational biological approach to psychological processes investigates the biological conditions and settings of psychological structure–function relations and the actions they express. This exploration is quite different from split foundationalist Cartesian-Split-Mechanistic approaches to biological inquiry that assume an atomistic and reductionistic stance toward the object of study. Neurobiologist Antonio Damasio's (1994, 1999) work on the brain–body basis of a psychological self and emotions presents an excellent illustration of this biological relational standpoint. In the context of this standpoint, Damasio (1994) is emphatic that:

> A task that faces neuroscientists today is to consider the neurobiology supporting adaptive supraregulations [e.g., the psychological subjective experience of self] . . . I am not attempting to reduce social phenomena to biological phenomena, but rather to discuss the powerful connection between them. . . . Realizing that there are biological mechanisms [sic] behind the most sublime human behavior *does not imply a simplistic reduction* to the nuts and bolts of neurobiology. (pp. 124–125; emphasis added)

A similar biological example comes from the Nobel laureate neurobiologist Gerald Edelman's (1992, 2006) work on the brain–body base of consciousness:

> I hope to show that the kind of reductionism that doomed the thinkers of the Enlightenment is confuted by evidence that has emerged both from modern neuroscience and from modern physics. . . . To reduce a theory of an individual's behavior to a theory of molecular interactions is simply silly, a point made clear when one considers how many different levels of physical, biological, and social interactions must be put into place before higher order consciousness emerges. (Edelman, 1992, p. 166)

And finally, to return in the present context to a point made earlier, Gilbert and Epel (2009), in presenting ecological developmental biology (eco-devo), describe several "revolutions" occurring in biology, including a new relational orientation: "Rather than analyzing independent 'things' a new focus of developmental biology concerns '*relationships*.' Nothing, it seems, exists except as part of a network of interactions" (p. xiii; emphasis added).

A third synthesis standpoint recognizes that *Person and Physical* are coordinated by *Society*, and again granting that our domain of scientific interest is psychological (i.e., inquiry about psychological processes), then *culture* or *sociocultural* represents a standpoint as the synthesis of *person* and *biology* (see Figure 2.9). Thus, a relational cultural approach to psychological processes explores the cultural conditions and settings of psychological structure–function relations. From this *cultural standpoint*, the focus is on cultural differences in the context of psychological functions as complementary to the person standpoint's focus on psychological functions in the context of cultural differences.

Valsiner (1998) gives one illustration of a relational, developmentally oriented *cultural standpoint* in his examination of the "social nature of human psychology." Focusing on the "social nature" of the person, Valsiner stresses the importance of avoiding the temptation of trying to reduce person processes to social processes. To this end, he explicitly distinguishes between the *dualisms* of split foundationalist metatheory and *dualities* of the relational stance he advocates.

When the three points of synthesis—biology, person, and socioculture—are cast as a unity of interpenetrating coacting processes, there emerges what Greenberg and Partridge (2010) describe as a *biopsychosocial* model of the organism. But it is important to note that synthesis of wholes is not limited to only three. For example, *discourse or semiotics* may be taken as a synthesis of *person* and *culture* (Latour, 1993). In this case biology and person are conflated and the biological/person and culture represents the opposites of identity that are coordinated by discourse. The point of greatest significance is that it is in the synthesis of wholes, of however many can be generated, that we find the justification for *Multiple perspectives* or *standpoints* as a replacement for the *Cartesian*-Split perspectives of *Objectivism vs. Subjectivism.*

Explanation and Understanding

Explanation and understanding are properly epistemological topics. It would take, and has taken, volumes (e.g., see, Bunge, 1979; von Wright, 1971) to come close to adequately discussing this central yet unresolved feature of knowing generally, and scientific knowing specifically. Here only a hint of an outline can be presented (see Overton, 2006, 2014, for more extended discussions).

In the Cartesian-Newtonian materialist approach, explanation, as discussed earlier, is *mechanical explanation*, which proceeds according to the rules of (a) reduction, (b) finding the "forces," and (c) inductively generalizing the law. In finding the forces, Newton limited explanation to ontological *efficient* cause. The meaning of this cause comes from Aristotle as "the original source of change or rest. For example, . . . a producer causes a product and a changer causes a change" (*Physics*, Book II, 3). As Bunge (1979) points out,

> What must now be stated is the peculiarity of mechanics and mechanistic philosophy with regard to the causal problem, namely, the reduction of *cause to force* . . . . It was Newton who enlarged the notion of force, the mechanical representative of cause. . . . In short what was peculiar to both mechanics and mechanistic philosophy, from Galileo to the Newtonians, was not causality but . . . *mechanical causality* as contrasted to the richer but chimerical forms of causation imagined by Aristotle. (p. 108)

At this point, in embracing a Process-Relational worldview we have moved from a mechanical to an organic understanding of nature, and there is no room for mechanical causality in this understanding. As Schelling (1803/1988) pointed out,

> As soon as we enter the realm of the *organic nature* all mechanical linkage of cause and effect ceases for us. Every organic product exists *for itself*. . . . The organic . . . produces *itself*, arises *out of itself* . . . . Every organic product carries the reason of its existence in itself, for it is cause and effect of itself. No single part could arise except in this whole, and this whole itself consists only in the *interaction* of the parts. . . . It *organizes itself* . . . . Not only its form but its *existence* is purposive. It could not organize itself without already being organized. The plant nourishes itself and subsists through assimilation of external matter, but it can assimilate nothing to itself unless it is already organized. (pp. 30 –31)

Keeping in mind that actual entities like food, water, parents, siblings, and communities constitute the process-relational context or greater whole, within which the individual organism develops, these actual entities come to constitute *resources, assests,* or *affordances* (Good, 2007) for the further becoming of organization. They are not, however, efficient causes.

Structure-Function Explanation. With the elimination of mechanical efficient cause, and its close relative, material cause ("that from which a thing is made"), any causal understanding of process is limited to Aristotle's formal ("the form or pattern") and final ("what the happening is for") (*Physics*, Book II, 3) explanatory forms.

Formal explanation has already been mentioned in connection with necessary organization and structure-function relations. Taking the psychological person as an example, this organized actual entity (structure of processes) (our vertical dimension of Process-Relational) acts in the world (function of structure) (our horizontal dimension). The act itself is successful or unsuccessful in achieving a goal (reaches a *satisfaction*, for both Pepper and Whitehead). If unsuccessful, then variations arise and, perhaps, there is an emergent novel act (take the car rather than walk to the store). The degrees of success/nonsuccess feeds back to the person and to some degree the structure changes to accommodate this feedback (e.g., see Schneirla's, 1957, concept of *circular functions and self-stimulation in ontogeny*). As this process repeats and repeats, the structure of the person changes to the point that a novel integration emerges and the actions operate within the novel structural pattern. A concrete example is that of the infant with a sensorimotor structure of action searching for and attaining a hidden object. Novel actions emerge such a removing a cover to attain the object. Based on the repetition of many varied sensorimotor actions in many different problem contexts a novel vertical structural integration emerges, which may be described as thinking.

Aristotle's *final explanation* enters in two ways. Following Brentano, James, Dewey, and Whitehead, all acts, even those at the most basic sensorimotor level have an intention, aim, direction, goal, satisfaction. Thus, all of nature is the passage of nature directed toward an end. This view is final explanation with respect to the horizontal dimensions of external acts. Along with this becoming there is also a necessary becoming from potential to actual along the vertical or person dimension. Whether from fetus to late adulthood, or from global and lack of differentiation to differentiation and hierarchical integration, again, all of nature is the passage of nature directed toward an end.

The Process-Relational approach, thus, introduces *multiple explanatory types* substituting for the single Newtonian efficient cause. There is, in fact, a reasonable argument that the term causality be dropped from the vocabulary of science. Thus, Miller (2010) suggests that in place of *causality* we use "perhaps with less baggage, *explanation*, or even just discoveries of regularities in nature" (p. 725), while Redhead (1990) goes further and argues against the need for the concept of causality at all in science. *Causality* is confusing and arguments for its elimination have merit. Even those causal concepts associated with the Process-Relational approach—*relational bidirectional causality*, *relational causality*, *circular* and *downward causality*—could readily be eliminated in favor of structure-function analyses where these ideas divide into systems investigations (formal explanation) and becoming or becoming investigations that examine transitions from one form to the next.

Resources and Conditions. There are two further features of explanation within a Process-Relational approach that requires mention. The first is simply to point out that the notions of resources, assets, and affordances do not constitute sufficient conditions for the process of becoming. Resources, assets, and affordances may be conditions that facilitate the optimization or the retardation of the becoming process, but as will be described next, they are not sufficient conditions of the process.

For the second point, it will be recalled that Whitehead (1929/1978), in discussing an event as a process of becoming, described the event as having a past, present, and future. The present entails anticipation of the future (formal and final explanation), whereas the past entails the necessary conditions of the present. This idea means that once we grant with Schelling (1803/1988) that, "the organic . . . produces *itself*, arises *out of itself*" (p. 30), we have found the sufficient reason for becoming (i.e., the action of the process itself). As a consequence logically the search for sufficient conditions (or causes) must cease. One of the most eminent methodological developmental scientists of the 20th century, Joachim Wohlwill (1973), expressed this fact as follows:

> Once we grant the existence of "normal developmental processes," that is, acting independently of *particular* specifiable external agents or conditions, there follows a much more far-reaching consequence. That is that we can only hope to isolate necessary, rather than sufficient . . . [conditions] i.e., those without which we can assert development does not take place, rather than those thanks to which it does take place. (p. 319)

The final conclusion to be drawn is that with respect to explanation and understanding there are three primary tasks to be undertaken. First there are the structure-function analyses, which will entail system modeling; second there is the enquiry into the necessary conditions associated with the process of becoming; and third there is the enquiry into resources, assets, and affordances that facilitate the optimization or the retardation of the normal process of becoming.

To this point the ontological and epistemological categories of the Cartesian-Split-Mechanistic and the Process-Relation worldviews or metatheories have been compared and contrasted (see Table 2.2 for a summary) and several Cartesian metatheories of the middle range have been described. The chapter now turns to a presentation and discussion of a broad middle-range metatheory constructed within the conceptual frame of the Process-Relational metatheory: Relational-Developmental-Systems.

TABLE 2.2 A comparison of the ontological and epistemological categories of the Process-Relational and Cartesian-Split-Mechanistic metatheories.

Worldviews	
Process-Relational	**Cartesian-Split-Mechanistic**
Ontological Categories	
Holism	Atomism
Activity	Fixity
Nature as Process	Nature as Substance (Matter)
Change—Becoming	Stasis—Being
Dialectic	
Necessary Organization	Uniformity
Structure-Function Relations	
Pluralistic Universe	Dualistic/Monistic Universe
Epistemological Categories	
Holism	Reductionism
Constructivism	Realism
Relational Understanding	Split Understanding
Identity of Opposites	
Opposites of Identity	
Synthesis of Wholes	
Multiple Standpoints of Analysis	Objectivism vs. Subjectivism
Multiple Forms of Explanation	Efficient/Material Causal Explanation
Formal Explanation	
Structure-Function	
Final Explanation	
Necessary Conditions	

RELATIONAL-DEVELOPMENTAL-SYSTEMS

Taken as a whole—including both ontological and epistemological assumptions—Process-Relational metatheory operates as the contextual frame for the construction of middle-range metatheories. As discussed earlier, middle-range metatheories are less broad in scope, more specific to particular domains of inquiry, and together with a worldview metatheory, constitute a *conceptual framework* for a scientific paradigm. Relational-Developmental-Systems is the most inclusive of several middle-range metatheories that are contextualized by the Process-Relational metatheory, and all of these middle-range metatheories incorporate systems concepts—including developmental, dynamic (Witherington, Chapter 3, this *Handbook*, this volume), psychobiological (Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume), dialectical, and transactional (Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume), systems, as well as a model termed *enaction* (Stewart et al., 2010).

It is important to note that there is *no* Relational-Developmental-Systems *theory*; Relational-Developmental-Systems is a metatheory (see Figure 2.2). There are, however, theories that are informed by Relational-Developmental-Systems and, hence, one might say that there are *relational developmental systems theories*. Also, it is the case that the actual entity that develops is the *relational developmental system*. Relational-Developmental-Systems represents an extension (Lerner, 2006, 2012a; Lerner & Benson, 2013; Lerner & Overton 2008, 2014; Overton, 2006, 2010, 2013a, 2013b; Overton & Lerner, 2012, 2014) of the original developmental systems "theory" described by Ford and Lerner (1992) and Gottlieb (1996) (see also, Lerner, 2002). This extension was motivated by an increasing recognition of the Process-Relational worldview as a central component of the conceptual framework of this alternative scientific paradigm to that formulated within the Cartesian-Split-Mechanistic worldview.

The broad aims of Relational-Developmental-Systems coincide with the aims of contemporary Developmental Science, which are "to describe, explain, and optimize intrandividual changes in adaptive developmental regulations as well as interindividual differences in such relations across life" (Lerner, 2012a, p. 29). As noted early in this chapter, deriving from the ontological and epistemological Process-Relational categories, Relational-Developmental-Systems as metatheory characterizes the living organism as an *inherently active, self-creating (autopoetic, enactive), self-organizing, and self-regulating, relatively plastic, nonlinear complex adaptive system*. The system's development occurs through its own *embodied activities and actions* operating *coactively* in a lived world of physical and sociocultural objects, according to the principle of *probabilistic epigenesis*. This development leads, through positive and negative feedback loops created by the system's organized embodied action, to increasing system differentiation, integration, and complexity, directed toward adaptive ends.

The Process-Relational-System and Developmental Process

Relational-Developmental-Systems takes a life-span approach to the scientific study of *systematic intraindividual changes*—from conception to the end of life—of an organism's behavior, and of the systems and processes involved in those changes and that behavior. This approach encompasses the study of several categories of change such as ontogenesis (development of the individual across the life span), embryogenesis (development of the embryo), orthogenesis (normal development), pathogenesis (development of psychopathology), and microgenesis (development on a very small time scale such as development of a single precept). But the approach is also comparative and, thus, includes the study of phylogenesis and evolution (development of the species), as well as historical and cultural development.

Intraindividual change processes constitutes the fundamental defining feature of development, but it is important to immediately emphasize that not all change is necessarily developmental change. Developmental change processes and the relational developmental system itself entails six necessary defining features: (1) *organization of processes* (also termed *structure* and *system*); (2) *embodiment;* (3) *order* and *sequence*; (4) *direction*; (5) *epigenesis* and *emergence*; and (6) *relative permanence* and *irreversibility*. These features frame two broad forms of change that traditionally have been considered developmental, but have also at times been considered competing alternative definitions of developmental change—transformational change (i.e., morphological change or change of form) and variational (the degree or extent that a change varies from a standard, norm, or average) (see Ram & Grimm, Chapter 20, this *Handbook*, this volume, for an extended methodological discussion of transformational and variational change).

Transformational and Variational Change

Understanding the place of transformational and variational change in development requires a type-token distinction, which is also a distinction between structure and content. Perception, thinking, memory, language, affect, motivation, and consciousness are *universal* psychological processes (*types*), characteristic of the human species as a whole. Any given percept, concept, thought, word, memory, emotion, or motive represents a *particular expression* of a universal process (*tokens*). Although each form of change is entailed by any behavioral act, transformational change primarily concerns the acquisition, maintenance, and retention, of *universal* processes (types), whereas variational change primarily concerns the acquisition, maintenance, retention, or decline of *particular* expressions (tokens) and individual differences in expressions.

Historically, within the Cartesian-Split-Mechanistic paradigm transformational and variational change were considered competing alternative for the term *development*. From a Process-Relational perspective this competition is unnecessary and unwise. The two types of change constitute a whole reflecting two coequal and indissociable complementary processes. This solution claims a reality in which the processes assume differentiated functional roles, but each process in itself explains and is explained by the other. Put simply, the relational developmental system acts, acts show variation, and variations feedback to the system, which leads to transformation of the system (see Figure 2.10 and refer back to Figure 2.5) (Overton & Ennis, 2006). Any relational developmental system by its nature produces acts consistent with the structure of the system (flies produce fly acts; pigeons, pigeon acts; and humans, human acts). *Acts are embodied actions in the world, and they succeed or fail to various degrees in attaining their intended goals*. Partial success feeds back to the system, which uses the feedback as a resource in changing (transforming) the system. The transformed system, in turn, produces further variants of the act. Thus, all development entails cyclical movements between transformation and variation that result in increasing complexity of the system and increasingly refined variants (Gestsdóttir & Lerner, 2008; Overton, 2006). As Demetriou, Mouyi, and Spanoudis (2010) state,

> The relations between the general and the specialized processes are complex and bidirectional. On the one hand, general processes set the limits for the construction, operation, and development of the domain-specific systems. On the other hand, specialized processes provide the frame and raw material for the functioning of general processes. (pp. 322)

This relational solution clarifies the *de facto* situation that much of the research in developmental science currently takes place at one or the other pole of the whole, and the solution encourages an integrated vision for future study.

At this point the six defining features of developmental change processes and the relational developmental system will be examined in detail.

Organization of Processes: System

Developmental change entails change in the form, organization, or structure of a system. In the case of ontogenesis, the system is the living organism, whereas subsystems consist of cognitive, affective, and motivational (i.e., psychological) processes together with their biological correlates. Embryological changes constitute some of the clearest and most concrete examples of transformational or morphological change (Edelman, 1992; Gottlieb, 1992).

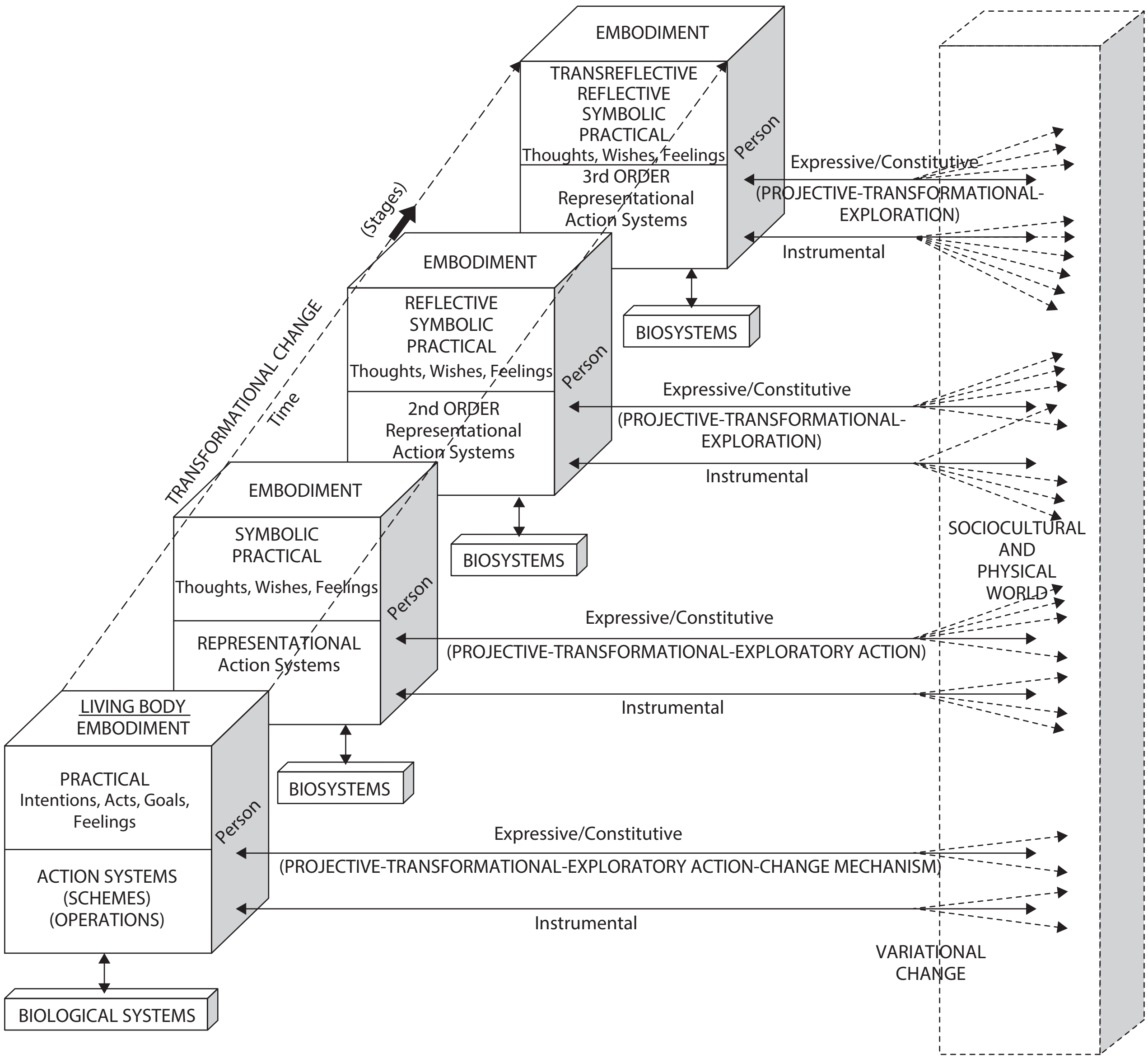

Figure 2.10 Synthesis of transformational and variational developmental change. Acts (expressive/constitutive/instrumental) emerge from embodied systems, aim at completion-satisfaction. Blocking of satisfaction results in variational acts, which feedback to system leading to transformational change. Bottom half of cubes at left represent *subpersonal system* concepts; top half of cubes represent *psychological* concepts.

Through processes of differentiation and reintegration, movement occurs from the single-celled zygote to the highly organized functioning systems of the 9-month fetus. Some cognitive and social-emotional phenomena of human ontogenesis have also been conceptualized as reflecting transformational change.

For example, sensorimotor action undergoes a sequence of transformations to become symbolic thought, and further transformations lead to a reflective symbolic thought exhibiting novel logical characteristics (see Mascolo & Fischer, 2010, Chapter 4, this *Handbook*, this volume; Sokol, Hammond, Kuebli, & Sweetman, Chapter 8, this *Handbook*, this volume). Memory may reflect transformational changes moving developmentally from recognition memory to recall memory. The sense of self and identity (Chandler, Lalonde, Sokol, & Hallett, 2003; Damon & Hart, 1988) has been portrayed by some as moving through a sequence of transformations. Emotions have been understood as differentiations from an initial relatively global affective matrix (Sroufe, 1979). Physical changes, such as changes in locomotion, have also been conceptualized as transformational changes (Thelen & Smith, 2006). Again, it requires emphasis that all of this transformational change occurs in the context of the variational changes in the system's actions

Developmental change implies an entity that is changed. Under the dominance of the Cartesian-Split-Mechanistic paradigm—when developmental science could be conceived as a *discipline assuming substance rather than process as its ontological* base—the entity changed was simply observable behavior. At the core of neo-positivism and behaviorism, and strict Contextualism, observed behavior and its associations with biological and environmental variables formed the bedrock and exclusive context of inquiry. As a consequence, within these metatheoretical frames, it was possible to identify developmental change with variational behavioral change that was not relationally connected to any organization of processes. In fact, it was, and to a significant extent continues to be, an era in which the gold standard of developmental explanation was to find the *mechanism* (i.e., causal force) producing the behavior under consideration.

As developmental science has moved to a more relational stance—becoming a *process rather than a substance discipline*—it is the living, inherently active, open, self-creating, self-organizing, and self-regulating system of processes that constitutes the entity changed. *System* has been defined in various ways. For example, van Geert (2003) offers "any collection of phenomena, components, variables" (p. 655). However, this conception and other "collection" or aggregate-like definitions are inconsistent with holism and, consequently, inconsistent with Relational-Developmental-Systems. A more adequate relational definition of system is "a whole which functions as a whole by virtue of the interdependence of its parts" (Overton, 1975, p. 73). Thus, a system is by its nature a set of organized processes and this set is organized holistically. Further, the relational developmental system is an adaptive system. Here *adaptation* refers to how the system acts in the context of changing environments—*perturbations* in systems language, or *affordances*, assets, *resources*—so as to increase its probability of survival; not in the sense of *adjusting* to an environment. Adaptive systems are defined in contrast with *determined systems*. In determined systems, the relation between inputs and outputs are exactly and reproducibly connected. For example, an automobile is a determined system. When the driver presses the accelerator or turns the steering wheel, both driver and passenger expect the auto to speed up or turn. All components of the auto must be fully determined to achieve this collective response. And determined systems are linear in the sense that small inputs result in small outputs; large inputs in large outputs—thus, outputs are predictable. In adaptive systems, the parts follow simple rules, whereas the behavior of the whole system is not determined; it is probabilistic because it is a function of all of the timing of the relations among the interpenetrating events, including nonnormative events.

As an inherently active system, *the system acts*, and its acts, have the following characteristics: (a) acts and their variation express the underlying organization of the system (i.e., any act is *expressive*); (b) acts function as the means for communicating within the sociocultural world, while changing and being changed by both the sociocultural and the physical world (i.e., any act is *communicative/instrumental*); and (c) *acts constitute the basic change process* that, through coaction with the world, results in system's transformation. It is *the relational developmental system itself* that organizes and regulates itself through complex and multidirectional relational coactions with its biological, socio-cultural, and physical environmental subsystems (see Figure 2.10).

Embodiment

All acts are embodied acts, and consequently the general case is that it is not simply acts, but rather it is *embodied action* that *constitutes the fundamental process for all development change* (i.e., the *sufficient condition* of development). Embodiment represents the relationally interpenetrating processes among person, biology, and culture. It is the claim that perception, thinking, feelings, desires—*the way we behave, experience, and live the world*—is contextualized by our being *active agents* with this *particular kind of body* (Overton, 1994a, 1994b, 2008; Taylor, 1995). The kind of body we have is a constitutive precondition for having the kind of behaviors, experiences, and meanings that we have. Embodiment includes not merely the physical structures of the body but *the body as a form of lived experience, actively engaged with the world of sociocultural and physical objects*. The *body as form* references the biological standpoint, the *body as lived experience* references the psychological subject standpoint, and the *body actively engaged with the world* represents the sociocultural standpoint. Within a process-relational context, embodiment is a concept that bridges and joins in a unified whole these several research points of synthesis discussed earlier (see Figure 2.9).

Order and Sequence

The overt or observable embodied acts of a relational developmental system exhibit variations (e.g., there are many ways to reach for and grasp a cup), and these variations produce sequences. These behavioral sequences are *contingent* (i.e., under changed conditions can be different). However, change in the form or organization of the system itself exhibits a *necessary order* and *universal sequence* (e.g., the development of human *grasping*). Any complex living system is an adaptive system, and any adaptive system, if it is to survive and thrive, necessarily moves from lesser to greater levels of complexity. The transformations from zygote to embryo to fetus, to neonate, for example, are not contingent (although they entail contingent variable acts); they are universal, and could not be otherwise. Similarly, the transformation of a system characterized by sensorimotor functioning to a system characterized by complex reflective thought represents a necessary and universal ordered sequence.

Directionality

Any notion of order implies a *direction* to the change. That is, any ordered system implies an *orientation toward a goal* or end state (termed *attractors*, or *equilibria* in dynamic systems; Molenaar and Nesselroade, Chapter 17, this *Handbook*, this volume; Witherington, Chapter 3, this *Handbook*, this volume). The notion of a goal orientation (*telos*) has often befuddled and even frightened those developmental scientists who continue to be held in the grasp of the Cartesian-Split-Mechanistic approach. To talk of a *telos* seems to raise the worry of admitting a discredited teleology into the science. This fear is based on competing metatheoretical assumptions and conceptual confusions. One conceptual confusion concerns subjective versus objective teleology. Subjective teleology involves *subjectively* held *purposes, aims*, or *goals* (e.g., "I intend to become a better person") and is irrelevant to the definition of developmental change. Objective teleology, in contrast, involves the construction of principles or rules designed to explain (Aristotle's final explanation)—in the sense of making intelligible—phenomena under investigation (e.g., "the development of X moves from lack of differentiation to more equilibrated levels of differentiation and hierarchic integration"). The rule so constructed conceptually "finds" or "discovers" or "identifies" the sequential order and the end state. Any position that seriously embraces the Process-Relational and Relational-Developmental-Systems approach necessarily accepts both goal directedness and the fact that the specific goal articulated is a theoretical concept—not a slice of physical nature, nor the positing of an *entelechy*—designed to illuminate the nature of the developmental change under study.

It is simply a conceptual confusion to argue that adequate descriptions are more important than the positing of end points (e.g., Sugarman, 1987), or similarly to suggest a movement away from end points and toward "a more neutral, person-time-and-situation-geared conception of development" (Demetriou & Raftopoulos, 2004, p. 91). There is no "neutral" standpoint, and no description could possibly occur without a positing of endpoints. The question here is what one would possibly describe if one did not understand development as tending toward some specified end? If one wishes to describe/explain the course of acquiring language, then adult language is, of necessity, the end point toward which development moves. No "description" of the language of the child would be possible without this ideal end point. In a similar fashion, if one wishes to describe/explain the transformational development of reasoning, or thought, or problem solving, or personality, or anything, a conceptual end point must serve as the ideal ultimate model.

A related feature of this confusion over the positing of developmental end point arises from the mistaken notion that positing a goal or endpoint necessarily leads to an "adultomorphic perspective [that] forces one to view earlier behaviors and functions as immature versions of adult functions" (Marcovitch & Lewkowicz, 2004, p. 113). Central to this argument is its faulty assumption that all developmental change, including transformational change, is additive (linear, strict continuity) and, conversely, the failure to recognize that in relational developmental systems, nonlinearity (nonadditivity; discontinuity) is frequently the rule. For example, Piaget's interest in examining the development of the reasoning process from a Relational-Developmental-Systems perspective resulted in his identifying deductive propositional reasoning as the end point of inquiry; whether this was a good idea or a poor idea is irrelevant to the current argument. What is relevant is that Piaget described several quite different forms of reasoning (e.g., preoperational and concrete operational) that function as discontinuous precursors to this adult form, and these early forms are not simply immature versions of the adult function. Rather, they are qualitatively distinct forms of reasoning.

A final conceptual confusion is the notion—abroad for many years—that focusing on sequences and positing endpoints introduces rigidity and denies the *relativity plasticity* of development. This notion is quickly debunked by recognizing that the concept of *equifinality* (i.e., that there are multiple means to the same end) is a core concept of the relational developmental systems. Although each level of organization of the system is a part of the normative sequence moving toward a normative end, there are multiple means or action paths to each system level.

The centrality of an understanding of developmental processes of transformational/variational change—including the relational developmental system, embodiment, order, sequence, and directional characteristics—is meaningful only to the extent that the understanding of developmental science and scientific method in general have advanced beyond the Cartesian-Split-Mechanistic paradigm. It will be recalled from an earlier discussion, that this paradigm includes what has traditionally been termed *Newtonian mechanical explanation* according to which scientific explanation, and, hence, science itself, was ultimately reduced to the search for individual and additive observable forces that were taken as efficient *causes or mechanisms*. In the Process-Relational and Relational-Developmental-Systems paradigm, as mentioned earlier, any search for efficient causes or mechanical mechanisms is rejected. These are replaced by the identification of dynamic action *patterns*—both synchronously as actual action events and diachronically as organized, sequential, directional, relational developmental systems. This identification of action patterns and the processes they entail is logically prior to the identification of necessary conditions and resources for development. It is in fact the specific relational developmental system under investigation that defines both conditions and resources. To consider *genes*, *neurons*, *cultural objects*, *parents*, *peers*, or *neighborhoods* to be sets of additive mechanical causes that drive development is to miss the point that these are all resources and conditions that the relational developmental system itself uses to develop. It is the relational developmental system itself that is the cause of development—if we must use the word *cause*—and this system enacts development by engaging in a multitude of complex relational actions with these resources and conditions.

From a Cartesian perspective, these complex actions have been termed *interactions*, but that term is totally inadequate to describing the relational interpenetrations of coacting part processes that operate as the relational developmental system. In order to capture both the merging (or *fusion*; Greenberg & Tobach, 1984) of parts into a single identity, while maintaining their individual identity as differentiations, the terms *interpenetration* (merging) and *coaction* (←→) (Gottlieb et al., 2006) must be substituted in place of *interaction*, except in those cases that refer to a simple additive combination of elements, such as statistical interactions. At times—perhaps unfortunately—a relational process notion of causality as *reciprocal bi- or multidirectional* (←→) or circular (positive and negative feedback loops) are introduced. However, it is *imperative* that it be clearly understood that these bear no relation to mechanical efficient or material causes.[7]

Epigenesis and Emergence

The concept of *epigenesis* was originally introduced in biology by Waddington (Van Speybroeck, 2002) as a counter to the idea of *preformation* in the explanation of the appearance of increasingly organized complexity from a relatively undifferentiated egg to a highly differentiated organism. Although epigenesis has a long history with several twists and turns (see Lickliter & Honeycutt, 2010, Chapter 5, this *Handbook*, this volume), today, conceptualized relationally as *probabilistic epigenesis* (Gottlieb, 1992), the concept designates a *holistic* approach to understanding developmental complexity. *Probabilistic epigenesis* is the principle that the role played by any part process of a relational developmental system—gene, cell, organ, organism, physical environment, culture—is a function of all of the interpenetrating and coacting part processes of the system. It is through complex relational bidirectional and multidirectional reciprocal interpenetrating actions among the coacting part processes that the system moves to levels of increasingly organized complexity. Thus, epigenesis identifies the system as being completely *contextualized* and *situated; time and*

[7] An example of the confusion that results from the failure to make this distinction appears in the writings of Pigliucci and Müller (2010a) and Müller (2010). In discussions of new trends in evolution, these authors acknowledge the centrality of systems concepts, but simultaneously describe this as “a shift towards a causal-mechanistic approach . . . a shift . . . to a causal-mechanistic theory” (Pigliucci & Müller, 2010a, p. 12), and a “turn towards the mechanistic explanation of phenotypic change” (Müller, 2010, p. 309). There is a profound difference between the claim that there has been a trend away from correlational approaches, and the claim that there has been a trend away from correlational approaches and to *mechanistic* causal approaches.

place matter (Elder, 1998; Elder, Shanahan, & Jennings, Chapter 2, this *Handbook,* Volume 4). The contextualization of the system is important because it points to the necessity of exploring contextual processes as a part of the overall developmental research enterprise (Bronfenbrenner & Morris, 2006).

Epigenesis also points to a closely related feature of transformational/variational developmental change: *emergence*. Change in complexity results in the *emergence of system novelty*. As forms change, they become increasingly complex. This increased complexity is a complexity of pattern rather than a linear additive complication of elements. The butterfly emerges from the caterpillar through the differentiation and reintegration of organization, the frog from the tadpole, the plant from the seed, the organism from the zygote. In an identical fashion, higher order psychological structures emerge from lower order structures; also in an identical fashion, new patterns of organization exhibit novel characteristics that cannot be reduced to (i.e., completely explained by) or predicted from earlier forms. This impossibility of reduction asserts what Witherington refers to as ontological or *strong emergence* (Witherington, 2011; see also Blachowicz, 2012). The novel properties that emerge are termed *systemic*, indicating that they are properties of the whole system and not properties of any individual part process. This emergence of novelty is commonly referred to as *qualitative* change in the sense that it is change that cannot be represented as purely additive.

Similarly, reference to *discontinuity* in development is simply the recognition of emergent novelty, and qualitative change of a system (Overton & Reese, 1981). Concepts of *stages, phases*, and *levels* of development are theoretical concepts, which within a Process-Relational and Relational-Developmental-Systems paradigm reference transformational change together with the associated emergent novelty, qualitative change, and discontinuity. Each of the classic grand developmental theories of the 20th century—Piaget (1967), Vygotsky (1978), Werner (1958), and Erikson (1968)—acknowledged the centrality of nonlinearity and emergence: Piaget and Werner via their ideas of development proceeding through phases of differentiation and reintegration; Erikson through his epigenetic principle of development; Vygotsky in his argument that development is not "the gradual accumulation of separate changes . . . [but] a complex dialectical process characterized by . . . qualitative transformations of one form into another [with an] intertwining of external and internal factors" (1978, p. 73). Systemic emergence is not limited to homogeneous stages such as those offered by the grand theories. Mascolo and Fischer (2010) for example, in discussing *skill theory* describe development as an "emergent developmental web":

> The developmental web represents development in terms of a series of partially distinct pathways that, depending on developmental circumstances, move in different diverging or converging directions. Higher order psychological structures emerge from the integration or coordination of lower-level structures that develop along partially distinct trajectories. The splitting and converging of developmental trajectories is not something that can be specified or predicted a priori. (p. 163; see also Fischer & Bidell, 2006; Mascolo & Fischer, Chapter 4, this *Handbook*, this volume).

Relative Permanence and Irreversibility

A final feature of transformational change of a system is that it is not circular, transitory, or willy-nilly reversible. Transformational change particularly—system change—is relatively permanent, relatively irreversible. This eliminates sleep, digestion, going to the movies, and any behaviors that are readily extinguishable from the list of transformational changes. Although this attribute is generally a straightforward feature of transformational change, it raises an issue with respect to life-span development. If it were found empirically that there were declines in middle or late adulthood in behaviors associated with transformational systems (e.g., if the form of thinking deteriorated or regressed to an earlier form), would this change be considered something other than development? Would it be necessary to introduce two radically different processes into our life-span understanding such as *development* on the one hand and *aging* on the other? Not necessarily. The modifier *relatively* partially addresses this issue. And it might be possible to conceptualize the late adult years as having their own order, sequence, epigenesis, and permanence well into the late adult years (see Overton, 2010)

The description of the nature of the Relational-Developmental-System's active complex organism, along with the description and analysis of six other defining features of the Process-Relational system and developmental processes, essentially completes the task set out at the beginning of this chapter: A rethinking of the traditional Cartesian-Split-Mechanistic research paradigm and the offer of an alternative Process-Relational and Relational-Developmental-Systems paradigm.

WHEN VOCABULARY MATTERS

Although the main goal of the chapter has been achieved, there remains the knowledge that, even as we change sets of basic categories, we are often, as Searle (1992) suggested, still captives of the Cartesian vocabulary we have inherited and, as mentioned earlier in this chapter, the "vocabulary is not innocent, because implicit in the vocabulary are a surprising number of theoretical claims" (p. 31). In this final section, I describe some of the Cartesian vocabulary terms and their alternatives.

Avoiding *Stimulus*, *Response*, *Elicit*, *Evoke*, and Even *Behavior* and *Interaction*

As suggested earlier in the chapter, one taking an active organism (system of organized processes) approach should avoid, except in very limited cases, the terms *stimulus, reinforcement, response, elicit,* and *evoke. Affordance (opportunity to act), resources,* and *asset* should be substituted for both stimulus and reinforcement, and *activity* (at the biological level) and *action* or *act* (applied to the psychological level, entailing intention or goal directedness) should be used to replace *response* and *behavior*. As also described earlier, the term *interaction* should be eliminated from our scientific vocabulary—again, except in very limited cases—and replaced with *coaction*.

An example of assuming the Process-Relational category system, but being stuck in the Cartesian vocabulary is found in a discussion in which Greenberg (2014) describes Zing-Yang Kuo's (1967) work with chick embryos as an illustration of the significance of activity and action in development. As Greenberg (2014) correctly points out, Kuo's investigations discovered that the pecking activity of the newly hatched chick was not the product of some genetic determinism, but rather the outcome of the embryonic chick's spontaneous activity prior to hatching. However, from a Relational-Developmental-Systems perspective, the embryonic activity itself was not, in fact, the product "of something that was *happening to* it [the embryonic chick]" (Greenberg, 2014, p. 2; emphasis added). The embryonic activity was actually something *the chick was doing*. That is, the organized system (embryonic chick) qua organized system is inherently active and, although this organized active system can be described with respect to part–part relations (i.e., "because of the musculature of the head, as it rose and fell, the beak would open and close . . . and the reflexive action of peristalsis would . . . [lead] the embryo to swallow" Greenberg, 2014, p. 2), these relations in no way nullify the centrality of the chick's inherent activity in the overall process.

The Meaning of *Experience*

The active organism characterization also affects the meaning of the term *experience*. The conventional Cartesian meaning of experience is an event or object (stimulus) that is split off from and antecedent to the activity/action of the organism. However, as William James (1912) pointed out, "experience" is a "double-barreled" (p. 10) concept and, as John Dewey (1925/1958) elaborated, "It includes what men do and suffer, what they strive for . . . and endure, and also how men act and are acted upon" (p. 8). The Cartesian understanding of experience was exclusively on "how men [sic] are acted upon," a split-off concept that entailed efficient causal forces (stimuli—endogenous or exogenous) that were taken to explain behavior and development. As a consequence, from the Cartesian perspective it was reasonable to split off nature from nurture (experience).

The process-relational active organism position focuses on the individual, on "how men [sic] act." Experience is the action of observing, manipulating, exploring, symbolizing, languaging. Affectively, the feel of the action is the *feeling of experience*. Thus, one does not have a "frightening experience," one has an experience (an action) that feels frightening. Further, the object of an action is the *object of experience*. Thus, for example, one does not "experience a bright light," one has the experience (an action) of a bright light (the object of experience). This latter example illustrates how perception can be understood as an active process (see, e.g., Noë, 2004).

Within the process-relational frame, embodied organized activity or action is the primary definition of experience. Thus, at the microscopic and macroscopic level, all development is the result of, and all action is identified as, *experience* (i.e., embodied organized action). Hence, there is no such thing as *nature versus nurture*, and there is no such thing as *nativism versus empiricism*, there are only the organized embodied activities and actions of the system (experience), whether these operate on a biological, psychological, or cultural level of organization.

It is, for example, not the case that "early perceptual and behavioral asymmetrical biases *can provide experiences* relevant to the formation of . . . nascent sensorimotor systems" (Michel, 2014, p. 37; emphasis added); "rather, it is that the experiences entailed by early perceptual and activity asymmetrical biases constitute the basis for the formation of . . . nascent sensorimotor systems." Similarly, we do not "inherit . . . our . . . experiences" (Michel 2014, p. 42); rather, experience (embodied activities and actions) constitutes the fundamental processes that make inheritance possible.

The Elimination of *Innate* and *Maturation*

Taken seriously, the Relational-Developmental-System characterization of the living organism and its development renders other Cartesian-inspired concepts meaningless and/or scientifically counterproductive; foremost among these being the concepts *innate* and *maturation*. Unless used in its strict sense (i.e., present at birth), and it rarely is used this way, *innate* implies that a characteristic is acquired through a split-off encapsulated evolutionary or biological process, independent of experience. But as illustrated in the discussions by Greenberg (2014) and Michel (2014) (see also Bateson, Chapter 6, this *Handbook*, this volume; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume), and as outlined earlier, developmental psychobiology has already demonstrated that any characteristic is the outcome of a long and continuous epigenesis entailing embodied activities and actions (experiences), beginning at conception and continuing through prenatal and postnatal phases of development, as well as across the life span. Thus, for example, various action patterns present at birth, including the nascent form of hand-use preference, have a long experiential history, as is nicely demonstrated in detail by Michel (2014).

The concept *maturation* is analogous to *innate*, for here, too, an appeal is made to a split-off encapsulated biological determinism, independent of experience. Maturation was popular many years ago, even among some of the most advanced patriarchs of relational thought For example, Piaget (1970) discussed one of the three "classical factors of development" as being "maturation" (p. 719), and Schneirla (1957) differentiated maturation and experience by maintaining that "*maturation* connotes processes contributed through growth and differentiation" (p. 102). However, in today's relational approaches, the concept *maturation*, like the concept *innate,* functions as a blind spot choking off, conceptually and empirically, a full understanding of development through the coactions of biology ←→ person ←→ environment in the context of processes of epigenesis.

The Elimination of *Mechanism*

It will be recalled from the earlier discussion of *cause* that in mechanistic philosophy cause is *always* defined in terms of some *force that produces a change* (i.e., an efficient or material cause) (Bunge, 1979). In that discussion it was suggested that the term *cause* be eliminated in favor of *explanation*, or else carefully defined each time it is used. From a Process-Relational and Relational-Developmental-Systems perspective *cause* would never be used as we already know that the relational developmental system is the sufficient condition of its own development.

The term *mechanism* is a mechanistic term designating the *force* of mechanical explanation. For example, according to the mechanistic philosopher Glennan (2002) a mechanism refers to "an interaction of parts, where the interactions are occasions on which a change in a property of one part *brings about a change* in a property of another part" (p. S344; emphasis added), while another group of mechanistic philosophers (Machamer, Darden, & Craver, 2000) drop the "interactions" and refer to mechanisms as "entities and activities *producing* regular changes (p. 3; emphasis added). In fact, these philosophers and others have been active in promoting a "new mechanistic" movement in the sciences. As Tabery (2004) has noted:

> The search for and discovery of mechanisms in the sciences abounds. Whether it is geology or molecular biology, biochemistry, or cosmology, what is taken to be a causal explanation often consists of the description of a mechanism. The last two decades have seen a return to the philosophical analysis of the concept of a mechanism, but these efforts have predominantly evaluated the use of mechanical explanations in specific sciences. . . . Recently, . . . Stuart Glennan and the team of Peter Machamer, Lindley Darden, and Carl Craver . . . have attempted to assess the concept of a mechanism more generally. (p. 2)

Now it should be clear that *mechanism* has no place in a Process-Relational ontology because external split-off forces do not produce changes, the becoming and the fading away. The term *process*, in fact, fits very well in any location someone might be tempted by the ghost of Cartesian ontology past to use the term *mechanism*.

There is a certain ironic twist to the "New Mechanist" understanding of mechanism. Bechtel and Abrahamsen (2005) now define *mechanism* as:

> a structure performing a function in virtue of its component parts, component operations, and their organization. The orchestrated functioning of the mechanism, manifested in patterns of change over time in properties of its [*organization*,] parts and operations, is responsible for one or more phenomena. (p. 423)

The irony is that, except for my needing to insert the term *organization* in this definition, it would have been quite an acceptable definition of *process*, but as such it would lose all meaning associated with its mechanistic philosophical base category of an exogenous force. This quote, therefore, is an example of conceptual incoherence, and the worst kind of incoherent eclecticism; asserting a set of ontological and epistemological principles, and then defining core concepts that are incoherent with respect to those principles.

CONCLUSIONS

The broadest and most important conclusion to be drawn from this chapter is that *concepts matter*, and to echo again Robert Horgan's (2001) statement that "all the empiricism in the world can't salvage a bad idea" (p. 27). Developmental science is an empirical science, but *empirical* refers to being based on experience, and concepts are a part of the warp and woof of experience. It was, in fact, under a split-off Cartesian *concept laden* philosophical *doctrine* termed *empiricism* that we were led to a *conceptual understanding* that empirical science entails only pristine observations and experiments; clearly a conceptual incoherence worthy of analysis.

Today science generally acknowledges that concepts and methods go hand in hand; they form an indissociable relation (see Nesselroade & Molenaar, 2010; Overton, 2014). However, the ghost of empiricism, which itself is an epistemological tentacle of the Cartesian-Split-Mechanistic worldview, continues like an invisible hand to haunt the halls of academia, funding agencies, and publication boards. In a sense this effect is highly irrational. There is now more than enough evidence—piles and piles of data—demonstrating, as exemplified in the opening pages of this chapter, that in the field of developmental science and in other scientific fields, including physics, biology, anthropology, sociology, and cultural psychology, this paradigm simply is not working any longer; it is not successfully participating in the problem solving function of science. In another sense, the continuing impact of the unseen hand of the Cartesian paradigm is rational: It follows the rule articulated long ago by Thomas Kuhn that a research paradigm "is declared invalid only if an *alternative candidate is available* to take its place. . . . The decision to *reject one paradigm is* always simultaneously *the decision to accept another*" (Kuhn, 1970, p. 77; emphasis added).

In this chapter, I try to make visible the usually unseen hand of the Cartesian-Split-Mechanistic paradigm and offer an alternative candidate to take its place, the Process-Relational and Relational-Developmental-Systems paradigm. I believe that this alternative better explains the wealth of new data in various developmental science subfields addressing issues of inheritance, evolution, cognition, affect, moral values, and the sociocultural context; that it resolves problems that have existed for decades and decades (e.g., nature-nurture, subject-object, continuity-discontinuity); and that it offers directions for future scientific productivity. This paradigm is not a theory, but relational developmental systems theories have been derived from it; this paradigm is not a methodology, but it has a methodology associated with it and methods have been constructed within its framework; this paradigm is not an actual entity, but the actual entity that is the object of developmental science inquiry is the *relational developmental system*.

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CHAPTER 3

Dynamic Systems in Developmental Science

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The focal question facing developmental science remains the question of process: *How* do new forms, functions and levels of organization arise in development from precursor forms, functions, and levels? Throughout the field's history, answers to this question have frequently invoked arguments by design: An aspect of the developing organism—for example, its phylogenetically entrained genetic code—or of the organism's contextual surround—for example, socialization practices, cultural institutions, or other structural regularities of the world into which the organism is born—harbors preexistent "information" for the developmental construction of the organism, information that prefigures the very processes that actually engender development (Oyama, 1985). In arguments by design, developmental process involves little more than the transmission of information from various, autonomous parts of the organism-environment system to the organism as a whole (Witherington & Heying, 2013). Such answers to the question of process, in Oyama's (1985) words, reflect a "preoccupation with organisms as material objects whose design and functioning must be imparted to them" (p. 12) and effectively sidestep the very question they purport to answer by marginalizing—if not eliminating altogether—the constructive, formative activity of process itself and the true novelty to which this activity gives rise.

I sincerely thank Shirley Heying for her help in preparing this manuscript and I thank Jane Jackson for quantitative guidance.

An alternative answer to the question of process arrives in what Overton (2013, Chapter 2, this *Handbook*, this volume) has termed the *Relational-Developmental-Systems paradigm*. Emblematic of *relationalism* or *relational metatheory* (Overton, 2006, 2010), this paradigm embeds the development of structure and function precisely within the constructive activity of process by invoking the dynamic, interpenetrating *relations* among various intra- and extraorganismic components—not the components themselves or the information housed in them—as the formative source of truly emergent, developmental change (Lerner, 1978, 2002). Over the past three decades, amid renewed commitment in developmental science to antireductionist, process-focused conceptions of development, numerous relationally oriented approaches have emerged as potential mid-range metatheories for developmental science, from Sameroff's (1983) transactional approach and Ford and Lerner's (1992; Lerner, 2002, 2006) developmental systems approach—modified to a "relational developmental systems approach" (see Overton & Lerner, 2012)—to Gottlieb's (1992; Gottlieb, Wahlsten, & Lickliter, 2006) developmental psychobiological systems view and Bronfenbrenner's (2005; Bronfenbrenner & Morris, 2006) bioecological model. Of all these approaches, however, few have enjoyed quite the level of prominence and impact in the field within the past 20 years as the dynamic systems (DS) approach to development (Hollenstein, 2011). Two prior *Handbook of Child Psychology* chapters (Thelen & Smith, 1998, 2006), numerous edited volumes (e.g., Fogel, King, & Shanker, 2008; Kunnen, 2012; Lewis & Granic, 2000), and a plethora of empirical applications across a wide variety of content domains (e.g., Bassano & van Geert, 2007; Camras, Lambrecht, & Michel, 1996; Lewis, 2005; Schutte & Spencer, 2002; Snapp-Childs & Corbetta, 2009; van der Maas & Molenaar, 1992) all testify to the DS approach's broad-based appeal, an appeal borne in no small measure from the approach's comprehensive research agenda.

Running the gamut from specific analytic techniques to overarching metatheoretical treatments, the DS approach to development covers all levels of the research process. Analytically, the DS approach weds the mathematics of nonlinear dynamics to the study of developmental phenomena, highlighting the centrality of *nonlinearity* for understanding processes of change; whereas traditional linear models of change assume that "outcomes are proportional to inputs in a straightforward manner," nonlinear models assume that "change is not proportional to inputs. Large inputs sometimes produce small results, and a small input at the right time can produce a dramatic result" (Guastello & Liebovitch, 2009, p. 1). At one level, then, the DS approach to development represents a set of geometric modeling techniques and analytic tools for formally charting stability and change in nonlinear systems (Abraham & Shaw, 1992; van der Maas & Raijmakers, 2009; van Geert, 1997a). However, the DS approach is also a methodological agenda for developmental science that emphasizes the study of intraindividual variability through frequent sampling of individuals (or individual systems) across time, both on microgenetic and ontogenetic scales (Nesselroade & Molenaar, 2010; Newell & Molenaar, 1998; Thelen & Smith, 1994; van Geert & van Dijk, 2002). At the conceptual level, the DS approach articulates a set of principles for understanding developmental process such as self-organization, emergence, multicausality, and soft assembly (Lewis, 2000a; Thelen & Smith, 1994). At the level of theory, the DS approach supports different theoretical treatments of real- and developmental-time phenomena such as Spencer, Schöner, and colleagues' dynamic field theory of embodied cognition (e.g., Schöner & Thelen, 2006; Spencer, Perone, & Johnson, 2009; Thelen, Schöner, Scheier, & Smith, 2001) and Fogel et al.'s (1992) social process theory of emotional development in social context. Finally, as an overarching worldview or metatheory, the DS approach elaborates a set of guiding ontological and epistemological assumptions regarding the nature of development and what constitutes legitimate explanatory and causal frames for understanding developmental process (Granic & Hollenstein, 2003; Spencer et al., 2006; Spencer, Dineva, & Schöner, 2009; Thelen & Smith, 1994).

In its comprehensiveness, the DS approach is uniquely positioned among modern Relational-Developmental-Systems approaches to serve as a guiding model for developmental science, especially given its concrete and unified grounding in the mathematics of nonlinear dynamics. Yet despite its basic analytic unification, the DS approach is beset by long-standing disagreement among its proponents over what phenomena constitute legitimate objects of study and explanation in dynamic analysis (Lewis, 2000a; Thelen & Smith, 1994; van der Maas, 1995; van Geert & Steenbeek, 2005). With respect to this question, van Geert and Steenbeek (2005) have formally demarcated two distinct stances: their own "Groningen approach" and the "Bloomington approach." Proponents of the Groningen approach freely admit psychological constructs such as object permanence and theory of mind into their dynamic analyses as more macroscopic levels of action patterning. In contrast, for proponents of the

Bloomington approach—such as Thelen and Smith, as well as Spencer—many psychological constructs cannot serve as legitimate variables for dynamic systems analysis; only variables grounded in the real-time dynamics of specific activity in context count as viable source material.

What does this disagreement suggest about the conceptual coherence of the DS approach? Is the disagreement simply a reflection of surface-level differences among varied articulations of an otherwise ontologically unified approach? Or does it reflect a more fundamental metatheoretical rift among proponents of the approach? Van Geert and Steenbeek (2005) avoided characterizing disparity between their approach and the Bloomington approach as anything more than a difference of degree or emphasis, arguing that the Groningen approach's admittance of all manner of organizational properties and levels of abstraction into the mix of dynamic modeling should be read in purely pragmatic terms rather than as an endorsement of the "mental" status of these constructs. In fact, they suggested that ultimately "these variables and dimensions will have to be brought back to the working of a so far unknown short-term dynamics that incorporates the embodied acting person that Esther Thelen brought in to the study of human development" (pp. 436–437), emphasizing the bottom-line unity of the two DS stances (see also Thelen & Bates, 2003). However, even the most cursory examination of the typical narratives employed to capture the historical significance of the DS approach reveals two qualitatively distinct vantage points from which to view the approach, calling into question the approach's deep unity.

THE DYNAMIC SYSTEMS APPROACH: A TALE OF TWO NARRATIVES

For DS proponents such as van Geert (1998a, 1998b; van Geert & Fischer, 2009), van der Maas (1995, 1998; van der Maas & Raijmakers, 2009), and Lewis (1997, 2011a, 2011b), the DS approach fundamentally aligns with the constructivist philosophy of Piaget and establishes mathematical formalizations for the general developmental processes articulated in Piaget's, Vygotsky's, and Werner's (among others) classic systems approaches to psychological development (Lewis & Granic, 1999a; van Geert, 2000). The narrative that surfaces in the writings of these DS proponents, in other words, is one that historically frames the DS approach as a *return to* and *elaboration of* the relational, dynamic thinking already evident in Continental-European developmental psychology circles during the first decades of the past century. From Piaget's central focus on self-organization in open systems (Garcia, 1992) and on how novel forms emerge (Chapman, 1988; van Geert, 1998b) to the idiographic, microgenetic focus of the Würzburg school, elaborated in Werner (1956) and Vygotsky's (1987) own microgenetic work (Diriwächter, 2009; Wagoner, 2009), to Stern's (1900) call for person-centered, intraindividual-focused research (Lamiell, 2009), reflected in contemporary developmental science in the methodological work of Nesselroade and Molenaar (2010), the pervading climate in pre–World War II Europe conceptually prefigured the central tenets of the DS approach, absent only the analytic tools of nonlinear dynamics (Toomela, 2009; van Geert, 1998b).

Van Geert (1998b) characterized this early period in the field's history as "developmental-science-in-the-making" and specifically highlighted its thoroughgoing process orientation: "What is most striking in the works of the founders is that they believed that the reason for or the causes of development are *inside the developmental process*" (pp. 143–144). By the mid-20th century, as developmental psychology grew increasingly analytic in its orientation, the field's initial process orientation had become recast through the lens of a more rigid independent-dependent variable orientation, grounded in associationist models of antecedent-consequent relations. Isolable variables, not integrated systems, came to occupy center stage, and researchers sought to exert greater statistical control and representativeness of results through increasing focus on large sample, normative group data, time tables for developmental acquisitions, and the independent variables that impact such acquisitions (Toomela, 2009; van Geert, 1998b). For van Geert (1998a, 2004), the DS approach not only revives and confers mathematical legitimacy on the field's classic systems accounts of psychological development but also promotes the synthesis of these classic process orientations by "bridging the gaps between related theories and . . . bringing the central, common elements to the fore" (p. 635). For van der Maas and Raijmakers (2009), the DS approach is "a theory-free approach, in the same way that statistical methods are largely theory-free approaches" (p. 302); as a consequence, this narrative frames the novelty of the DS approach not in conceptual or metatheoretical terms but principally in terms of the analytic tools available under its aegis.

A fundamentally different narrative—reflected in the *Handbook of Child Psychology*'s two prior treatments of the DS approach—arises from DS proponents such as Thelen and Smith (1994, 1998, 2006), and Spencer

(Spencer et al., 2006; Spencer, Dineva, et al., 2009; Spencer, Perone, & Buss, 2011). For these DS proponents, many of the central tenets characteristic of Piaget's, Werner's, and Vygotsky's classic systems approaches fail to adequately capture actual developmental process, largely through what Thelen and Smith (1994) regard as the substitution of static portrayals of global order for the truly dynamic variability of local, real-time interaction. Thelen and Smith (1994, 1998) specifically repudiated Piaget's "grand sweep" approach: the characterization of development as an orderly, irreversible sequence of qualitatively distinct and increasingly abstract levels of psychological organization yielding a fundamental directionality teleologically framed in terms of end points toward which organisms develop. By their explicit denial of the explanatory legitimacy of structure, sequence, and directionality in Piaget's approach to development, Thelen and Smith effectively positioned the structuralist traditions of pre–World War II European developmental psychology as ontologically incompatible with the DS process orientation. Along similar lines, Spencer et al. (2011) have argued that Piaget's framework, like those of nativism and cognitive/information processing, is fundamentally at odds with what they called the "systems metatheory" (p. 261) and its "new grand theory of development" (Spencer et al., 2006, p. 1533) in the form of the DS approach.

The DS approach as *new metatheory* and overarching conceptualization for developmental science offers as its historical progenitors the embryological and psychobiological traditions of Waddington (1957), Schneirla (1957), and Kuo (1967) and the ecological and field theory traditions of Gibson (1979) and Lewin (1946), rather than the classic systems approaches of developmental psychology per se (Thelen & Smith, 1998, 2006). By elevating those traditions that focus on anatomical, morphological, and behavioral analyses over those traditions that focus on psychological analyses and "higher-order" structural explanations, proponents of the DS approach as new metatheory establish a historical narrative ontologically grounded in "concrete" rather than "abstract" levels of organization (this despite the fact that at least some of the historical progenitors whom Thelen, Smith, and Spencer elevate [e.g., Schneirla] explicitly repudiated the notion that *any* level of system organization, from the biological to the psychological to the sociocultural, was ontologically foundational). Within this historical narrative, the DS approach actively rejects both the "mentalistic assumptions" (Thelen & Smith, 2006, p. 268) of classic systems approaches in developmental psychology—in keeping with a Gibsonian heritage—and the reductionist assumptions of mechanistic approaches to development—such as nativism and empiricism (Spencer, Blumberg, et al., 2009)—which assign privileged formative status to certain elements of a system over others. Development, instead, is couched in terms of the concrete, here-and-now specifics of multiply determined, embodied activities, softly assembled to confront the unique properties of individual contexts across time (Spencer et al., 2006; Thelen & Smith, 1994).

Does the DS approach to development establish a new metatheoretical framework for developmental science that leaves behind the structuralism of classic systems approaches, as Thelen, Smith, and Spencer's narrative suggests? Or does the DS approach mark a return to and elaboration of that very structuralism and its concomitant process orientation, as van Geert, van der Maas, and Lewis's narrative suggests? Something more than just surface-level disagreement fuels these two qualitatively distinct narratives. A much more substantial *worldview* division exists *within the DS approach*, bearing directly on the framing of the approach's conceptual principles, such as self-organization and emergence, and on its basic conceptualization of developmental process (Witherington, 2007, 2011; Witherington & Margett, 2011). The purpose of this chapter is to examine the DS approach to development in light of this deep-seated metatheoretical division and to articulate the two fundamentally divergent ontological stances that different proponents of the approach adopt with respect to the very nature of explanation in developmental science.

As this chapter argues, the ontological stance of one DS approach—embodied in the narrative espoused by van Geert, van der Maas, and Lewis—promotes an *inclusive*, explanatorily pluralistic framework within which to study development and operates fully within the Relational-Developmental-Systems paradigm (Overton, 2013, Chapter 2, this *Handbook*, this volume) through its synthesis of organismic and contextualist worldviews. In contrast, the ontological stance of a second DS approach—embodied in the narrative espoused by Thelen and Smith and by Spencer—promotes an *exclusive*, explanatorily monistic framework within which to study development and reinvokes the specters of foundationalism and reductionism, establishing it as a Cartesian-Split-Mechanistic paradigm (Overton, 2013) through the radical contextualist worldview it espouses. In essence, when viewed through the lens of its inclusive vantage point, the DS approach sits at the forefront of the Relational-Developmental-Systems movement in developmental science. But when viewed through the lens of its exclusive vantage point, the DS approach threatens to undermine relationalism by furthering the very split metatheoretical framework it purports to transcend (Overton, 1998; Witherington, 2011).

This chapter begins with an examination of two key historical influences on the DS approach to development: von Bertalanffy's general systems theory and nonlinear dynamical systems theory. It next discusses alternative possibilities for the integration of these multidisciplinary influences as the backdrop for current ontological divergence among DS proponents. What follows is a delineation of the DS approach, its principles, and its overarching conceptualization of development from the perspective of both its inclusive and exclusive metatheoretical stances, with specific focus devoted to the work of Lewis, van Geert, Thelen and Smith, and Spencer. Finally, the chapter concludes by framing ontological division in the DS approach to development more broadly in terms of the Relational-Developmental-Systems and Cartesian-Split-Mechanistic paradigms.

HISTORICAL FOUNDATIONS FOR THE DYNAMIC SYSTEMS APPROACH: GENERAL SYSTEMS THEORY AND NONLINEAR DYNAMICS

Protean are the historical roots of the DS approach to development, as the preceding narratives attest. Arguably the most prominent and influential historical rendering of the intellectual traditions that positively inform the approach arrived in Thelen and Smith's (1998, 2006) two prior *Handbook* chapters, and as previously illustrated, their account of the approach's historical significance deviates in significant ways from that of van Geert (1998b) and others, for whom "Piaget *was* an early DS theorist" (Lewis, 2011b). Nonetheless, all DS proponents routinely acknowledge the central role of von Bertalanffy's general systems theory in the shaping of the DS approach to development. And as definitions for the DS approach uniformly appeal to the application of nonlinear dynamics principles to the phenomena of development, nonlinear dynamical systems theory similarly occupies pride of place among DS proponents in the approach's origins (Thelen & Smith, 1998, 2006). This chapter selectively focuses on von Bertalanffy's general systems theory and nonlinear dynamical systems theory as setting the historical precedent for the DS approach to development, both because of their multidisciplinary focus and because of their unquestionable status as core sources of influence for the approach.

Von Bertalanffy's General Systems Theory

Despite its translation, "general system theory" is not a theory—the English word fails to adequately capture the broadened meaning of the German *theorie* in *allgemeine systemtheorie* (von Bertalanffy, 1975, foreword by Ervin Laszlo). It instead is a perspective, a metatheoretical approach, for understanding systems, with a system being any set of interacting components or parts that, through the interdependence of their relations to one another, constitutes an organized whole or totality. As a metatheory, general system theory (GST) moves scientific endeavor beyond the mechanistic orientation of conventional physics—what von Bertalanffy, like Pepper (1942), called *mechanism*—in which all phenomena are modeled after machines and analytically decomposable into a foundational set of elemental parts and forces (Overton, Chapter 2, this *Handbook*, this volume; Reese & Overton, 1970; von Bertalanffy, 1933, 1968b). In place of this mechanistic stance, GST promotes a science of *organization* and *wholeness* and establishes broad, multidisciplinary principles for characterizing the organizations (structures, forms, or patterns) of different kinds of systems irrespective of their specific content, be it physical, biological, or social (Overton, 1975; Sameroff, 1983; von Bertalanffy, 1933, 1968a, 1975).

At the core of GST rests von Bertalanffy's (1933) particular focus on living systems and the irreducible organizational qualities—such as purposiveness, self-maintenance, and goal-seeking—required to understand them. Viewing life as irreducible in itself, however, does little to distinguish von Bertalanffy's systems approach. After all, vitalism, the long-standing rival to mechanism's reductionist stance, similarly conceived of life's higher-order organization in terms irreducible to the inorganic physicochemical world of conventional physics. Yet von Bertalanffy's GST was as much a reaction against vitalism as it was a reaction against mechanism—and not just because vitalism explained living phenomena through an appeal to immaterial, transcendent factors, such as entelechies, that were resistant to investigation within the traditional purview of natural science. Both mechanism and vitalism, von Bertalanffy argued, shared a common metatheoretical root: their adherence to the materialism and determinism of conventional physics (von Bertalanffy, 1933, 1975). In effect, both mechanism and vitalism presupposed the foundationalism of mechanism's worldview, namely that the universe is composed of bedrock elements—particles and forces—independent and isolable from one another, which, by themselves and in linear combination, constitute the "ultimate building blocks of reality" (von Bertalanffy, 1975, p. 71). Vitalism merely added a transcendent factor to the mix. And as von Bertalanffy (1933, 1975) highlighted, this transcendent factor, though unresolvable to physicochemical materials and forces in the natural world, nonetheless operated within the same antecedent-consequent causal framework applied to physicochemical forces: that of *efficient causality*.

Efficient causes are the classic, push-from-behind forces of causality—the initiating or propelling forces typically characterized as temporal exchanges of energy *from an antecedent to a consequent*—that have served as the hallmark of scientific orthodoxy since the 17th century (Bates, 1979; Emmeche, Koppe, & Stjernfelt, 2000). Efficient causes can involve both extra- and intraorganismic antecedents: in post-Humean terms, they are any concrete event or circumstance that reliably precedes a phenomenon, thereby explaining it (Lear, 1988). Examples of efficient causes in the context of psychology include explaining behavior by means of inertial forces and muscle interactions, physiological or neurological processes, or particular stimulus events or environmental factors. Though vitalism regarded its vital "guiding forces" (von Bertalanffy, 1933, p. 44) as immaterial, these forces nonetheless were framed as temporal antecedents for the establishment and maintenance of living phenomena. They conferred a life "essence" on the otherwise lifeless, machine-like matter of the physicochemical world, much as the kinetic energy of one billiard ball is imparted to another by spatiotemporal contact. As antecedents, they sat apart from the matter on which they acted and imbued this matter with life through what amounted to a transfer of energy. In other words, vitalism reified its transcendent forces, "hypostasizing the concepts necessary for the teleological description of vital processes into active natural factors or entelechies" (von Bertalanffy, 1933, p. 14) and creating, in the process, "soul-like factors—little hobgoblins as it were—hovering in the cell or the organism" (von Bertalanffy, 1968a, p. 89). Life had been explained through recourse to a life-giving, efficient causal force independent of the matter it enlivened.

For von Bertalanffy, the problem with vitalism lay as much in this unquestioning endorsement of mechanism's *explanatory monism*—efficient causality and only efficient causality constitutes explanation—as in its appeal to immaterial factors. Through the call to "expand physics to include life phenomena rather than reduce biology to conventional physics" (von Bertalanffy, 1975, p. 117), von Bertalanffy sought to overhaul the very frameworks of foundationalism and efficient causality on which both mechanism and vitalism relied. In his GST, there exists no material bedrock of foundational elements for constructing all organizational complexity; rather, "organization runs right through all levels of reality and science" (von Bertalanffy, 1968b, p. 34). Parts and processes at any level of analysis necessarily presuppose a system—an organized whole—within which they are embedded, requiring in von Bertalanffy's (1968b) words "an *expansion of categories*, models and theory" (p. 37) beyond those of conventional physics.

GST's call for category expansion involved nothing less than a paradigmatic reorientation in scientific endeavor. For in embracing wholeness and organization as fundamental categories of scientific thought, von Bertalanffy had called for an ontological expansion of the very nature of scientific explanation itself, an expansion beyond its exclusively mechanistic framing in terms of antecedent-consequent relations via efficient causality. He called for science to employ the organization of systems—the unitary structure of the whole—as a form of explanation *in its own right*.

The System as Cause: Moving Beyond Antecedent-Consequent Relations

Von Bertalanffy (1933) heralded the *organization* of physicochemical materials and processes—not some new organizing force/process or substance existing beyond the realm of the physicochemical—as the key to distinguishing living from nonliving phenomena. To understand life, he argued, "the most exact knowledge of its ingredient materials and processes does not suffice. We can only speak of such an understanding when we know the laws which govern the organization of these materials and processes" (pp. 49–50). For von Bertalanffy, decomposing a living system into its components/materials and into the processes that interrelate those components can only go so far in explaining the activity and nature of the system, even if all processes are rendered completely. Without also understanding the *configurational wholeness* or *organization* of these component parts and processes—what von Bertalanffy (1933) called "organic description in the realm of the organic" (p. 15)—the qualities that comprise the system qua system remain elusive. But what does examination of the system qua system—of its wholeness—add to a complete accounting of the dynamic interrelations that obtain among the components that comprise the system? After all, isn't the wholeness or organization of a system definable precisely *in terms of* those dynamic interrelations, *as* arising bottom-up from process dynamics? How does organization in itself add significantly to process explanations in science?

Recall that, by dint of its argument against foundationalism, GST conceptualizes processes as always embedded within an organizational framework. Organization, far from being built on a foundational level of process, comprises the very nature of process; in von Bertalanffy's (1975) words, "all that can be said about the processes in question depends on the form of these processes" (p. 70). Though processes—the interactions among components in a system—yield new levels of organization in a system, these processes always operate within the context of an existing level of organization, an organization that necessarily constrains the very nature of the processes themselves. At every level of analysis, then, from micro to macro, process is organized. Because all organization is process and all process is organization—with neither foundational to the other—an understanding of system process must always be embedded within an understanding of system structure, and vice versa (von Bertalanffy, 1933, 1968a). Though indivisible, organization and process nonetheless offer different vantage points for understanding the same phenomenon; in this way, organization offers a unique form of explanation, distinct from that offered via the vantage point of dynamic processes themselves.

When, in fact, we as scientists examine the indissociable unity of organized process from the *bottom-up* vantage point of dynamic process, we establish a context of *temporal precedence*. Mapping the relations that characterize a system's component parts necessarily invokes a temporal dimension of analysis in terms of antecedent-consequent relations. As soon as we begin to investigate any given process, we position our lens of inquiry toward events that unfold over time, wherein a single interaction or set of interactions give rise to a product. This antecedent-consequent framing holds true even when models of dynamic process appreciate the reciprocal nature of relation among a system's components. In living systems, for example, where the component parts are "internally" related such that the identity of each component part depends on its relation to other component parts (Kitchener, 1982; Lerner, 1978; von Bertalanffy, 1968a), each part-to-part interaction involves simultaneous influence between the components (e.g., component A is affecting, while simultaneously being affected by, component B, and vice versa). Under these conditions, absolutist notions of antecedent and consequent, cause and effect at the part-to-part level disappear, because any given component can be both cause and effect (Ford & Lerner, 1992). Because the whole is multiply determined—with each part of the whole a necessary but insufficient interactant in the joint production of the whole—efficient cause becomes distributed across all of the parts that make up the whole such that each part equally influences the emergence of the whole without determining it (Turvey, Shaw, & Mace, 1978). Nonetheless, the products to which these part-part relations give rise—the wholes arising in the parts-to-whole relation—are still framed as a consequent relative to the push-from-behind, antecedent forces of part-part relations when adopting a bottom-up vantage point.

When, however, scientists examine the indissociable unity of organized process from the *top-down* vantage point of organization, they establish a context of *atemporal embeddedness*. This form of explanation is akin to the manner in which the ground in a figure-ground relation conditions the meaning of the figure embedded within it. For von Bertalanffy (1968a), organization captured the *singular*, *instantaneous* totality of the system as a whole: "While we can conceive of a sum as being composed gradually, a system as total of parts and interactions has to be conceived of as being composed instantly" (p. 55). Conceiving of a system in instantaneous terms requires a form of explanation that invokes the atemporal embeddedness of structural explanation rather than the temporal precedence of antecedent-consequent, functional explanation. Wholeness thus captures what a temporal charting of lower-order process dynamics cannot: the structural *totality* of relations that comprise a system. Systems, as wholes, *constrain* in whole-to-parts fashion the very nature of their components and the relations that can occur among those components (Deacon, 2012; Juarrero, 1999). They impart meaning to and provide a structural, topological precondition for understanding those processes, not as an antecedent to a consequent defined in temporal terms but as a critical explanatory backdrop or framework—a ground—against which the temporally unfolding local dynamics of the system—the figure—must be understood (Overton, 1975; Thompson, 2007).

Von Bertalanffy's treatment of system organization—its form and teleology—as an explanatory vantage point in its own right recalls the *formal* and *final* causes of Aristotle's classic pluralistic explanatory framework (Jurich & Myers-Bowman, 1998; Overton, 1975; von Bertalanffy, 1968a). Unlike the temporal antecedent or propelling force explanations captured through efficient cause, formal and final causes—or better for the modern reader, formal and final explanations—are atemporal, organizational levels of explanation that lend *meaning* to the temporal, cause-effect sequences of efficient cause (Juarrero, 1999; Rychlak, 1988). Whereas efficient cause necessarily presupposes a temporal context, formal and final explanations invoke abstraction itself as a means of partial explanation, without recourse to the flow of time (Emmeche et al., 2000; Rychlak, 1988). Formal explanations abstract a pattern—a form, structure, organization—from the particular, real-time dynamic content of a phenomenon, and that pattern functions as a partial explanation for the phenomenon. Final explanations abstract a function, future-end, or purpose from the particular, real-time dynamic content of a phenomenon to explain the phenomenon. This abstracted patterning—both formal and teleological—has explanatory value because it "introduces order and organization into the domain under investigation" (Overton, 1991, p. 220), rendering the domain intelligible and providing a meaningful, holistic context within which to investigate the real-time dynamics of process.

As psychologists, when we appeal to constructs such as emotions, cognitive scripts, and personality structures—constructs that capture organismic functioning as a whole, across specific actions and contexts—or to a particular stage or developmental level of organization, we are essentially invoking formal explanations for understanding real-time organismic activity in context. When we appeal to goals and intentions—and, more generally, to the function served by an action, conscious or otherwise—or when we posit ideal endpoints and directional sequences of organizational change, like Werner's (1957) orthogenetic principle (i.e., whenever there is development it proceeds from an initial state of globality and lack of differentiation to states of increasing differentiation, articulation, and hierarchical integration), we are essentially invoking final explanations for understanding real-time organismic activity in context. What constitutes higher-order form/organization and what constitutes lower-order dynamic content depends on one's level of analysis and perspective; for a molecular biologist, cells as organized wholes comprise the formal explanation for understanding the real-time activity and interrelations of their constituent components, for example, DNA, RNA, proteins. However, the orthodox approach of modern science, with its exclusive adherence to efficient cause, views formal and final levels of explanation as temporary heuristics devoid of any true explanatory power and only rendered as legitimate forms of explanation when reduced to or reframed in terms of an efficient cause (Overton, 1991). By the orthodox approach, explanation counts only when filtered through the narrow lens of efficient cause.

Such scientific orthodoxy effectively encourages the reification of formal and final explanatory modes. Abstractions—like goals, mental schema, or personality structures—thus routinely become conceptualized as particular objects or things in their own right, antecedent forces relative to some consequent such as the real-time behavior of the organism. Just as proponents of vitalism explained living organization by reifying organization as a guiding force, causally antecedent to the living organization it explained, psychologists frequently reframe as efficient causes what should be considered formal and final explanations in their efforts to account for real-time activity in context, structurally reifying these organizational qualities of the whole as concrete parts of the system. This results in the incorrect framing of formal and final explanation in terms of antecedent "forces" that initiate consequent activity—activity from which they are, in fact, abstracted—as when, in developmental circles, Piagetian object permanence is framed as an antecedent force, which causes infants to engage in exhaustive search rather than as an organizational constraint that imparts meaning to infants' exploratory efforts (Lourenco & Machado, 1996; Rychlak, 1988).

Reification of formal and final explanation constitutes a fundamental category mistake (Ryle, 1949). Whereas efficient cause serves to contextualize—in bottom-up fashion—our understanding of an organism's specific activity in terms of the events and conditions that temporally and regularly precede that activity, formal and final explanations are not meant to identify the antecedent circumstances for such activity or to account for its variable content. Instead, formal and final explanations serve to contextualize—in top-down fashion—our understanding of an organism's specific activity in terms of the organization and directional purpose which that activity evinces as a whole (Overton, 1991; Tolman, 1991). In Aristotle's pluralistic framework, formal, final, efficient, and material cause (i.e., explaining a phenomenon by means of articulating the material substrate underlying the phenomenon) all represent unique, equally legitimate perspectives or vantage points for understanding phenomena. None of these vantage points offers sufficient explanation by itself, but all are necessary to fully understand any phenomenon, with no one perspective privileged as an explanatory gold standard relative to any other.

In keeping with the general spirit of Aristotle's explanatory pluralism, GST explicitly articulates what von Bertalanffy (1968a, 1968b, 1975) called a *perspectivist* philosophy to counter the absolutism of mechanism and its foundationalist enterprise. For GST, perspective conditions all understanding, no one perspective constitutes "ultimate truth or ultimate reality" (von Bertalanffy, 1968b, p. 67), and fuller understanding requires alternate perspectives on the same whole, given the inherent limitation and approximation of any given perspective. GST's perspectivism mirrors the ontological stance of relational metatheory: an inclusive framework within which classic polarities such as structure and function, process and pattern, are recognized as distinct, alternative, yet equally legitimate perspectives taken toward the same whole, each being contextualized with respect to the other and neither assuming an absolute foundational status (Overton, 2006, 2010, Chapter 2, this *Handbook,* this volume). In describing his perspectivist philosophy, von Bertalanffy (1968a) left no doubt as to its relational, dialectical underpinnings:

> The same object is quite different if envisaged from different viewpoints. The same table is to the physicist an aggregate of electrons, protons, and neutrons, to the chemist a composition of certain organic compounds, to the biologist a complex of wood cells, to the art historian a baroque object, to the economist a utility of certain money value, etc. All these perspectives are of equal status, and none can claim more absolute value than the other . . . ultimate reality is a unity of opposites; any statement holds from a certain viewpoint only, has only relative validity, and must be supplemented by antithetic statements from opposite points of view. (pp. 236, 248)

As previously outlined, GST established its own "unity of opposites" for understanding systems in the form of two alternative yet complementary perspectives/vantage points for viewing system functioning: an atemporal, organizational focus that targeted the wholeness of dynamic process and a temporal, process focus that targeted the dynamics of wholeness. With this general introduction in place, the chapter turns to an elaboration of each of these vantage points to illustrate the inclusive, explanatory pluralism that von Bertalanffy's GST embodies—a pluralism with critical implications for understanding ontological splits in the DS approach to development.

The Wholeness of Dynamics: The View From Above

For von Bertalanffy (1960, 1968a), the key distinction between living and nonliving phenomena resolved to two organizational criteria: the openness of the system to its environmental surround and the system's self maintenance of wholeness. With respect to the first of these criteria, von Bertalanffy established a broad contrast between two forms of system: open and closed. *Closed systems* are those that populate the world of conventional physics (von Bertalanffy, 1950, 1975). Such systems—exemplified in the form of the spring-driven clock—embody orthodox science's mechanistic orientation: The system as a whole reduces to its elemental components and the linear relations that obtain among them (Overton, 1975). Time-reversible and deterministic (Prigogine & Stengers, 1984) closed systems involve no exchange of matter with their surrounding environment. The only directionality in such systems is completely definable in terms of the second law of thermodynamics: The inexorable movement toward states of maximum entropy and maximum probability, or equilibrium, in which differences in the system are leveled, resulting in uniform, homogenous distribution of matter and energy from which no work can be obtained (von Bertalanffy, 1950).

Open systems, however, involve exchange of both matter and energy with their surrounding environment, yielding a continual dissolution and generation of the component parts that comprise the system. In the midst of this continual exchange with their surround, open systems can assume states of stability in which the system as a whole remains constant (von Bertalanffy, 1950). At all levels of the living hierarchy, from cells to living organisms generally and persons specifically, such higher-order stability subsuming continuous exchange of lower-order components is evident: Cells remain cells organizationally despite ceaseless exchange of their chemical constituents just as organisms remain organisms organizationally despite ceaseless exchange of their material components (e.g., cells, proteins). Unlike the true equilibrium of closed systems—borne of irreversible entropic breakdown—the stable states of open systems are characterized by *disequilibrium*, "maintained in distance from true equilibrium" (von Bertalanffy,1968a, p. 142) and permitting the capacity for work. Directionality in open systems thus involves movement toward states of increasing improbability and decreasing entropy (negative entropy): states of organization, heterogeneity, and complexity (von Bertalanffy, 1950, 1968a).

Von Bertalanffy (1950, 1968a) coined the term *Fliessgleichgewicht*, or steady state, to characterize these dynamic states of disequilibrium: constant and "time-independent" at the level of the whole, yet ceaseless flow and turnover at the level of the material and energetic components that comprise the whole. In the context of *living open systems*, von Bertalanffy (1933) further insisted that steady states require a teleological framing:

> All vital processes are so organized that they are *directed to* the maintenance, production, or restoration of the wholeness of the organism . . . the physic-chemical description of the vital processes does not exhaust them. They must also be considered from the standpoint of their significance for the maintenance of the organism. (pp. 8–9; emphasis added)

In other words, living systems *self-maintain*, preserving their own macroscopic organization in the face of microscopic flux; their parts and processes—the continual, local dynamics of the system—are only fully explicable when considered as being for the sake of the whole, ordered in such a way as to serve the maintenance of the system's organization itself (von Bertalanffy, 1968a, 1975). In von Bertalanffy's (1975) words, "the self-preservation of living systems requires and presupposes an ordering of their processes" (p. 118).

By the same token, the system as a whole is only organized by virtue of its ceaseless dynamic flux, able to maintain itself only "by a continual import and export of matter which is built up and broken down" (von Bertalanffy, 1975, p. 109). Nonetheless, von Bertalanffy stressed that the lower-order dynamics of the system cannot by themselves account for the nature of those open systems that are *living* systems. The very patterning of the processes that comprise the living system—the system's organization of process—"guarantees the maintenance, restoration, or reproduction of the system. This is the main difference between the processes going on in a living system and the reactions taking place in inert material or in a decaying corpse" (von Bertalanffy, 1975, pp. 97–98). In their self-maintenance, living systems constitute *active systems*, never at rest, with autonomous activity being primary to the very organization of the living system and establishing the continuous ground against which all open exchange between the living system and its surround is understood (von Bertalanffy, 1968a).

Von Bertalanffy's emphasis on living systems as self-maintaining finds elaboration in the work of Maturana and Varela and colleagues on *autopoiesis*, a core organizational feature of life from cells to the organism as a whole (Maturana, 1978; Maturana & Poerksen, 2004; Maturana & Varela, 1980; Varela, 1979; Weber & Varela, 2002). In most *physicochemical* dissipative systems—nonliving, physical systems that, as dissipative structures, remain energetically and materially open to their surround, taking in molecules high in free energy and low in entropy while dissipating high entropy energy back in to the environment (Prigogine & Stengers, 1984)—the emergence and maintenance of spontaneous organization and pattern depend on boundary conditions *external* to the system itself. Without exogenously controlled conditions, such organization in these open systems disappears (Juarrero, 2009; Ruiz-Mirazo & Moreno, 2004). Some physicochemical systems, like the candle flame, exhibit a form of organizational *self-maintenance* in that they can promote their own order within narrowly constrained environmental circumstances but are limited in not being able to "maintain the property of being self-maintenant" (Allen & Bickhard, 2011, p. 108; Bickhard, 2009). Living dissipative systems, or *autopoietic* systems, in contrast—which Bickhard (2009) terms *recursively self-maintenant*—evidence autonomous generation and maintenance of organization by generating the very boundary conditions required for creation and maintenance of their *self*-organization (Ruiz-Mirazo & Moreno, 2004). *Autopoietic systems, in other words, construct themselves*.

The generation of organization in typical physicochemical dissipative systems requires no autonomous activity on the part of the system for its explanation of emergent patterning, because organization in such systems is essentially assembled from without. However, in autopoietic systems, the system's organizational integrity, within which the local dynamics of the system are contextualized, is a necessary component of explanation for the system's patterning. The autopoietic system *qua system* produces the very components that give rise to it, establishing its own self-maintaining processes through its incessant exchange of energy and matter with its surround (Thompson, 2007; Weber & Varela, 2002). Thermodynamically open, autopoietic systems establish *organizational closure* in that they metabolically maintain their organization in the face of continuous turnover and renewal of their material and energetic constituents (Jonas, 1966; Moreno & Umerez, 2000; Varela, 1979; Weber & Varela, 2002). Autopoietic systems thus actively regulate the very external boundary conditions that produce them—by regulating the flow of energy and matter—thereby incorporating external boundary conditions into their own dynamics (Juarrero, 2009; Thompson, 2007).

The living cell exemplifies autopoiesis, functioning as a self-producing, metabolic system in which "every molecular reaction in the system is generated by the very same system that those molecular reactions produce" (Thompson, 2007, p. 92; Varela, 1979). The cell dynamically and continuously constructs its own membrane

—the semipermeable boundary that establishes self-other distinction, the divide between itself and its surround—through metabolic processes that exist and operate only by means of the membrane they construct (Thompson, 2007). Thus, the products of cellular process are necessary conditions for the enactment of the process itself (Juarrero-Roque, 1985). Such systems cannot be adequately explained through sole reliance on the temporal dynamics of efficient cause, for, as Kant (1790/2007) classically established, something that organizes itself is a "natural purpose," which means that it is "both cause and effect of itself" (p. 199). Autopoiesis, in keeping with von Bertalanffy's organizational focus, requires the framing of living phenomena in final causal, teleological terms, wherein "purposiveness" or "that for the sake of which" provides a key component of scientific explanation.

Von Bertalanffy's writings on the wholeness of dynamics did not confine themselves simply to *synchronic* articulations of organization and purpose—the organic unity that formally and functionally characterizes a system's real-time dynamics at any given point in time. Understanding system organization for von Bertalanffy (1933) additionally required a historical dimension of embeddedness, in which the meaning of current organization is only fully explicable through its relative positioning in a structural sequence of organizational forms, yielding a teleological frame at the level of developmental time. Von Bertalanffy's forays into these issues of *diachronic* organization, though less detailed than his work on synchronic organization, add a level of developmental organization to GST's emphasis on the wholeness of dynamics (Overton, 1975).

Diachronic Organization: The Organism's Development as Organized Emergence

Development begins and ends in wholeness; in von Bertalanffy's (1933) words, "the developing germ is to be conceived as a unitary system" and "the primary unity and wholeness of the individual prevails in all stages of life" (p. 179). For von Bertalanffy, changes in development fundamentally mapped onto a sequence of transformations in the organizational nature of the developing system's wholeness. Specifically, he argued that "organisms assume ever more improbable states of higher organization and order" (von Bertalanffy, 1975, p. 117) characterized by what he described as a tendency toward maximal organization: "so long as an organic system has not yet reached the maximum organization possible to it, it tends toward it" (von Bertalanffy, 1933, p. 186). In this, von Bertalanffy appealed to the fundamental *directionality* of development as an explanatory framework within which specific levels of organization during development were meaningfully embedded (Overton, 1975). System wholeness at any given point in time (the synchronic structure of the system) is itself part of a larger system wholeness abstracted across the history of organizational transformations in the system (the diachronic structure of the system) and is only fully explicable when framed in terms of that larger system wholeness. Through this focus on the structuring of development as a whole, von Bertalanffy (1933, 1968a, 1975) promoted a final explanatory framework for understanding development that mirrored the orthodox principles of directionality and sequence in development formalized in the classic embryological writings of von Baer (see Gottlieb, 1992) and given psychological extension through the classic systems approaches of Piaget (1971, 1985), Werner (1957), and Vygotsky (1978).

GST frames the directionality of living systems' development in terms of two complementary principles: differentiation and progressive mechanization (von Bertalanffy, 1968a, 1975). In contrast to mechanistic portrayals of development—as an assemblage of complex structures from the combination and association of basic, foundational elements—GST's approach to development establishes *differentiation as its primary organizational principle*: "The organization of biological wholes is built up by differentiation of an original whole which segregates into parts.... Progress is possible only by passing from a state of undifferentiated wholeness to differentiation of parts" (von Bertalanffy, 1968a, pp. 69–70). Development as differentiation involves directional transition from an initial, homogenous whole, diffuse in its organization—what von Bertalanffy (1968a) termed "an undifferentiated absolute of self and environment" (p. 212)—to increasingly heterogeneous wholes characterized by distinctly definable yet intercoordinated parts.

As development in the living system proceeds via differentiation, new levels of differentiated wholeness are marked by greater specialization of the system's parts, and the system becomes increasingly amenable to mechanized, closed system descriptions, even though the system as a whole always remains thermodynamically open to its surround. Once parts of the system assume distinct specializations, these parts—now as wholes in their own right—start functioning in increased, though never complete, autonomy from one another and from the larger system as a whole, with certain parts coming to predominate the activity of the whole. Von Bertalanffy (1960) termed this developmental trend *progressive mechanization*, wherein systems become more efficient but at the price of their equipotentiality and thoroughgoing interdependence: "ontogenetically . . . we find a transition from less mechanized and more regulable states to more mechanized and less regulable ones" (p. 17).

In highlighting the wholeness of dynamics vantage point, von Bertalanffy argued both for the ontological legitimacy of formal and final explanation and for the epistemological necessity of establishing an organizational framework of explanation to constrain investigation of a system's dynamic process. With respect to the process dynamics themselves—the temporal unfolding of interpenetrating relations among the component parts of a system—von Bertalanffy offered relatively few specifics but in no way undervalued the *dynamics of wholeness* as an equally important vantage point for understanding systems. As emphatic as he was in stressing the organization of process, von Bertalanffy was equally emphatic in stressing the process of organization, for "the primary order of organic processes must be sought in the processes themselves" (von Bertalanffy, 1960, p. 17).

The Dynamics of Wholeness: The View From Below

Characterizing systems from the vantage point of their dynamic processes, von Bertalanffy distinguished between *primary* and *secondary* regulations. Primary regulations form a base level of "dynamic" interaction among components of a system, involving what von Bertalanffy (1968a) described as a "free interplay of forces and mutual interaction between components" (p. 161). Given their incessant build-up and break-down of material constituents, open systems *both* incorporate molecules high in free energy and low in entropy from their environment *and* expel high entropy energy back into the environment, allowing for new levels of organization to emerge in the system by counteracting the irreversible increases in entropy that necessarily take place within the boundaries of any system (Brent, 1978; Prigogine & Stengers, 1984; von Bertalanffy, 1968a, 1975). As metabolic outgrowths of this ceaseless interchange of material and energy, primary regulations among the system's components lead the system toward new levels of organization, or *steady states* (von Bertalanffy, 1968a). These regulations govern all interrelations of system components in the early stages of development and remain the process ground for living system organization as a whole throughout the system's life span (von Bertalanffy, 1968a).

As systems undergo differentiation, more structurally constrained processes called *secondary* regulations—"controlled by fixed arrangements, especially of the feedback type" (von Bertalanffy, 1968a, p. 44)—arise from primary regulations. Secondary regulations map onto the feedback-based control mechanisms of cybernetics approaches and embody for von Bertalanffy "the Cartesian machine model of the organism, unidirectional causality and closed systems" (p. 163). Critically, secondary regulations always operate within the wider context of primary regulations, on which they energetically depend. Whereas primary regulations showcase the nonlinear, reciprocal, internal relations among components of a system—relations that transcend unidirectional notions of antecedent to consequent causality by framing systems in multiply determined terms via *distributed* efficient causality—secondary regulations showcase the orthodox antecedent-consequent, linear, and ultimately summative relations among system components that mark the progressive mechanization that systems exhibit with increased differentiation and specialization.

Von Bertalanffy (1968a) stressed the centrality of primary regulations over the more scientifically orthodox, mechanistic processes of secondary regulations, which, though important in their own right, were always a more locally constrained derivative of dynamic processes of interaction:

> The basis of the open system model is the dynamic interaction of its components. The basis of the cybernetic model is the feedback cycle. . . . The open systems model in kinetic and thermodynamic formulation does not talk about information. On the other hand a feedback system is closed thermodynamically and kinetically; it has no metabolism. . . . An open system may "actively" tend toward a state of higher organization, i.e. it may pass from a lower to a higher state of order owing to conditions in the system. A feedback mechanism can "reactively" reach a state of higher organization owing to "learning," i.e., information fed into the system. (p. 150)

When von Bertalanffy's grand accounting of *General Systems Theory* was published in 1968—just a few years before his death—the quantitative study of secondary regulations, through subdisciplines of GST such as cybernetics, had been flourishing for years. His own attempts to mathematically capture and systematically explore the nature of primary regulations, however, proved far less tractable.

To study systems from the vantage point of their dynamic relations, von Bertalanffy (1968a) clearly recognized both the need to map changing relations across time among multiple values or quantities (instantiating different components of the system as a whole) and the complexity involved in doing so mathematically. He wrote of systems that "the prototype of their description is a set of simultaneous differential equations which are nonlinear in the general case" (p. 19). In this, von Betalanffy left no doubt as to the critical function of *nonlinearity* in the temporal dynamics of primary regulations. However, nonlinear differential equations are not amenable to traditional closed-form, analytical solutions, and von Bertalanffy apparently knew little of the topological, qualitative mathematics—first developed by Poincare in the 19th century—available to study nonlinear systems (Gottman, Swanson, & Murray, 1999; Gottman, Swanson, & Swanson, 2002). He viewed the mathematical modeling of a system via multiple nonlinear differential equations as ideal but "impossible" (von Bertalanffy, 1968a, p. 20), with practicality dictating for von Bertalanffy the need to render by means of linear approximations the differential equations he employed for modeling purposes (Gottman et al., 1999).

Thus, although von Bertalanffy (1968a, 1975) pointed to the dynamic interactions of primary regulations as crucial processes through which organization arises in systems, his mathematical applications yielded little elaboration of the "dynamics" themselves and of how the development of higher levels of organization is made possible through such dynamics. During von Bertalanffy's lifetime, however, major advances in the mathematical understanding of nonlinear systems were already underway in the physical sciences, paving the way for what has come to be known as nonlinear dynamical systems theory (Gleick, 1987; Guastello, 1997; Molenaar & Raijmakers, 1998). Alongside von Bertalanffy's GST, nonlinear dynamical systems theory establishes—both in nomenclature and technique—the guiding conceptual framework for the DS approach to development. Encompassing many specific research foci, such as catastrophe theory (Thom, 1975), chaos theory (Barton, 1994; Gleick, 1987), far-from-equilibrium thermodynamics (Prigogine & Stengers, 1984), and synergetics (Haken, 1996), the study of nonlinear dynamics critically informs the *dynamics of wholeness* vantage point with precisely the kind of mathematical formalization that von Bertalanffy had considered "impossible" to achieve.

NONLINEAR DYNAMICS: MATHEMATICALLY FORMALIZING THE DYNAMICS OF WHOLENESS

In systems close to equilibrium—and thus amenable to description via classical thermodynamics—levels of flow process, or fluctuations, are minimal and can be accounted for through traditional linear equations (Capra, 1996; Juarrero, 1999). However, open systems, as von Bertalanffy (1950) described them, are "maintained in distance from true equilibrium" (von Bertalanffy, 1968a, p. 142) and exhibit order by means of incessant exchange of material and energy. Fluctuations in these far-from-equilibrium, dissipative systems increase both in variability and magnitude and, unlike those of close-to-equilibrium systems, involve complex temporal dynamics that can only be adequately modeled through *nonlinear* differential (and difference) equations (Barton, 1994; Prigogine & Stengers, 1984). This holds true for all manner of far-from-equilibrium systems, from the physicochemical systems of whirlpools and hurricanes to the autopoietic systems of living organisms and the physical and psychological levels of organization that they construct throughout their development.

Under certain thermodynamic conditions of exchange between far-from-equilibrium systems and their surrounds, flow processes yield stable regimes of organization, which can be maintained as long as these fluctuations remain within a given range. In the realm of development, for example, individual persons are characterized by stable organization over extended time periods in the form of a given stage or level of developmental organization so long as the ceaseless fluctuation and variability of their ongoing exchange with the world remains bounded within a certain range. But beyond certain thresholds of value, the same interplay of flow processes amplifies to render unstable the system's current level of organization, "compelling it to evolve toward a new regime" (Prigogine & Stengers, 1984, p. 141). Thus, in far-from-equilibrium systems, fluctuations serve as the process source for both instability and increasing levels of system stability and complexity; via positive feedback loops, microscopic flow processes become amplified, destabilizing the system at a macroscopic level but also opening up new possibilities for macro-level order (Prigogine & Stengers, 1984). Again, with respect to development, when the intrinsic variability and fluctuation that characterize an individual's active engagement with her or his world amplify beyond certain thresholds, a developmental transition occurs as that individual's previously stable level of developmental organization becomes unstable and gives way to new possibilities for developmental organization, as in, for example, the transition from sensorimotor to preoperational forms of intelligence or from unidimensional to multidimensional systems of thought.

By the late 1950s, the introduction of high-speed computers coupled with the visual graphical techniques of Poincare's topological approach had established the means to "probe the complex interior of nonlinear equations" (Briggs & Peat, 1989, p. 23), ushering in a new mathematics of complexity for capturing the fluctuation dynamics of far-from-equilibrium systems (Capra, 1996). This new mathematics of complexity established constructs and techniques for the study of change across a wide range of disciplines and phenomena—from the inorganic to the organic—giving birth to the multidisciplinary approach of nonlinear dynamical systems theory (NDS) (Guastello & Liebovitch, 2009). As a mathematical theory, NDS has revolutionized both the way we as scientists study the dynamics of process and the way we understand those dynamics, with nonlinearity, variability, and the importance of local conditions assuming center stage in the quest to reveal how organization arises in nature, without any set of instructions or prescription (Guastello & Liebovitch, 2009; van der Maas, 1998). In other words, to understand the dynamics of those broad and reliable developmental transitions in individuals' functioning—from one stable level of developmental organization to another—we as scientists must immerse ourselves in the intraindividual "performance" variability that we witness across real time as specific individuals continuously act in specific contexts.

The two sections that follow provide a "broad stroke," simplified overview of both the quantitative and qualitative mathematical tools and concepts with which NDS works (the analytic details of which are beyond both the scope of this chapter and the ken of its author). These tools and concepts provide a unifying framework for describing and understanding change in all its complexity, grounded in the importance of variability and nonlinearity. They reveal that incremental, quantitative change in an iterated set of equation variables can suddenly coalesce to shift the equation's solution to qualitatively new levels of patterning irreducible to any variable in the set; thus, the ceaseless, ever-present microfluctuations of systems, under far-from-equilibrium conditions, spontaneously yield new system qualities, driving the system to new (i.e., emergent) levels of macroscopic order.

The Quantitative Mathematics of Spontaneous Emergence

Examining the wholeness of systems—both synchronically (i.e., atemporally) and diachronically (i.e., developmentally)—from the standpoint of their dynamics requires immersion in the ever-present *motions* of systems, their ceaseless variability over both real and developmental time, during periods of organizational stability as well as transformation (Kelso, 2000). System organization during periods of developmental stasis consists of stable relations among the continuous motions of the system's components. For example, take a cognitive system consisting of attentional, motivational, and memory components: despite continual fluctuations and variability in the functioning of the components themselves, the cognitive system remains organizationally stable so long as the relations that obtain among these three component processes remain stable. Developmental transformations in system organization are characterized by fluctuations at the level of the relations themselves (e.g., a change in the nature of relations among the attentional, motivational, and memory components of the cognitive system). This leads to new, stable sets of relations among component motions, reflecting a new level of developmental organization in the system. Modeling the dynamics of a system at any point in its development involves temporally interrelating *rates of change* among the motions of the system's components—that is, the variables of the system. Mathematically, this is achieved through the use of equations of motion—such as differential equations—which, by tracking the short-term dynamics of the system, can establish longer-range forecasts for future states and transition points in the system (Abraham & Shaw, 1992; Hirsch, 1984).

Recall that a linear relation is one in which output is proportional to input, offering straightforward prediction as in the relation between how many times a clock is wound and how long that clock will operate (Friedenberg, 2009). More specifically, in a linear relation occurring between the changing quantities of two variables, both variables change at the same rate. Plotting one variable in relation to the other produces a line, the slope of which remains the same for all values of each variable, as Figure 3.1a illustrates. Thus, how much one variable, y, changes in

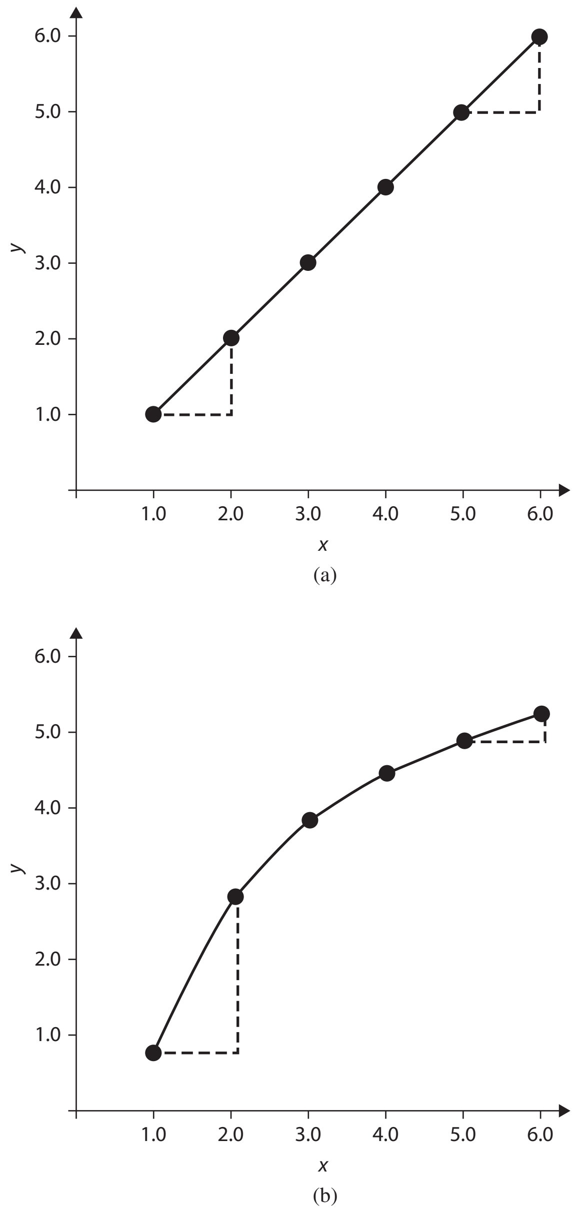


Figure 3.1 Examples of (a) a linear relation and (b) a nonlinear relation between variables *x* and *y*. Note that in (a), any two intervals of change in variable *x* (e.g., from 1 to 2 or from 5 to 6) are always associated with the same interval of change in variable *y*. In (b), however, different intervals of change in variable *y* accompany the same intervals of change in variable *x*.

relation to another variable, *x*, remains the same no matter what value of *x* is considered. From the perspective of changes in *x* leading to change in an outcome *y*, the effect of a change in *x* on *y* does not vary with the value of *x*—each wind of the clock yields a given length of time for its operation, and more winds yield proportionally longer operation.

In the realm of nonlinear relations, however, how much *y* changes in relation to *x does* vary as a function of what value of *x* is considered, meaning that nonlinear relations deal with *variable* rates of change. As Figure 3.1b illustrates, a nonlinear relation between two variables yields a curve, the slope of which changes point by point—for the same increment of change in *x*, change in *y* can vary dramatically. Weather patterns—where small changes in atmospheric conditions can suddenly lead to disproportionately large effects in weather output, making long-term prediction impossible—classically depict what it means for a relation to be nonlinear. Unlike equations depicting a linear relation between variables, nonlinear equations feature one or more variables either multiplied by itself or raised to a higher power; in other words, variables interact with, or feed back to, themselves in nonlinear functions. Relations of nonlinearity thus characterize variables that are "internally" related (Kitchener, 1982): the rate of change in one variable itself varies as a function of another variable's rate of change, and vice versa, magnified across a multitude of interdependent variables in complex systems. Or, in Gleick's (1987) words, "Nonlinearity means that the act of playing the game has a way of changing the rules.... Analyzing the behavior of a nonlinear equation ... is like walking through a maze whose walls rearrange themselves with each step you take" (p. 24).

Describing the slope of a curve for a nonlinear relation means being able to assess variable rates of change on the curve at any given point—the instantaneous velocity of the curve, modeled through a differential equation. By means of the method of differentiation, exact values for the rate of change in *y* as a function of *x* can be derived. Though all differential equations deal with how the rates of change among variables interrelate, not all differential equations are considered nonlinear. Those differential equations for which the function and its rate of change, or derivative, remain at a power of 1 are called linear differential equations. Linear differential equations are appropriate for systems whose components are varying in their rates of change relative to one another but for which the pattern of changes emerging from these varying rates of change can itself be modeled in terms of a functional relation that remains stable across time. In other words, the rate of change of the functional relation that is modeled in a linear differential equation is *itself* constant, even though the variables that comprise the relation are varying in their rates of change relative to one another.

By way of illustrating this property of linear differential equations in more general terms, take, as a highly simplified example, how y varies in relation to x in the function $y = x^2$. When $x = 1$, $y = 1$; $x = 2$, $y = 4$; $x = 3$, $y = 9$; $x = 4$, $y = 16$; $x = 5$, $y = 25$, and so on, as Figure 3.2a illustrates. Whereas each new x value differs from the previous value by 1—a constant rate of difference—each new y value differs from the previous value by varying quantities: first by 3, then by 5, then by 7, then by 9, and so on, a variable rate of difference. Thus, each of these variables exhibits different rates of change relative to one another, producing the curve of Figure 3.2a. Yet the *difference of the differences* between each value of y itself is constant, moving from 3 to 5, then from 5 to 7, then from 7 to 9, and so forth: It is always 2. Plotting the difference of the differences for y—a constant rate of change of 2—against the differences for x—a constant rate of change of 1—yields a straight line, or a linear relation, as Figure 3.2b illustrates. This demonstrates that a proportional functional relation still underlies the varying rates of change that x and y exhibit relative to one another.

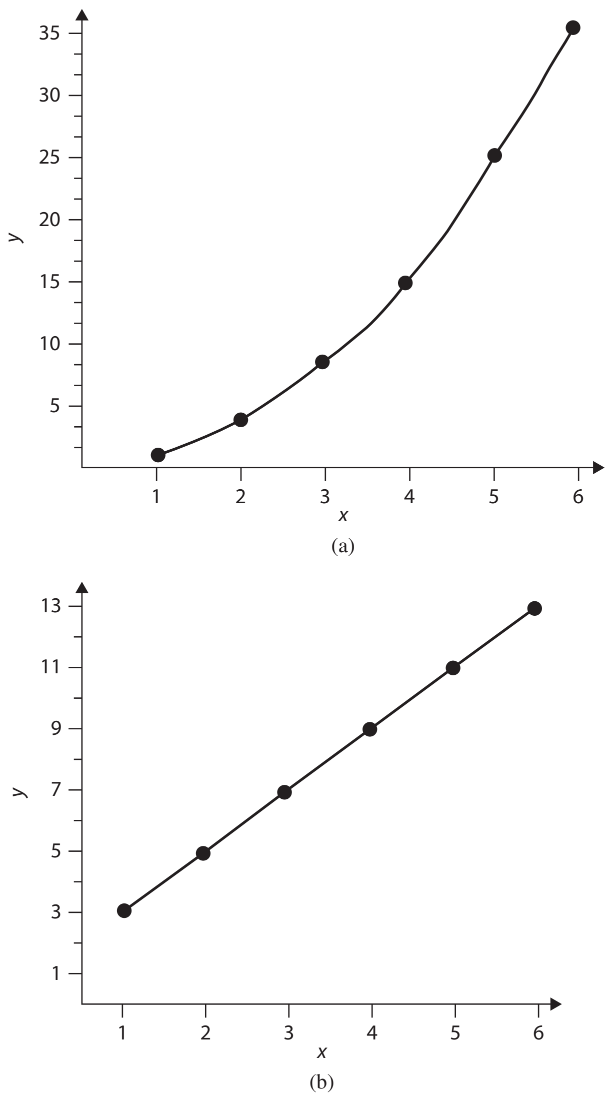


Figure 3.2 Graph (a) charts the equation $y = x^2$ and depicts the different intervals of change in variable y that accompany the same intervals of change in variable x. Though each new y value differs from the previous value by varying quantities across the same intervals of change in x, the difference of these differences is constant. Graph (b) demonstrates that a linear relation emerges from plotting the differences for x values against the difference of the differences for y values.

Nonlinear differential equations, however, are those for which the function and/or its derivative are multiplied by themselves or raised to a higher power. The rate of change in the functional relations that are modeled by these equations varies over time, just as the variables that comprise the relation vary in their rates of change relative to one another. Such equations, in other words, map change in the functional relation that itself captures varying rates of change among variables. This is precisely what is required to model the dynamics of organizational transformation in the *development* of a system, e.g., the transition from one stage or level of developmental organization (representing a given set of nonlinear relations among the system's components) to a new stage (representing a new set of nonlinear relations among the system's components). A common method for beginning to solve differential equations—and one that more adequately conveys what is going on in the modeling use of these equations—involves converting them into their discrete-time analogue: the difference equation. Difference equations are defined in terms of a recursive sequence of states such that each time state of the equation—its state at $t + 1$—is a function of its preceding time state, t, with this function being nonlinear for nonlinear difference equations (Kaplan & Glass, 1995). In other words, these equations operate through a process of *iteration*, of clear relevance to the modeling of developmental phenomena: the product of the equation's initial run—describing the instantaneous state of the system at $t + 1$—feeds back to the equation as a new initial state with which to produce a description of the instantaneous state of the system at $t + 2$, and so on (Guastello & Liebovitch, 2009; van Geert & Steenbeek, 2005).

Thus, the function modeled in the difference equation is repeatedly applied to itself by using the output from one iteration of the equation as input for the next iteration, yielding both negative and positive feedback loops (Briggs & Peat, 1989; Capra, 1996). Negative feedback loops serve a regulatory or maintenance function, decreasing the rate of a process as the magnitude of its product increases. The way in which thermostats control heaters through temperature monitoring—shutting off the heater when room temperature reaches a certain level—provides a classic example of a negative feedback loop. Positive feedback loops, in contrast, serve an amplificatory function, increasing the rate of a process as the magnitude of its product increases and creating the conditions for system growth. The deafening, screeching sound produced when a microphone is held too close to a loud speaker/amplifier—which essentially results in feeding the output of the amplifier back to the amplifier as input—provides a classic example of a positive feedback loop (Briggs & Peat, 1989). Both types of feedback loop play critical roles in far-from-equilibrium systems and the nonlinear differential/difference equations used to model them, but positive feedback processes, as detailed later, are especially central to understanding the dynamics of system instability and transformation (Ford & Lerner, 1992; Juarrero, 1999; Prigogine & Stengers, 1984).

Remarkably, a single nonlinear difference equation, through successive iterations, can capture various, qualitatively distinct states of the developing system across time: stable, repetitive patterning of variable motions, amplified periods of flux where output patterning breaks down altogether, and reconfigured patterning of variable motions (May, 1976). Defying conventional wisdom, even the most simple and deterministic of these equations can model highly complex stability and change in systems—with exact prediction often breaking down after many iterations of the equation, demonstrating that both ordered pattern and turbulent, chaotic instability arise from the same quantitative dynamics of motion (Abraham & Shaw, 1992; Briggs & Peat, 1989).

A widely cited mathematical example of such "complexity from simplicity" originates in the logistic equation $f(x) = rx(1 - x)$, first formulated by Verhulst in the mid-19th century as a model of population growth and extensively analyzed in the mid-20th century, reflected in May's (1976) systematic and integrative review. Converting this differential equation to its discrete-time analogue—the nonlinear difference equation $x_{n+1} = r(1 - x_n)\, x_n$—and mapping successive iterations of the difference equation reveal astonishing results, as Figure 3.3 depicts with x initially set at .5 and with values of r, a constant, gradually raised from 2.4 to 4.0. Bear in mind that the figure depicts for each value of r what solutions to the equation look like after multiple iterations (over 100) have ensued. At any given value of r lower than 3, the equation yields a series of oscillations with each successive iteration, but after

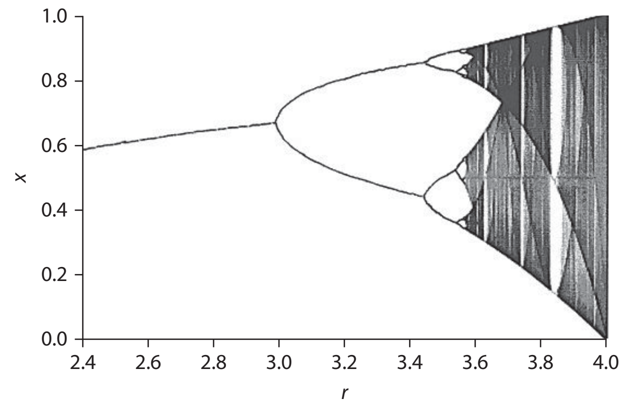


Figure 3.3 Bifurcation diagram for the logistic equation $x_{n+1} = r(1 - x_n)\, x_n$, revealing period-doubling transitions that eventually give way to chaos with x initially set at .5 and r raised from 2.4 to 4.0.

multiple iterations these oscillations eventually dampen around a single point of convergence, which is referred to as an *attractor*. As r is pushed closer and closer to a value of 3, larger oscillations arise with each new level of r but still eventually settle to reveal a stable point of convergence for each new level (Briggs & Peat, 1989). However, when the value of r eventually reaches 3.0, subsequent iterations of the equation now yield oscillatory patterns that eventually settle into not one but two stable cycles of convergence. As the value of r reaches 3.4495, subsequent iterations yield not two but four stable cycles, or "cycles within cycles" (Guastello & Liebovitch, 2009, p. 15). Each stable periodic cycle continues to double with quantitative increases in r—from a stable cycle, for example, of Period 4 to Period 8 when r reaches 3.5441 and again to Period 16 when r reaches 3.5644 (Kaplan & Glass, 1995). Eventually, when r reaches 3.5699, subsequent iterations no longer settle into stable periodic cycles but instead reveal the a periodic instability of chaos, where the activity of the system never repeats itself yet remains bounded (Guastello & Liebovitch, 2009), exhibiting "islands of order in a sea of randomness" (Briggs & Peat, 1989, p. 62) and making quantitative prediction impossible. Moving to even higher values of r results in the reemergence of stable periodic cycles from chaotic conditions, suggesting that "the route to chaos can simultaneously be a route to order" (Briggs & Peat, 1989, p. 64).

Both stable patterns of convergence and unstable, amplified fluctuations arise from the same positive and negative feedback dynamics of this equation. Within certain parameters of the equation, oscillatory patterns—fluctuations—are repeatedly dampened, only to amplify out of control within other equation parameters. Conditions of fluctuation amplification, in turn, set in motion system instability, out of which emerge new levels of order in the system, via the establishment of new relations among system components (Kossmann & Bullrich, 1997; Prigogine & Stengers, 1984). From the vantage point of the dynamics of wholeness, the bottom-up process dynamics of the system engender both transformation and organizational stability in development. The iterative results of this simple, deterministic equation further demonstrate that a continuous change in just one constant parameter of the equation—quantitatively identical to previous changes in that same parameter—can result at a certain threshold in qualitatively different and varied patterning for the output, or solution, of the equation. In other words, a *nonspecific* change in one component of a system, bereft of any "prescriptive information" or a set of formative instructions for what new forms will emerge, can nonetheless precipitate the system as a whole to establish new levels of organization (Molenaar & Raijmakers, 2000; Zanone, Kelso, & Jeka, 1993). Thelen, Fisher, and Ridley-Johnson (1984) provide a classic developmental example of this in their demonstration that quantitative changes in muscle-to-fat ratio prompt the context-specific "disappearance" of stepping movements in the early months of infancy.

All of this mathematically highlights the centrality of nonlinearity in the dynamics of wholeness: major, system-wide changes in organization can follow from small, nonspecific changes in one parameter of a system just as, conversely, a major change in one parameter of a system may have little to no system-wide impact on overall organization. Consider, for example, a quality that nonlinear systems evidence during periods of increased fluctuation and instability: sensitive dependence on initial conditions, or the "butterfly effect," whereby "two states differing by imperceptible amounts may eventually evolve into two considerably different states" (Lorenz, 1963, p. 133). In modeling fluid convection with three simplified nonlinear differential equations, Lorenz (1963) classically demonstrated that virtually identical initial values for the variables of the equations did not guarantee virtually identical trajectories of change after extensive iterations of the equations. Rather, altering by an infinitesimal amount the initial value established for even just one of the variables resulted in a trajectory of change that departed substantially from the same set of equations absent the infinitesimal alteration. Thus, even the most insignificant of differences can make a difference, especially as systems move toward instability, prompting Lorenz to assert that "prediction of the sufficiently distant future is impossible by any method" (p. 141). In particular, *numerical prediction becomes impossible* under the *unstable*—that is, easily susceptible to disturbance—and *aperiodic*—that is without regular cycles of repetition—conditions of system chaos (Kellert, 1993). As a routine and theoretically fundamental feature of both the living and nonliving worlds, sensitive dependence on initial conditions highlights the deep-seated inadequacy of traditional Cartesian-Mechanistic science for capturing natural phenomena of change in even the most rudimentary of open systems. Conceptualizing the natural world in clockwork terms—composed of linear, additive relations among isolable elements that can, with precise enough measurement, yield accurate, long-term prediction—is simply no longer tenable in the face of nonlinearity's ubiquity in natural systems (Gleick, 1987; Kellert, 1993).

Given the variety and complexity of patterning derivable from a single, deterministic equation, nonlinear functions rarely resolve to a single solution; instead, these equations yield "a pattern of solutions" (Barton, 1994, p. 6). Understanding this pattern of solutions in NDS takes place through the visual, *qualitative* techniques of geometrical modeling, the mathematical roots of which lie in Poincare's innovations for capturing the overall *shape* of a system's plotted motions (Abraham & Shaw, 1992; Hirsch, 1984). Gleick (1987) vividly describes the utility of these qualitative mathematics in terms of:

> The possibility of using a shape to help visualize the whole range of behaviors of a system. For a simple system, the shape might be some kind of curved surface; for a complicated system, a manifold of many dimensions. A single point on such a surface represents the state of a system at an instant frozen in time. As a system progresses through time, the point moves, tracing an orbit across this surface.... Shapes that look roughly the same give roughly the same kinds of behavior. If you can visualize the shape, you can understand the system. (p. 47)

Studying the geometry of a system's dynamics—its movement through an abstract mathematical space—establishes a holistic means for mathematically understanding system organization and its transformation. It allows for the abstraction of invariant patterning from the multitude of interdependent rates of change that characterize the motions of a system's components in relation to one another, even when local prediction of component motions breaks down.

The Qualitative Mathematics of Spontaneous Emergence

Equations of motion for system change can be topologically framed in terms of a *state* or *phase space*—a "geometric model for the set of all idealized states" of a system over time (Abraham & Shaw, 1992, p. 15). This multidimensional space is comprised of *at least* two axes, or dimensions, with every axis of the space corresponding to a variable employed in the equation(s) of motion. Each axis, in other words, captures a component of the system whose dynamics are being modeled. If the system of interest is emotion, for example, a state space for this system could consist of four separate axes corresponding to appraisal, goal, action tendency, and situational/contextual components. If the system of interest is the organism taken as a psychological whole, a state space could involve three axes of psychological functioning: cognitive, conative, and emotional. Or if the system of interest is a parent-child dyad, a state space might simply involve two axes: child and parent affect. The nature of the components themselves—and the axes that comprise the state space—depends on the questions being asked and the theoretical assumptions guiding one's characterization of the system, for as Kunnen and van Geert (2012b) note, systems (and the components that comprise them) "do not simply exist out there . . . we define them ourselves" (p. 19).

Every point within a state space marks a unique intersection among all of the variables that define the axes for the space; thus, every point on the state space reflects a possible instantaneous state of the system as a whole. In the case of a state space for the emotion system, each point in space could represent a current state of emotional experience or behavioral activity. When the changing states of a system are plotted, trajectories connecting successive points in the space demarcate temporal change in the states of the system, for example fluctuations in emotional activity across real-time. Through differentiation, not only can the instantaneous velocity of these specific trajectories at any point be established but also a broader velocity vector field that predicts tendencies for change of the system at different points in the state space can be constructed (Abraham & Shaw, 1992).

For a concrete and highly simplified example, take a state space that models the movement of a pendulum subject to friction and air resistance (e.g., Abraham & Shaw, 1992). Such a state space requires two axes—a standard Cartesian coordinate system—to plot the angle of elevation for the pendulum's bob against its rate of rotation. Figure 3.4a depicts an example of a movement trajectory for the pendulum, with each point of the trajectory representing an instantaneous state of the pendulum and with the trajectory connecting these points depicting change in the state of the pendulum over time. From the vantage point of its state space depiction, the movement of the pendulum resembles a spiral winding down to rest at the zero point of the two axes. In fact, when different points in the state space are chosen as starting points for the oscillation of the pendulum, the pendulum's trajectory will always assume the form of a spiral, inevitably coming to rest at the zero point of the space.

Unless a system is completely random in its state generation, it will not visit all portions of its state space (Juarrero, 1999). Instead, for any given system, certain regions of state space are more likely to be occupied than others; the system seems actively drawn or attracted to certain areas and repelled by others. As mentioned earlier, those portions of a state space toward which the trajectories of a system converge are called *attractors*. With reference to the example of an emotion system state space, attractors would correspond to stable patterns of emotional activity that, for any given level of developmental organization, establish an individual's characteristic emotion tendency repertoire. The effectiveness of an attractor in drawing system trajectories toward it depends on its range of influence within the state space—its *basin* of attraction. The wider the attractor basin, the more pull it has. In the pendulum example, the zero point of the state space constitutes the single attractor for this simple system, and the region surrounding the zero point comprises the attractor's basin. State spaces designed to model complex systems will routinely consist of multiple basins of attraction, reflecting multiple patterns of behavioral or state stability within the system, (e.g., qualitatively distinct and stable patterns of emotional activity for an individual, such as fear, anger, jealousy, happiness). Within the region of any given attractor, particular rules of motion apply, lending the attractor its particular geometric shape (e.g., the spiral characterizing the pendulum swing [Guastello & Liebovitch, 2009]). Attractors thus mark states of system stability—the dynamic states of disequilibrium that constitute steady states. They are the patterns into which the system settles after transient fluctuations are dampened: the asymptotically stable solutions to differential equations (Abraham & Shaw, 1992; Hirsch, 1984).

All regions of the state space that lie outside the basins of its attractors are called *separatrices* (Abraham & Shaw, 1992). Separatrices are those portions of a state space

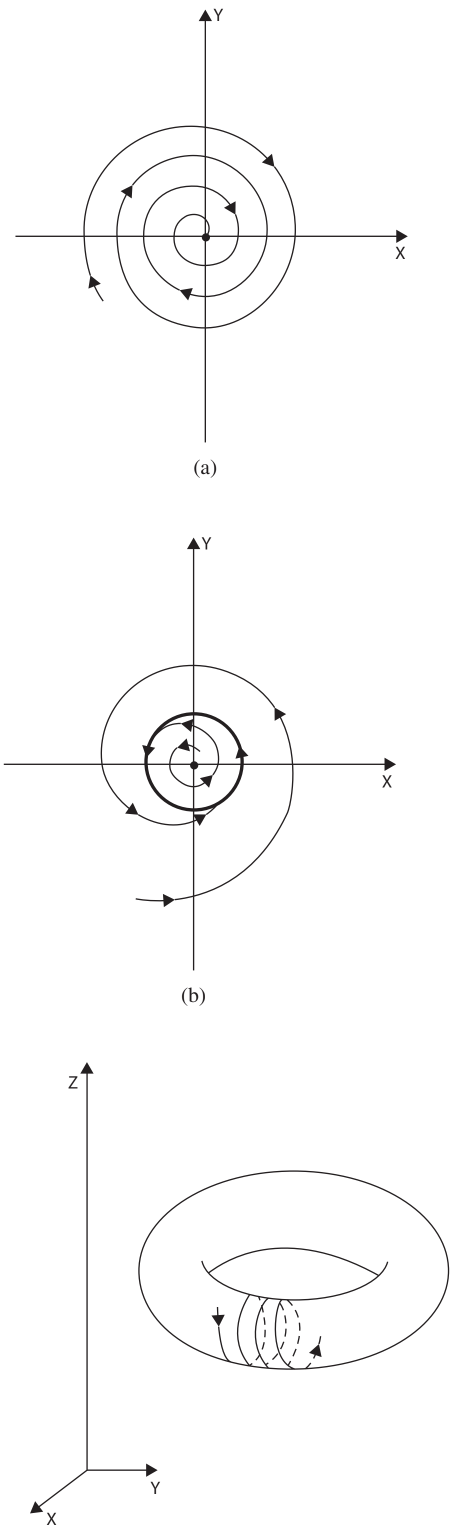


Figure 3.4 Examples of three types of attractor: fixed-point (a), limit-cycle (b), and toroidal (c). (a) and (b) specifically plot the angle of elevation for a pendulum (the *x* axis) against its rate of rotation (the *y* axis).

from which trajectories of a system diverge; movement of the system within these regions "is deflected away from the epicenter" of the separatrix, which is why these regions are also termed *repellors* (Guastello & Liebovitch, 2009, p. 10). System activity within separatrices, unlike that within attractors, is marked by instability—these regions are structurally unstable, in contrast to the structural stability of attractor regions. For example, in the emotion system state space of an easygoing individual who routinely "goes with the flow," hostile anger patterning might constitute a separatrix region of emotional activity. In what has become a common topographical metaphor, state spaces can be thought of in terms of an evolving landscape of hills and valleys, in which the hills represent separatrices and the valleys represent attractors (e.g., Briggs & Peat, 1989; Thelen & Smith, 1994, 1998, 2006). A spherical rock—representing the instantaneous state of a system—situated on any given hill of this landscape is easily displaced and will fall downward toward the valleys of the landscape. The steeper the hill, the more easily displaced the rock. Once the rock ends up in a valley, it will be relatively resistant to displacement from the valley, with deeper valleys more thoroughly constraining displacement of the rock. Given that state spaces, as abstract mathematical concepts, can conceivably assume any number of dimensions, Briggs and Peat (1989) reframed this metaphor in terms of "hills and valleys of energy. Systems in nature are attracted to energy valleys and move away from energy hills" (p. 36). The complete landscape/state space of a system, replete with its attractors, basins, and separatrices, establishes the system's *phase portrait* and "provides a global overview of the modes of behavior of the system" (Mosekilde, Aracil, & Allen, 1988, p. 21).

Attractors in a state space fall under one of four broad classes: fixed-point, limit cycle, toroidal, and chaotic. In a *fixed-point attractor*, all trajectories converge on a single point, as the pendulum in Figure 3.4a illustrates. Although all trajectories terminate on a fixed point within this class of attractors, different patterns can arise in movement trajectories within the attractor basin; for example, the spiral patterning of a pendulum's movement differs in its dynamics from a fixed-point attractor in which all trajectories *directly* converge to a single point (Guastello & Liebovitch, 2009). Of all classes of attractors, only those of the fixed-point class can operate in linear systems (Mosekilde et al., 1988). Their relative simplicity notwithstanding, fixed-point attractors have proven successful in modeling many forms of nervous system activity (Schöner, 2009). In a *limit cycle*, or *periodic*, *attractor*, trajectories converge not on a single point but on a cyclic path, oscillating around an epicenter. Trajectories within the cyclic path move outward from the epicenter of the cycle to the cycle itself just as trajectories outside the cycle are attracted to the cycle, not to its epicenter (Abraham & Shaw, 1992; Guastello & Liebovitch, 2009). The movement of a clock pendulum as depicted in Figure 3.4b—swinging at a steady rate and counteracting air resistance and friction due to the energy bursts it receives from its mechanical components—stands as a simple example of a limit cycle.

The coupling of two limit cycles creates interdependent oscillatory patterning—"a limit cycle that is cycling along two axes rather than one" (Guastello & Liebovitch, 2009, p. 11)—and results in the class of attractors known as *toroidal,* or *quasi-periodic*. Topologically, the torus attractor involves a curved-surface manifold, doughnut-like in shape, as Figure 3.4c illustrates. If, for example, the oscillatory patterns of two pendulums became interlocked with one another, one pendulum cycle would be embedded in another pendulum cycle, "as if cycle A is swept around in a circle by cycle B" (Briggs & Peat, 1989, p. 39). Both limit cycle attractors and their more complex extensions—toroidal attractors—readily capture oscillatory phenomena in living systems and have been classically employed in the study of brain dynamics (e.g., Kelso & Tognoli, 2009; Thatcher, 1998) and motor activity, coordination and its development (e.g., Fitzpatrick, 1998; Kelso, 1995; Thelen & Smith, 2006; Turvey, 1990), among other areas.

Attractors at their most geometrically complex involve *chaotic* motion, seemingly random when examined quantitatively at the level of local detail and prediction but actually highly patterned when viewed as a qualitative whole. The state values for systems in the midst of a chaotic attractor are numerically unpredictable and extremely sensitive to initial conditions yet remain within a bounded area of activity (Guastello & Liebovitch, 2009; Kellert, 1993; Mosekilde et al., 1988). Within this bounded area, motion trajectories "asymptotically approach almost every location in the thickened surface" (Abraham & Shaw, 1992, p. 294), making these attractors resistant to absolute quantitative prediction yet fully deterministic mathematically speaking. One of the most famous chaotic attractors is the Lorenz attractor, pictured in Figure 3.5 and generated from his three equations for convection (Lorenz, 1963). In keeping with previous pendulum examples, chaotic patterns of motion can also arise in the simplest of coupled oscillatory systems, as when two pendulums are *attached* to one another—pivot to

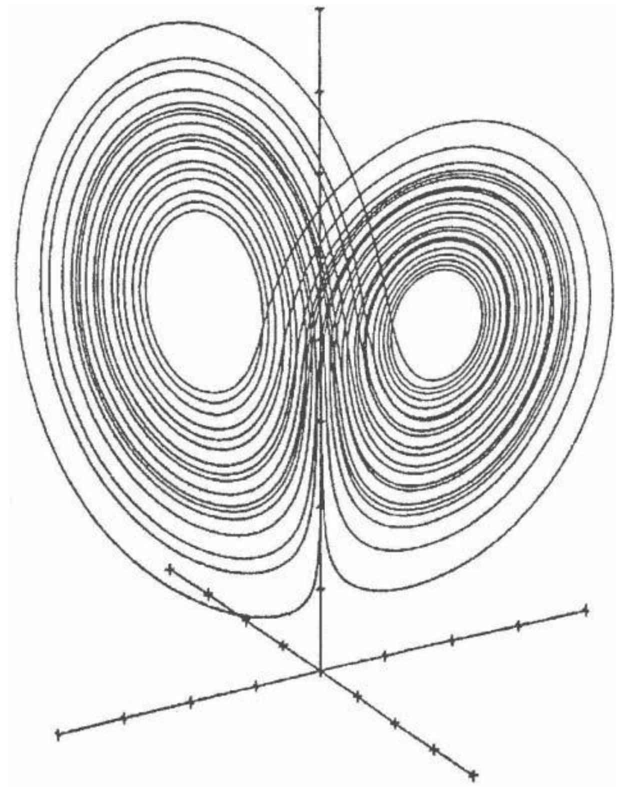


Figure 3.5 Example of a chaotic attractor, specifically the Lorenz attractor generated from his three equations for convection.

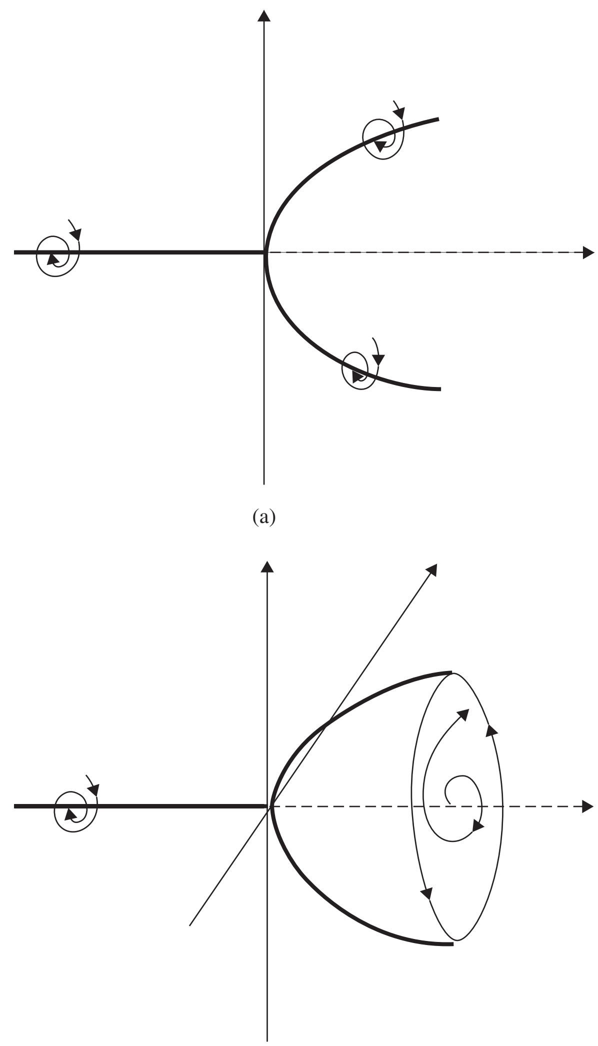
bob—and allowed to oscillate freely. Modeling neural activity in terms of chaotic attractors remains one of many prominent areas of scientific endeavor within the realm of living systems to employ principles of chaos, though such efforts are not without controversy (e.g., Durstewitz & Deco, 2007; Minelli, 2009; Skarda & Freeman, 1987; Tsuda, 2001).

Under conditions of system stability, the local, qualitative patterning of any given attractor—its broad class type and specific geometric patterning—persists despite quantitative alterations to the attractor, such as increases in its strength of pull or widening of its basin of influence. Similarly, the organizational stability that marks the system as a whole—during any given period of developmental stasis, for example—globally manifests itself in the topographical invariance of the system's phase portrait (Juarrero, 1999). In other words, a *phase portrait* consisting of stable topographical relations over time among a series of attractors and separatrices can correspond to a particular stage or level of developmental organization in an individual's developmental history. During such qualitative stability at the level of the system as a whole, the overall attractor and separatrix layout of the landscape remains configurationally intact, both in the midst of system activity moving from one attractor to another as a function of specific "task demands" and despite persistent *quantitative* alteration in the system's landscape, that is, its hills steepening and narrowing or its valleys deepening and widening. This relates to context-general, organizational characterizations of a system persisting in the midst of inherent fluctuation in the content of that system's activity across time and context; for example, the general organizational properties of the emotion system for a particular level of developmental organization persist whereas real-time emotional activity fluctuates both *between* local, stable patterns available to the system (moving from fear to anger to happiness, etc.) and *within* these stable patterns (intensity and duration changes, ease of elicitation changes, etc.). Thus, both locally and globally, the state space maintains its qualitative patterning in the face of flux during periods of system stability.

When, however, systems become unstable, either locally at the attractor level or globally at the state space level, *qualitative shifts* in the dynamics of the phase portrait arise, called *bifurcations*, yielding *new* levels of attractors and, by extension, state space organization. These bifurcations, in other words, can capture qualitative shifts from one stage or developmental level of stable organization in the system to another (via transitional periods of increased intrasystem variability). For example, consider the qualitative shift in infant emotional functioning from impulsiveness to wariness in the second half of the infant's first year of life. At the level of an infant's emotion system state space, this shift can be viewed in terms of the emergence of a new attractor corresponding to fearfulness between 7 and 9 months. This new attractor both adds a new valley of attraction to and reconfigures the existing topography of the attractor and separatrix landscape that characterized the largely impulsive character of infant overall emotional functioning at 4 to 6 months.

With respect to how bifurcations arise, recall that the graduated scaling of a certain parameter in nonlinear, deterministic equations can give rise to a dramatic reconfiguration for the output, or solution, of the equations. Such a parameter is known as a *control parameter*. Bifurcations in system dynamics manifest themselves under precisely those circumstances in which a control parameter moves beyond a critical threshold value for the maintenance of stability in a system, precipitating the *emergence* of new patterning in the system, both locally and globally (Guastello & Liebovitch, 2009). For example, self-produced movement experience could be construed as a control parameter for the transition from impulsiveness to wariness in infant emotional development, at least with respect to the emergence of fear of heights: converging evidence demonstrates that after a few weeks of accumulation in self-produced movement experience, infants begin to systematically avoid drop-offs (e.g., Campos et al., 2000; Thelen, 2000).

Different forms of bifurcation have been identified. Two of the most prominent forms are the *pitchfork* and the *Hopf*. Figure 3.6a illustrates a pitchfork bifurcation, in which two



(a)

(b)

Figure 3.6 Examples of two types of bifurcation: pitchfork (a) and Hopf (b). In (a), a fixed-point attractor bifurcates into two separate fixed-point attractors divided by a separatrix region. In (b), a fixed-point attractor bifurcates into a limit cycle attractor.

stable attractors—a bistable solution to system dynamics divided by a separatrix region of instability—emerge from a single stable attractor (Kelso, 1995). As a result of the bifurcation, what once was a stable region of attraction becomes a region of instability, flanked, in turn, by two, newly emergent regions of stability. Figure 3.6b depicts a Hopf bifurcation—"the complex equivalent of the pitchfork" (Kelso, 1995, p. 85)—consisting of the transformation of a fixed-point attractor into a limit cycle attractor when the critical threshold for a given control parameter is reached (Guastello & Liebovitch, 2009). Both forms of bifurcation can be thought of in terms of processes of differentiation in development; for example, the hypothesized differentiation of specific emotion patterns of anger and sadness from an undifferentiated pattern of distress. A complex variation on the simple Hopf bifurcation emerges from the logistic equation whose successive iterations were modeled in Figure 3.3. Figure 3.3, in fact, presents a bifurcation diagram illustrating the *period-doubling*, or *Feigenbaum*, *bifurcation* in which a system's dynamics undergo qualitative reorganization from fixed-attractor to limit cycles to chaos—in the midst of which new limit cycles emerge—all as a single control parameter gradually increases in value (Abraham & Shaw, 1992; Guastello & Liebovitch, 2009; Kelso, 1995).

Of the many types of bifurcation, perhaps the most primary is the *saddle-node*, or *fold bifurcation* in which fixed-point attractors are spontaneously created or annihilated in a state space (Thompson & Stewart, 1986). For example, a decrease in the value of a control parameter may result in an existent fixed-point attractor moving ever closer to the repellor point of the separatrix, which exists at the edge of the attractor's basin. When the attractor arrives at this boundary point, the attractor, its basin, and the separatrix are simultaneously destroyed. With an increase in the value of the same control parameter, the attractor and its separatrix spontaneously emerge (Abraham & Shaw, 1992; Thompson & Stewart, 1986). Fold bifurcations and their two control parameter complement—the cusp bifurcation—are foundational to the branch of bifurcation study known as catastrophe theory (Thom, 1975; Zeeman, 1977). *Catastrophe theory* has enjoyed successful application to the study of development in areas ranging from Piagetian stage transitions in the development of conservation (van der Maas & Molenaar, 1992) to the transition in motor development from reaching without grasping to reaching coordinated with grasping (Wimmers, Savelsbergh, Beek, & Hopkins, 1998).

The Continuity of Dynamic Process

The complementary quantitative and qualitative mathematics of NDS have revealed that surprising *nonlinear* complexity is available to even the most simple and deterministic of systems. In turn, these mathematical formalizations of the *dynamics* of wholeness highlight the continuity that exists in dynamic process across varied levels of complexity in the organization of real-world phenomena. Mirroring GST's call for the expansion of physics to include life phenomena and for the recognition that "organization runs right through all levels of reality and science" (von Bertalanffy, 1968b, p. 34), NDS calls for the acceptance of nonlinearity as more rule than exception at all levels of reality and science. And as previously indicated, NDS has established common principles of spatiotemporal stability and change for capturing the dynamics in any and all systems to which nonlinearity applies, from the inorganic to the organic, from the physical to the psychological (Kaiser, 2000).

Few examples have captured the nonlinear complexity evident in the most unsuspected of real-world phenomena quite as well as the chemical reaction known as the Belousov-Zhabotinskii reaction, discovered in the late 1950s. Under particular conditions of chemical concentration and temperature, random fluctuations in a glass dish mixture of malonic acid, bromate ions and a catalyst (cerium, manganese, or ferroin) amplify through autocatalytic feedback to produce remarkable macroscopic order, consisting of pockets of concentric circular and rotating spiral patterning that expand to fill the entire dish before eventually decaying (Madore & Freedman, 1987; Prigogine & Stengers, 1984). The complexity that arises under these inorganic chemical conditions bears more than a passing resemblance to the emergence of higher order morphogenetic patterning in living systems, as Madore and Freedman (1987) suggest:

> The spontaneous origin of forms within the Belousov-Zhabotinskii reaction, the subsequent growth and stability of the patterns, and the ever-increasing complexity of the structures (new ones are still being reported) are all more characteristic of living creatures than of simple chemical reactions. But simple they are. Without detracting from the beauty and the importance of these reactions, the mystery of their growth and development has been revealed by some of the simplest of computer simulations. (p. 254)

The inorganic physicochemical world, in fact, is replete with examples of spontaneous pattern formation, or *self-organization*. One need look no further than the hexagonally shaped convection cells that emerge when a shallow layer of liquid is heated or the cloud formations that materialize overhead under conditions of air saturation.

That such complexity can emerge within such simple, inorganic systems of relations—and be modeled by straightforward, deterministic equations—vividly illustrates how the complexity of organic developmental form could arise from the same basic iterative dynamics that mark any physicochemical system pushed toward far-from-equilibrium thermodynamic conditions. In fact, applications of nonlinear dynamics to the study of morphogenesis and developmental biology were already prominent in some of NDS's foundational work (e.g., Thom's [1975] catastrophe theory and Prigogine's [Prigogine & Stengers, 1984] far-from-equilibrium thermodynamics [Molenaar & Raijmakers, 2000]). What could be more natural but to extend principles of nonlinear dynamics to psychological development? Such an extension ushered in the formal birth of the DS approach to development (Thelen, 1992).

THE DYNAMIC SYSTEMS APPROACH TO DEVELOPMENT: GENERAL CONSIDERATIONS

The DS approach to development conceptually and analytically targets the question of *how* in development: How do new levels of system organization arise from previous levels of organization (Lewis, 2000a; Thelen & Smith, 1994; van Geert & Steenbeek, 2005)? *Self-organization*—the core idea behind the DS approach—provides the conceptual framework for answering this question. Undergirding this conceptual framework are (a) a focus on emergent form rather than preexistent design, and (b) a focus on the relations among components of a system, rather than the components themselves, as the source of developing form in a system. In effect, self-organization marks the process by which new levels of organization—new, irreducible patterns or wholes—spontaneously emerge in a system through coactions among the very components that comprise the system (Kelso, 2000; Lewis, 2000a; Lewis & Granic, 1999a). Spontaneous emergence means that the newly emergent organization of the system arises without design, without being prefigured in any of its components (Thelen & Smith, 1994). More specifically, stability and organization at the macrolevel of a system arise from and are constantly maintained by the ever-present microlevel variability and dynamics of the system (i.e., the internal relations among the components that comprise the system). Through the recursive nature of open systems—whereby system activity constantly feeds back to itself, both positively and negatively—the dynamics of microlevel variability can, under certain conditions, amplify to the point of rendering the system organizationally unstable, establishing in turn conditions for new levels of cooperation among the components of the system to emerge and fashion new macrolevels of stable organization. More complex levels of organization in development thus arise in genuinely novel fashion from the nonlinear interactions that obtain among the simpler component parts of the system, with such self-organization made thermodynamically possible through open systems under far-from-equilibrium conditions.

As a function of its grounding in the mathematical constructs and tools of NDS, the DS approach to development offers a unifying nomenclature and cadre of modeling techniques for analytically capturing self-organization in developmental process—the temporal dynamics of emergence in living, developing systems. Its lineage thus traces directly and unambiguously to the quantitative and qualitative mathematics that constitute the multidisciplinary study of nonlinear dynamics, and although applying NDS's principles of pattern formation in physicochemical systems to the realm of complex organic *behavior* and *development* is far from a simple, straightforward exercise (Kelso, 2000), the ingredients for such an application are well established through NDS. However, the broader *systems* lineage of the DS approach remains much more elusive and relatively ill-defined in DS writings. Apart from subscribing to the most general and rudimentary of systems tenets (i.e., that wholes are irreducible to the additive sum of their parts and that relations among components of a system, not the components themselves, are central to the understanding of the emergent order in systems), how does the DS approach to development map onto and/or extend the *organizational*, explanatory tenets of von Bertalanffy's GST?

The novelty of the DS approach arrives primarily in its central focus on the dimension of time, specifically the real-time, local dynamics of change that engender both developmental stability and transformation (Granic, 2005; Thelen & Smith, 1994). For many of DS's proponents, this temporal focus, coupled with an equally critical appreciation for within-system variability (e.g., psychological intraindividual variability) as the source of transformative system change, stand in marked contrast to the overweening emphasis on organizational invariance and maintenance of stability around which von Bertalanffy's GST centrally revolves (Aslin, 1993; Granic, 2005; Granic & Hollenstein, 2003). Moreover, charges pertaining to GST's *metaphorical* status and the need to move "beyond metaphor" to real-time, concrete action in context (Thelen, 1992, p. 191) routinely surface in DS accounts, particularly with respect to the "theoretically vacuous" (Beek, Hopkins, & Molenaar, 1993, p. 499) and "empirically bereft" (Granic, 2005, p. 388) standing of GST's developmental process conceptualization (Lewis & Granic, 1999a). This, in turn, begs two questions: What constitutes the metaphor of GST, and what role does metaphor play in the explanatory framework of the DS approach?

Is GST's atemporal, organizational focus—its *wholeness of dynamics* perspective—the metaphor beyond which the DS approach moves in its thoroughgoing temporal embeddedness? If so, what does moving beyond this metaphor entail? In the eyes of DS proponents, does the metaphor of GST serve an explanatory purpose in its own right, or is it merely a heuristic placeholder for the "true" explanation offered through the study of real-time variability and dynamics? These questions bear directly on how the DS approach to development conceptually integrates its GST and NDS lineages. How, in other words, does the broad, multidisciplinary metatheory of von Bertalanffy's general systems approach align with the equally broad, multidisciplinary mathematics of nonlinear dynamics to establish the new landscape of the dynamic systems approach for developmental science?

ALIGNING GENERAL SYSTEMS THEORY AND NONLINEAR DYNAMICS: AN INCLUSIVE APPROACH

Framing NDS as a conceptual and analytical elaboration of the *dynamics of wholeness* side of GST, as this chapter has done, presents one possibility for aligning the multidisciplinary forerunners of the DS approach to development. Such an alignment underlies the *inclusive DS approach* to development as articulated in the writings of Lewis, van Geert, and van der Maas. In this vein, the broad *perspectivism* of von Bertalnaffy's GST fosters precisely the sort of explanatory pluralism within which the more specific mathematical pluralism of NDS can comfortably reside. By means of its perspectivist philosophy, GST values both the temporal dynamics and the atemporal organization of phenomena as equally legitimate lines of sight from which to understand system functioning. Process and organization, activity and structure, go hand in hand at all levels of analysis, as two sides of the same coin (van Gulick, 1993). Von Bertalanffy (1933, 1975) stressed unequivocally that understanding systems and their development can never arrive through a reduction of all organization and pattern to process but must instead involve the dissolution of *foundationalism* and, consequently, a broadening of the notion of process to conceptually envelop organization. Like Piaget and other developmentalists operating within pre–World War II Continental-European circles of psychology, von Bertalanffy endorsed a *holistic structuralism* in which structure is both founded in constructive activity and constitutive of that very activity (Overton, 1975; Toomela, 2009). In Overton's (1975) words:

> The ideas of holistic structuralism then are based on the views of the universe as activity. From this perspective the organization or structure of the phenomena is not reducible to something else but, instead, it is a representation of the flux of everyday particulars. Structure is a *primitive construct* in the sense that it is given as a basic explanatory construct. (p. 66)

Subsumed under the explanatory auspices of GST's holistic structuralism, NDS offers what von Bertalanffy, in attempting to articulate the dynamics of wholeness vantage point of GST, could not: elaboration of self-organization in systems (i.e., how higher-order pattern arises through lower-order fluctuations and the nonlinearity of relations among the components that comprise a system). NDS highlights the importance of iterative processes and variability as keys to creative potential in nature through examination of both nonlinear equations of motion and qualitative topographical frameworks for modeling system stability and change over time. It stresses the importance of formal mathematical explanation, by which organization becomes temporally defined in terms of the real-time dynamics of fluctuation and motion. GST, in turn, stresses the importance of atemporal organizational explanation—the formal and final explanatory backdrops—by which higher-order abstractions organizationally constrain and meaningfully define the dynamics of specific temporal relations.

ALIGNING GENERAL SYSTEMS THEORY AND NONLINEAR DYNAMICS: AN EXCLUSIVE APPROACH

A different means of aligning GST and NDS is revealed through the *exclusive DS approach* to development, articulated most prominently by Thelen and Smith in their seminal 1994 book as well as their prior *Handbook of*

Child Psychology chapters. Adopting an explanatory monism, Thelen and Smith privilege the here-and-now of real-time, task-specific activity over all other levels of analysis; for them, "the cornerstone of a dynamic theory of development is this emergent nature of behavior assembled in *real time*" (Thelen & Smith, 1994, p. 73). Their explanatory privileging of real-time dynamic process means that *organization*—the global order and pattern abstracted from the real-time particularities of specific actions in specific contexts—is only something *to be explained*, a product of process, not a kind of explanation in its own right (Witherington, 2007, 2011; Witherington & Margett, 2011). Thelen and Smith (1994) write that "order is . . . created in the process of action" (p. 63), that "form is a product of process" (Thelen & Smith, 2006, p. 271), that "no knowledge exists that is divorced from the constituent dynamics of the task itself" (Thelen et al., 2001, p. 76). Explanation for Thelen and Smith, as well as for Spencer, is limited exclusively to temporally based mechanisms, concretely grounded in real-time activity dynamics. Because structures (forms, organizations), as abstractions, cannot explain according to Thelen and Smith's criterion, structural explanation cannot serve as true explanation from the standpoint of an exclusive DS approach (Witherington & Heying, 2013).

The antistructuralist stance of the exclusive DS approach thus mandates a different outlook on the relation between GST and NDS, one in which the study of nonlinear dynamics serves to *redefine* and *reconfigure* in temporal, dynamic terms the atemporal, organizational abstractions of von Bertalanffy's general systems approach. The exclusive DS approach to development dispenses with the idea of alternate, complementary lines of sight in favor of privileging temporal explanation and the dynamics of wholeness vantage point. This suggests that the organizational focus of GST—the wholeness of dynamics—cannot be explanatory in its own right; it cannot serve as a legitimate, meaningful vantage point of explanation but ultimately must be explained by means of the real-time dynamics of activity, the dynamics of wholeness. The behavior of any system "is always assembled in time," thus the only way to understand such behavior is through an analysis of its embeddedness within time, as "patterns assembled for task-specific purposes" (Thelen & Smith, 2006, pp. 278, 284). The global order of the system—its holistic structure—merely exists as a "momentary *product* of a dynamic system, not a dissociable cause [i.e., explanation] of action" (Thelen & Smith, 1998, p. 617). In this reframing, the system itself becomes only an object of study, not also a subject of explanation—via formal and final explanation—in its own right.

INCLUSIVE AND EXCLUSIVE APPROACHES TO DYNAMIC SYSTEMS COMPARED

At its core, the metatheoretical divide between inclusive and exclusive versions of the DS approach to development revolves around whether to frame the temporal dynamics of NDS within the broader explanatory context of holistic structuralism, as evinced in von Bertalanffy's GST. This question, in turn, conditions what constitutes legitimate explanation within the DS approach. Is a system's organization or global order—its pattern, structure, form—explanatory in its own right or merely a transient, epiphenomenal byproduct of local process dynamics? Is form abstracted from the here-and-now as integral to explanation as real-time contextual factors? Is process explanatorily foundational to organization, or is all process necessarily organized, just as all organization is necessarily a process? Are the sequencing and directionality of development mere appearance or necessary components of developmental explanation? Inclusive and exclusive variants of the DS approach offer ontologically incompatible answers to these questions, despite being unified through adherence to the principle of self-organization and the mathematics of NDS. Owing to its grounding in both the organizational explanation of GST and the dynamical explanation of NDS, the *inclusive DS approach*: (a) fully admits higher-order, emergent form into its explanatory framework; (b) embraces an explanatory pluralism encompassing not just efficient and material cause but formal and final explanation; (c) considers developmental time as emergent from but irreducible to real time; (d) regards the process of self-organization in both bottom-up and top-down terms, which, as will soon be discussed, entails full adherence to the principle of *circular causality*. For the inclusive DS approach, organization and process (i.e., structure and function) are two sides of the same explanatory coin, conferring equally legitimate perspectives on the same whole; both top-down organizational constraint and bottom-up dynamic construction are vital to understanding the development of complex systems, at all levels of organizational abstraction.

The *exclusive DS approach*, in contrast—owing to its recasting of the organizational "heuristics" of GST in terms of the dynamical explanation of NDS: (a) rejects higher-order, emergent forms as explanatory in any real sense; (b) embraces an explanatory monism in wedding its analysis exclusively to activities in the context of the here-and-now; (c) reduces developmental time to real time; (d) treats as illusory the orderly, directional flow of development viewed in macroscopic terms; (e) regards the process of self-organization in primarily bottom-up terms. For the exclusive DS approach, process is foundational to organization, in unidirectional fashion; organization is the epiphenomenal byproduct of process, establishing bottom-up dynamic construction as the *fundamental* level of explanation for understanding change in all far-from-equilibrium systems (Witherington, 2007, 2011).

The essence of this overarching ontological difference in DS frameworks is aptly captured in a well-established conceptual distinction prominent in modern philosophical discussions of emergence: the distinction between *epistemological*, or "weak," emergence and *ontological*, or "strong," emergence (Bedau, 1997; Silberstein & McGreever, 1999; Witherington, 2011). Both epistemological and ontological approaches to emergence treat higher-order forms arising in systems as neither fully predictable from nor fully expressible in terms of the lower-order components of the system (Silberstein & McGreever, 1999). Both also acknowledge the genuine irreducibility of emergent form such that something new—some new property of a system—comes into being, having not previously existed in or been prefigured by any of the parts that comprise the system. For advocates of an epistemological approach to emergence (e.g., Spencer et al., 2011; Thelen et al., 2001; Thelen & Smith, 1994), however, higher-order form—though irreducible to lower-order form—*causally reduces* to the lower-order, local process dynamics that engender it, maintain it, and into which it falls out of being. In other words, emergent pattern may not be reducible to other patterns but *is* ultimately reducible to the processes that gave rise to it, meaning that a strict, ontological distinction exists between causal processes and emergent products (Clayton, 2006; Gregersen, 2006; Silberstein & McGreever, 1999). The forces or laws that govern new emergent forms operate solely at lower levels of explanation, the level of local here-and-now process, of real-time dynamics in the physicochemical world; all causality involves micro- to macrolevel determination, not the reverse.

Advocates of an *ontological* conceptualization of emergence (e.g., Kunnen & van Geert, 2012a; Lewis, 2000b; van der Maas, 1995), in contrast, fully embrace the *causal irreducibility* of emergent form. Rather than privileging a bottom-up, microdeterministic view of cause, these advocates affirm both bottom-up, microlevel determinism and top-down, macrolevel determinism (Silberstein, 2006; Sperry, 1986). Top-down, *whole-to-parts* determinism, however, involves a fundamentally different mode of causal explanation than its bottom-up counterpart. Advocates of ontological emergence uniformly reject the notion of *efficient,* temporal causality from an independent higher level to a lower one. In effect, conceptualizing the vertically downward influence of higher-order wholes on their lower-order constituents in terms of the antecedent-consequent, force-like process orientation of efficient causality—distributed or otherwise—essentially amounts to a revival of vitalism (Campbell, 1974; Emmeche et al., 2000; Juarrero, 1999; Sperry, 1986). Instead, the top-down, macrolevel determinism of ontological emergence involves a *downward* or *systematic causation*, in which systems qua systems constrain the properties of their lower-order components and the interactions of those components with one another (Campbell, 1974; O'Connor, 1994; Silberstein, 2006). Systematic causation does not operate by generating new physicochemical "forces" or by altering existing forces but by *topologically constraining* the distributed, efficient causal interactions among the system's components (El-Hani & Pereira, 2000; Moreno, 2008). In other words, consistent with von Bertalanffy's treatment of system organization, systematic causation invokes formal and final explanations (El-Hani & Pereira, 2000; Emmeche et al., 2000; Juarrero, 1999). Through systematic causation, a system's organization—the unitary structure of the whole—constitutes a subject of explanation in its own right by establishing an *organizational* (i.e., formal) explanatory grounding for the very part-part relations that give rise to it. Macrolevel patterns are just as causally real as the microlevel dynamics that give rise to them.

In ontological emergence accounts, the explanatory causality of a system's organization rests in its top-down constraint. Constraint involves a lessening of variability, a narrowing of degrees of freedom, and as such plays a critical role in explanation by virtue of establishing limitations for what kinds of bottom-up processes are available to a given system; thus, the nature of local interactions cannot be fully understood divorced from the organizational whole in which these interactions are embedded (Deacon, 2012; Juarrero, 1999; Murphy, 2009; Thompson, 2007). Constraint—a negative property—refers to absence rather than presence. As Deacon (2012) articulated:

> The concept of constraint does not treat organization as though it is something added to a process or to an ensemble of elements. It is not something over and above these constituents and their relationships [*sic*] to one another. And yet it neither demotes organization to mere descriptive status nor does it confuse organization with the specifics of the components and their particular singular relationships [*sic*] to one another. Constraints are what is not there but could have been, irrespective of whether this is registered by any act of observation. (p. 192)

Constraints establish the causal power of a system by restricting its options for change and thereby promoting specific degrees of freedom under which the causal power of the system operates. In Deacon's words, "it is precisely by virtue of what is not enabled, but could otherwise have occurred, that a change can be forced.... whenever new constraints are generated, a specific capacity to do work is also generated" (p. 198). The system as a whole cannot be fully understood through decomposition into temporally sequenced part-to-part relations. It must also be simultaneously understood as a totality, in its own terms, by means of its organization and invariant ordering across the particularities of specific time and context (Witherington, 2011).

By espousing systematic causation via top-down constraint, ontological emergence approaches establish an inclusive, pluralistic approach to explanation, akin to GST, and endow the emergent organization of a system—its structure, form, pattern—with its own distinct kind of causal significance (Campbell, 1974; Silberstein, 2006; Silberstein & McGreever, 1999). In the process, these approaches evidence a strong commitment to the notion that multiple levels or orders of reality coexist, separate yet interdependent, in contrast to the exclusivist framework endorsed by sole reliance on epistemological emergence and the privileging of microdetermination (Bickhard & Campbell, 2000; Emmeche et al., 2000). Adherence to levels of organization undermines reductionist notions of a fundamental reality: cultural, social, and psychological levels of organization are as equally real as the physicochemical levels of organization on which they are built (Bickhard, 2008; Bickhard & Campbell, 2000). Reality assumes both a vertical and a horizontal dimension, both in terms of pattern and in terms of process (Witherington & Heying, 2013). In fact, the explanatory pluralism of ontological emergence approaches frames system behavior simultaneously in terms of its antecedent and material conditions and in terms of its higher-order patterning, the forms and functions of the behavior abstracted from the particularities of its specific content in context. This breaks down the arbitrary divide between process and pattern, cause and effect. Emmeche et al. (2000) explain that "upward and downward causes are not temporally distinct (the lower level does not cease to make up the higher one while this is assumed to 'cause back').... The same phenomena are at the same time cause and effect for each other" (p. 21). Bottom-up and top-down causes offer different but simultaneous levels of explanation, with neither level privileged either temporally or ontologically (Ellis, 2009).

In brief, epistemological emergence conceptualizes emergence exclusively in terms of the bottom-up generation of higher-order pattern from lower-order, local processes—processes to which the higher-order pattern causally reduces. Ontological emergence, however, conceptualizes emergence more broadly by invoking both local-to-global and global-to-local causality via the interdependence and interpenetration of micro and macro levels of reality, wherein "part and whole co-emerge and mutually specify each other" (Thompson, 2007, p. 38). Mapping these two conceptualizations of emergence onto the ontologically distinct stances of the DS approach to development is both straightforward and revealing: An inclusive DS approach embraces ontological emergence, whereas an exclusive DS approach embraces epistemological emergence (Witherington, 2011). What follows offers further delineation for each of these two DS approaches to development with an eye toward instantiating their ontological differences through the work and writings of their leading proponents.

THE INCLUSIVE DYNAMIC SYSTEMS APPROACH TO DEVELOPMENT: ALL IS ORGANIZED PROCESS

Illustrating the inclusive DS approach to development are the conceptual frameworks of Lewis and van Geert, two of

DS's most prominent adherents whose extensive theoretical writings vividly articulate the explanatory pluralism endemic to the inclusive narrative for the approach. Nearly 20 years ago, however, van der Maas (1995) was one of the first DS proponents to capture the heart of metatheoretical divide between an inclusive and exclusive DS approach in his trenchant critique of Thelen and Smith's (1994) antistructuralist stance:

> In spite of their rejection of reductionism, to me this is a reductionist view. The rejection of reductionism is only correct if structures influence the local processes that created them and initiate other local processes. . . . This is what self-organization is about. *The local processes are not more real than the emergent structures. One reason for this statement is that the local processes themselves are macroscopic structures of lower order local processes*. (pp. 631–632; *italics* added)

By asserting the ontological reality and causal irreducibility of higher-order wholes, van der Maas was advocating the admittance of structure into the explanatory efforts of a DS approach to development. Rejecting Thelen and Smith's absolutist stance toward process as foundational reality, van der Maas embraced what amounts to the perspectivism of von Bertalanffy's GST: All process is itself an organization (structure) and all organization is itself a process (function). Whether a phenomenon is construed in organizational/structural or dynamic/process-oriented terms depends on the perspective adopted toward the phenomenon (Witherington & Heying, 2013), for as van der Maas argued, no ontological dividing line exists between what constitutes process and what constitutes structure. Reframing this in the language of parts and wholes reveals a classic systems principle: Every part of a system is simultaneously a whole relative to its own lower-order parts, just as every system whole is simultaneously a part of a larger system whole (Sameroff, 1983).

This view of self-organization as structure-process reciprocity—not simply the privileging of process over structure through exclusive reliance on bottom-up dynamic construction of organization—stands as the cornerstone of an inclusive DS approach to development. It also happens to be reflected in a central principle from one of NDS's intellectual progenitors, the field of synergetics (Haken, 1977, 1996). That principle is *circular causality*, and no DS proponent has done more to explicitly uphold the centrality of this principle for understanding development through the DS approach than Lewis, to whose work the chapter now turns.

Lewis and the Centrality of Circular Causality

Grounded in a neo-Piagetian context, Lewis, even in his early forays into DS thinking (e.g., Lewis, 1994, 1995), emphasized the DS approach as a framework within which both microscopic dynamics and macroscopic structure, experientially specific trajectories of individual variation and stable diachronic organizational change, can reside as alternate, explanatorily compatible perspectives on the same whole. His work has taken particular aim at the interrelations among different levels of system organization—from relations between real- and developmental-time scales in cognition-emotion coupling to those between neurobiological and psychological levels of analysis—but always with an eye toward framing these vertical interrelations in *both* parts-to-whole *and* whole-to-parts terms (e.g., Lewis, 2000b, 2005; Lewis & Ferrari, 2001).

For Lewis, capturing the complexity of emergence in self-organizing systems entails *fully reciprocal bidirectional* (←→) relations both within and across levels of organization in systems and their development. These relations are manifested in two basic "directions of influence between scales of self-organization" (Lewis, 2002, p. 186). Lower-order interactions among components of a system yield higher-order forms, both at the scale of real-time self-organization by generating temporary, short-term emergent forms (e.g., organized, task-specific activity) and at the scale of developmental-time self-organization, by generating longer persisting, stable levels of organismic organization (e.g., stages of development). But just as critical to understanding development is the directional influence of these higher-order wholes—both those that emerge at short-time scales and those that characterize long-standing periods of developmental organization—on their lower-order components (Lewis, 2001, 2002).

The relational reciprocal bidirectional (←→) nature of influence in self-organizing systems revolves around two forms of process explanation: *reciprocal* and *circular causality* (Lewis, 2000b), depicted in Figure 3.7. Reciprocal causality simply reflects the bottom-up perspective of influence wherein lower-order components of a system nonlinearly coact with one another in part-to-part fashion to dynamically construct higher-order, macroscopic organization, (i.e., parts-to-whole influence). Circular causality broadens reciprocal causality by assigning explanatory status to *both* bottom-up and top-down processes, with full recognition of the different but simultaneous levels of explanation involved in each (e.g., temporal

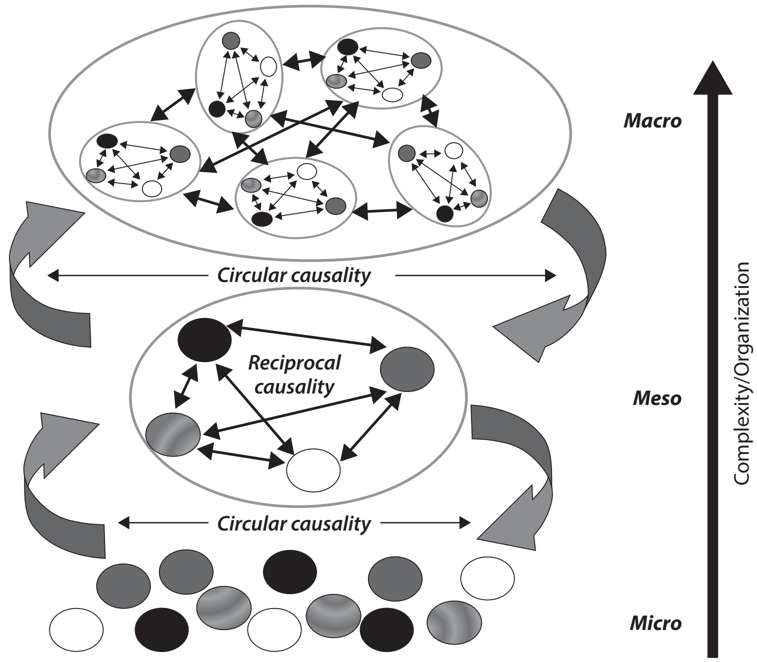


Figure 3.7 Illustration of reciprocal and circular causality, demonstrating both bottom-up dynamic construction and top-down organizational constraint.

Source: From *State Space Grids: Depicting Dynamics Across Development*, by T. Hollenstein, 2013, New York, NY: Springer (Figure 1.1, p. 4). Reprinted with kind permission from Springer+Business Media B.V. and from Tom Hollenstein.

precedence *and* atemporal embeddedness). In Lewis' (2005) words, circular causality means that "a coherent, higher-order form or function *causes* a particular pattern of coupling among lower-order elements, while this pattern simultaneously *causes* the higher-order form" (p. 174). Complementing the parts-to-whole perspective of bottom-up processes, top-down processes introduce hierarchy and higher-order form into explanation. As *systematic causes*, these whole-to-parts relations operate in terms of constraint: the system as higher-order, organizational whole conditions or constrains the degrees of freedom within which its local dynamics—the reciprocal causality of part-to-part relations—can operate (Haken, 1996; Juarrero, 1999; Kelso & Engstrom, 2006). In developing systems, this extends to what Lewis has called *cascading constraints* (Lewis, 1997), whereby the system's current organization constrains subsequent possibilities for organization in development such that "later assemblies must be compatible with the orderliness already laid down by earlier ones" (Lewis, 2000b, p. 40).

Lewis' adherence to the explanatory pluralism of circular causality is exemplified in his psychological model of emotional self-organization (Lewis, 1995, 2000b, 2005; Lewis & Granic, 1999b; see also Hollenstein, Lichtwarck-Aschoff, & Potworowski, 2013, for an extension of this model to the domain of socio-emotional flexibility). Articulated at three time scales of self-organization, the model delineates (1) the real-time, microdevelopmental emergence of emotion episodes over seconds and minutes, (2) the consolidation of mesodevelopmental mood patterning that can last hours, days, or weeks, and (3) the macrodevelopmental self-organization of personality structures that remain stable for months and years (Lewis, 2000b). With respect to the microdevelopmental self-organization of emotion episodes, Lewis has posited some form of "trigger"—such as a sensory event, a memory, or a change in arousal—as the initiation point for an emotion episode through its perturbation of the emotion system. This, in turn, sets in motion a process of "self-amplifying interaction among appraisal and emotion elements" (Lewis, 2005, p. 176), which eventually yields a higher-order patterning for the emotion system that Lewis (2000b; Lewis & Granic, 1999b) has termed an *emotional interpretation* (EI). Specifically, various cognitive appraisal components—concepts, expectations, images, plans—begin to couple or synchronize with one another around interaction with an emotional feeling state—"a global, non-reducible affective state . . . elicited by a specific class of situations related to the organism's goals" (Lewis & Granic, 1999b, p. 689)—via recursive, positive feedback loops, marking a phase of reciprocal amplification among these components. By the same token, reciprocal bidirectional causal relations among the cognitive and emotional components constrain one another via negative feedback loops (Lewis, 2005). The higher-order, irreducible whole (the EI) that emerges from these distributed, iterative causal relations constitutes a real-time intention for engaging the world. Whenever this temporary, organizational coherence of components—this particular EI—emerges in the context of a future perturbance of the system, it enjoys increasing stability in an individual's emotion system repertoire and comes to represent a behavioral attractor in that individual's state space, the topography of which routinely consists of multiple EI attractors at any given point in development.

Lewis has emphasized that emergent EIs themselves "cause the lower-order coordination of cognitive and affective elements that (circularly) cause those intentions" (Lewis, 2000b, p. 44), explaining the coupling of lower-order components through whole-to-parts constraint. The constraint that EIs establish for the entrainment of their cognitive and emotional constituents is invoked at the microdevelopmental level of real-time, temporary activity-in-context. Higher-order organizations of *moods* characterize emotional self-organization at the mesodevelopmental scale of hours, days, and weeks and constrain the microdevelopmental EIs from which they emerge. Moods constrain as temporary modifications of the *topography* of an individual's entire state space. Whereas EIs, as intentions, dissipate once action is taken, moods arise when actions in the service of the intention fail to satisfy the intention, leading to the preservation of organizational patterning in interpretation and emotion over an extended period of time. Moods reflect a longer-term emotional interpretation tendency, or a *global intentional orientation*, within which the real-time emergence of EIs is embedded, thereby constraining such real-time emergence (Lewis, 2000b, 2002). This means that real-time "interpretations of events no longer start from 'zero'" (Lewis, 2000b, p. 48) but instead are constrained by a modified state space topography that biases the system, "a temporary constriction of the state space, representing a cognitive-emotional bias: attractors are strengthened for some EIs and weakened or absent for others, and trajectories between states are more limited" (Lewis & Ferrari, 2001, p. 186).

Thus, real-time EIs give rise to more global mood orientations over longer time scales, just as mood orientations themselves constrain the real-time process of EI emergence. However, in their time scale of stability, moods only involve temporary reconfigurations of an individual's state space, leading to biased orientations at the time scale of hours, days, and weeks. Macrodevelopmental time scales of organizational stability at the level of months and years involve more firmly entrenched topographical changes in the state space, built up from the mesodevelopmental level of moods, which "not only modify the cognitive-emotional state space temporarily but lay down permanent changes if they recur sufficiently often" (Lewis, 2000b, p. 57). Lewis has characterized this long-term organizational stability as personality—or continuity in sense of self—reflecting a stable, cross-situational manner by which individuals intentionally engage their worlds. In circular causal fashion, macrodevelopmental organizational qualities constrain the mesodevelopmental emergence of moods, which constrain the cognitive-emotion relations of real-time, microdevelopment: "Thus, it is the nesting of mood in personality that constrains EIs in real time, and their joint effects curtail the variance available for making sense of and feeling about the world" (Lewis & Ferrari, 2001, p. 189).

Throughout Lewis' writings on emotional self-organization and cognition-emotion interplay—both at the psychological and the neurophysiological levels—his articulations of the DS approach have relied on "hierarchically nested self-organizing processes, by which the emergent products at each level assemble themselves according to complementarities among their elements and constraints from above and below" (Lewis & Ferrari, 2001, p. 189). From the concreteness of activity in the here-and-now to the abstraction of structures stably maintained in developmental time, higher-order forms *organizationally constrain* the coupling of lower-order components, which themselves give rise to the higher-order pattern through real-time, bottom-up processes of dynamic construction. Developmental-time *organized process* both emerges from real-time *organized process* and constrains in circular causal fashion the very real-time organized dynamics that gave rise to it (Witherington, 2011). Lewis' inclusive DS approach to development is as committed to the ever-present hierarchy of organization within which dynamic, local process is embedded as it is to the dynamic construction of new levels of organization through the real-time particularities of specific actions in context, demonstrating his approach's grounding in the ontological reality and explanatory significance of higher-order form—both synchronic and diachronic—not just lower-order dynamic process.

Lewis' inclusive focus on structural constraint translates directly to his empirical work and methodological innovation. Methodologically, Lewis and his colleagues have developed and successfully applied a technique for graphically realizing preferred behavioral states (attractors) that is suitable for categorical or ordinal data and amenable to more traditional analytic strategies in psychology: *the state space grid* (e.g., Granic, Hollenstein, Dishion, & Patterson, 2003; Hollenstein, 2013; Hollenstein & Lewis, 2006; Lewis, Lamey, & Douglas, 1999; Martin, Fabes, Hanish, & Hollenstein, 2005). State space grids consist of two ordinal or categorical variables measured in time-locked fashion over a real-time, microdevelopmental period for a given system, such as an individual child or a single dyad. These variables produce a two-dimensional cell matrix for the system, juxtaposing, for example, five intensity levels of infant distress expressions with five levels of infant gazing activity to create a 25-cell state space grid of possible behavioral states (Lewis et al., 1999). Measurements of attractor strength within the state space grid may involve simple frequency counts for visits to regions of the space, assessments of how quickly attractors that have been occupied are again occupied, or analyses of the probability that cell activity outside of the attractor areas at time 1 will fall into the attractor area at time 2 (DiDonato, England, Martin, & Amazeen, 2013). Individual systems studied longitudinally generate state space grids for each longitudinal sampling point and allow for the charting of changes in cell values across grids, revealing potential qualitative transitions in system organization over developmental time (e.g., Lewis, Zimmerman, Hollenstein, & Lamey, 2004).

Empirical applications of the state space grid methodology to young children's socio-emotional development have revealed *both* neo-Piagetian inspired stage shifts in the *formal* organization of socio-emotional activity *and* individual variation in its *content* across these bifurcations, or phase transitions (Lewis et al., 1999; Lewis et al., 2004; Lewis & Cook, 2007). By actively employing the topological, qualitative methods of nonlinear dynamics within the organizationally focused conceptual framework of stage theory, Lewis has demonstrated the thoroughgoing compatibility of traditional structuralist models of development with developmental science's current focus on real-time variation and temporal dynamics. The utility of couching the "dynamics of wholeness" mathematics of NDS within the broader holistic structuralism of systems thinking—the "wholeness of dynamics" perspective—finds its fullest elaboration in the work of the "Dutch Masters" (Lewis, 2011b), such as van der Maas and Molenaar's applications of catastrophe theory to the study of Piagetian stage transitions (e.g., Jansen & van der Maas, 2001; Molenaar & Raijmakers, 2000; van der Maas & Molenaar, 1992; van der Maas & Raijmakers, 2009). No Dutch Master, however, has had a greater influence on the establishment of an inclusive metatheoretical framework for the DS approach to development than van Geert.

Van Geert and the "Groningen Approach"

Van Geert has long championed a principally *methodological* and *analytic* rendering of the DS approach to development, viewing the approach as a mathematical tool for supplementing conceptual frameworks already evident in the holistic structuralism accounts of classic developmental science, such as the work of Piaget (e.g., van Geert, 1997a, 1998b; van Geert & Steenbeek, 2005). In van Geert's (2004) words:

> The dynamic viewpoint is perfectly compatible with a great variety of developmental theories, simply because they entail many principles of change that are intrinsically dynamic. In that case, the dynamic viewpoint is almost like a methodological addition to those theories, providing them with tools that help them turn their conceptual statements into mathematically formulated, deductive models. (p. 374)

For van Geert and his Groningen approach, the defining feature of a DS approach to development rests in its *iterative* or *recursive focus*, wherein the state of a variable at time $t + 1$ is viewed as a function of the state of that variable at time t (van Geert, 1997a; van Geert & Fischer, 2009; van Geert & Steenbeek, 2005). In other words, the DS approach concerns itself with how one state transforms into another state over time—in broader terms, with developmental sequence and the process of movement from a preceding developmental level of organization to a subsequent one—and "any model that complies with this basic definition is a dynamic systems model" (van Geert & Steenbeek, 2005, p. 412).

With respect to what kinds of variables constitute appropriate material for dynamic systems modeling, van Geert (1997a) has adopted an "extremely liberal stance" (p. 280), arguing that the variable "need not be a physical thing and neither does it need to be directly reducible to known physical states of a system" (van Geert & Fischer, 2009,

p. 317). The level of organizational abstraction involved in a construct or variable is, in fact, immaterial to its viability as a frame of understanding within the DS approach to development. To quote van Geert (2006), "mathematics is a tool for understanding reality and is thus applicable to virtually anything that can be conceptualized, observed, or presumed, at any stage of psychological inquiry" (p. 504). Like Lewis, van Geert has argued for the ontological "reality" of all levels of organizational abstraction, from lower-order concrete acts to higher-order structural wholes (van Geert, 1998b, 2011; van Geert & Fischer, 2009). Thus, transformations from one context-general, organismic state of a system to another across macrodevelopmental time—for example, the transformation from one level of development in object permanence to another or from sensorimotor to preoperational intelligence—represent just as legitimate an ontological focus for DS modeling as the transformations from one real-time behavioral state to another in both micro- and macrodevelopmental time, for example, the shift from a walking to a running gait or the developmental transition from one kind of search behavior to another.

In their DS modeling efforts, van Geert and his Groningen colleagues have run the gamut from microdevelopmental studies of dyadic play—involving psychological parameters such as appraisals and goals—to macrodevelopmental studies of identity (e.g., Lichtwarck-Aschoff, Kunnen, & van Geert, 2010; Lichtwarck-Aschoff, van Geert, Bosma, & Kunnen, 2008; Steenbeek & van Geert, 2007, 2008; Vleioras, van Geert, & Bosma, 2008). Much of their modeling work makes use of logistic growth equations based on the Verhulst equation designed to model species population growth. As previously discussed, these iterative difference equations employ both positive and negative feedback loops to model the pattern transformative and pattern conservative forces at work in developmental process. Van Geert (1997a, 2000) has explicitly pointed out that the same kind of iterative processes undergird the local dynamics foundational to Piaget's model of development, as well as those of other classic systems theorists, such as Vygotsky. In fact, earlier modeling work by van Geert (1998a, 2000) notably produced successful developmental simulations of Piaget's broad stages of intelligence by computationally implementing the local process interplay of assimilation and accommodation.

Eschewing any form of foundationalism, proponents of the Groningen approach have explicitly articulated the relativity of "macro" and "micro" designations, recognizing that any level of an organizational whole, no matter how "abstract," can always be viewed as part of the bottom-up dynamics of some higher-order level of organization, just as the most "concrete" of system components can itself be viewed as a top-down, constraining whole relative to its lower-order dynamics (e.g., Kunnen & van Geert, 2012b; van Geert, 2011). Consequently, under the auspices of the Groningen approach, *explanation in developmental science involves the articulation of both structure and dynamics—organization and process—as complementary explanatory frames*, with the structures and stages characteristic of Piaget's and other classic systems approaches to development regarded not simply as epiphenomenal or illusory outgrowths of real-time, local dynamics but as explanatorily significant ways to structure our understanding of the local dynamics themselves, "enabl(ing) one to make developmentally relevant distinctions" (van Geert, 2006, p. 502; see also van Geert, 1998b). In other words, the characterization of organisms and their development in integrated whole terms is just as indispensible an explanatory context for the understanding of local dynamic fluctuation and variability as the characterization of local dynamics is for explaining the structure of the organism and its development as a whole.

Like Lewis, van Geert has appealed to the structure or topography of the state space to capture the context-general organization of organisms, both synchronically and diachronically. As van Geert (1997b) has suggested:

> a person's skill (or competence, ability, or whatever word one wishes to use) should be viewed as a *particular range in a phase space* . . . a competence, qua psychological property of a subject, is context-determined, as well as a well-defined property of the subject. (p. 196)

Just as the real-time dynamics of motion that take place within a state space are necessarily constrained by the stable structural properties of that state space, so an articulation of a system's real-time activity in context is necessarily framed within a broader understanding of the system qua system of that which characterizes the organism as a whole across time: "the person in his characteristic multitude of contexts" (van Geert & Fischer, 2009, p. 327; see also van Geert, 2006). As Piaget (1952) argued, every action of the organism speaks both to task-specific adaptation and to organism-specific organization. Or to quote van Geert and Steenbeek (2008) specifically with respect to the cognitive characterization of organisms, "knowledge and concepts are at the same time substance and process . . . are at the same time transient and 'soft-assembled' on the one hand and causal and conditional entities of the mind on the other" (p. 76).

As should now be evident, proponents of the Groningen approach, such as Lewis and his colleagues, embrace the explanatory pluralism of circular causality (Kunnen, Lichtwarck-Aschoff, & van Geert, 2012; Kunnen & van Geert, 2012a, 2012b; Lichtwarck-Aschoff et al., 2008). Their full endorsement of circular causality—across levels of organizational and time-scale abstraction—establishes *both* the here-and-now activity of an organism within a temporally specific context *and* the context-general, organizational quality that characterizes the organism in the longer term as distinct but complementary frames of explanation (van Geert, 1997b, 2003; van Geert & Fischer, 2009). Lichtwarck-Aschoff et al. (2008) have noted that "because of this reciprocal relationship between micro level processes and macroscopic structures, direct cross-generalizations across different time scales are in fact problematic" (p. 378). Invoking macroscopic structures as short-term antecedent mechanisms for understanding microdevelopmental process violates the distinct but reciprocal explanatory frames offered by these different contexts of analysis. Yet just as problematic is a reduction of macrolevel structure to microdevelopmental processes. It thus proves critical to establish both micro- and macrolevels of explanation for any phenomenon and its development and to recognize the complementary but unique processes involved as a function of the time scale and level of organization examined.

For an example of their commitment to circular causality, consider forays by proponents of the Groningen approach into the study of identity formation across both micro- and macrolevels of development. As Kunnen et al. (2012) have highlighted:

> Identity on a developmental time scale emerges out of real-time and day-to-day experiences, interactions and processes—that is, how one defines oneself is the product of many cumulative real-time interactions with the environment. At the same time, behaviors, thoughts, and emotions are constrained by the way a person defines herself. One's identity, self-definition, commitments, and values will determine why, when and how one reacts to a potential threat to one's identity—the identity sets the conditions and defines the parameters of the immediate goals and concerns. (p. 154)

With respect to the development of identity from early adolescence to adulthood, Kunnen and her colleagues have distinguished between specific micro and macrolevel qualities of identity formation. Microlevel dynamic aspects of identity revolve around real-time, nonreflective activity in context, that is, the context-specific couplings of real-time goals, emotions, thoughts, and actions in daily experiences involving conflicts over autonomy issues and the thwarting of specific goals. Macro-level dynamic aspects of identity, in contrast, revolve around individuals' explicit reflections on and abstractions of their stable and characteristic features, that is, commitment structures and levels of meaning making in knowing who one is and what one wants to be that are maintained and transformed in the midst of external information either consistent or actively conflicting with these extant structures (Kunnen, 2012; Kunnen & Bosma, 2000, 2012; Lichtwarck-Aschoff et al., 2008). Attempts to integrate the micro-level dynamics of real-time, specific goal-related conflicts and the macro-level dynamics of commitment formation have emerged from the Groningen group in the form of DS mathematical models that chart the coupled relations between the growth of autonomy and the growth of connectedness over developmental-time, employing parameters that instantiate both local, real-time dynamics and macroscopically stable characteristics of the system to attempt to capture bottom-up processes of dynamic construction *and* top-down processes of constraint (e.g., Kunnen et al., 2012; Lichtwarck-Aschoff et al., 2008).

Van Geert and his Groningen approach colleagues remain at the forefront of efforts to bring the quantitative mathematics of NDS to developmental science. Their work has few rivals both in terms of its mathematical rigor and its thoroughgoing process orientation, with strong emphasis placed on promoting the study of intraindividual variability in small *n*, longitudinal samples of individual systems (e.g., van Dijk & van Geert, 2007; van Geert & van Dijk, 2002). Yet despite the grounding of their work in the short-term fluctuation and variability of real-time dynamics, van Geert and his colleagues have endeavored to maintain equal grounding in the broader, macrodevelopmental structures and general processes for which the classic grand narratives of developmental science are known. Akin to the inclusive DS orientation of Lewis and his colleagues, proponents of the Groningen approach regard the dynamics of wholeness perspective of NDS not as a substitute for the holistic structuralism of classic systems perspectives but as a *supplement* to the explanatory legitimacy of organization. In the Groningen approach, all local dynamics of process operate within certain conditions of constraint—conditions which themselves transform over developmental time—and the grand narratives of Piaget, Werner, Vygotsky, and others have already established fully viable renderings of these constraints, specifically in terms of the synchronic and diachronic structures of developmental sequence. Thus, the inclusive DS approach to development—instantiated in the work of Lewis, van Geert, and their research colleagues—brings to developmental science a much needed focus on the real-time dynamics of process *without losing sight* either of the organizational whole that is the organism/system at any given point in time or of the developmental sequence of wholes within which the organism's/system's current level of organization is embedded. Full appreciation of the meaning of an organism's actions within its world requires *both* an embedding of that activity in the real-time dynamics of process *and* in the dynamically maintained structure or organization of the organism taken as a whole, across time and contexts, which itself is meaningful only when fully embedded within a developmental sequence of wholes.

THE EXCLUSIVE DYNAMIC SYSTEMS APPROACH TO DEVELOPMENT: ALL IS PROCESS, AND ORGANIZATION IS DERIVED

Undercutting the explanatory pluralism of the inclusive DS approach, the exclusive DS approach to development—instantiated most notably in the writings of Thelen and Smith, as well as Spencer—*privileges* the dynamics of wholeness vantage point over a wholeness of dynamics perspective. For proponents of the exclusive DS approach, all explanatory efforts ultimately resolve to the here-and-now dynamics of process, with the adaptive context of real-time activity becoming the only meaningful focus of scientific understanding. Proponents deny the explanatory legitimacy of atemporal, organizational abstraction, arguing instead that characterizations of the organism as a system totality—abstracted across time and context and embedded within a directional sequence of transformations in system organization—offer little insight into an understanding of systems and their activity until such characterizations are embedded and embodied in time-dependent, process-oriented, *dynamics of wholeness* terms. As such, the exclusive DS approach to development differs from its inclusive counterpart by its *antistructuralist stance*: Explanation arrives by embedding an organism's activity *exclusively* in the real-time, content-specific dynamics of adaptation (Witherington, 2007, 2011; Witherington & Heying, 2013; Witherington & Margett, 2011).

It is important to note that this antistructuralist stance amounts to a repudiation of *structural explanation*, not to a repudiation of "mental structures" per se. Though Thelen and Smith's early articulations of the approach (e.g., Smith & Thelen, 1993; Thelen & Smith, 1994, 1998) largely targeted behavioral and motor development—and, in the process, marginalized the "psychological" world of the organism by emphasizing, in particular, how organisms directly act on and in the world rather than via mediating representations of the world—Thelen, especially in her later writings (e.g., Thelen, 2005; Thelen & Bates, 2003; Thelen & Smith, 2006), markedly softened the anti-mental-structure rhetoric attached to her motor development articulations of the DS approach. As Thelen and Bates (2003) explained:

> Gibson's ideas had a strong influence on the initial works within dynamic systems theory as it was first applied to behavioral development (especially motor development). This emphasis on structure *outside the organism* led to a de-emphasis on the structures that are building up *inside the organism*. As a result Thelen and Smith's two books in 1994 focused more on behavior than the contents of the mind . . . in fact, there is no incompatibility between dynamic systems theory and the exploration of mental structures. . . . The difference has been really a matter of emphasis. (p. 388)

In fact, mental structures—in the sense of system components that characterize the inner, psychological workings of the organism—play an integral role in the dynamic field theory of embodied cognition first articulated in Thelen and Smith's dynamic systems reconceptualization of infants' A-not-B errors. Over the past decade, dynamic field theory has received theoretical and empirical elaboration in the neurologically oriented cognitive development work of Spencer and his colleagues and currently stands as the most prominent theoretical/modeling outgrowth of the exclusive DS approach to development (e.g., Buss & Spencer, 2014; Johnson, Spencer, & Schöner, 2008; Schutte & Spencer, 2010; Simmering, Schutte, & Spencer, 2008; Simmering & Spencer, 2008; Smith, Thelen, Titzer, & McLin, 1999; Spencer & Schöner, 2003; Thelen et al., 2001).

Nonetheless, an acceptance of structures, mental or physical, as components or parts of the organismic system does not entail an acceptance of holistic structuralism: the explanatory significance of structure *as a whole*. Proponents of the exclusive DS approach to development embed all talk of structure within the real-time initiating forces that give rise—in antecedent-consequent fashion—to physical activity in context. In other words, structures become legitimate facets of explanation only to the extent that they operate as real-time parts of a system in conjunction with other structures or parts—both intra- and extraorganismic—all of which, by means of their reciprocal relations with one another, contribute in bottom-up fashion to the establishment of system patterning, equally and without prescription. Structure as *abstraction* from real-time activity, signifying the form or organizational quality of that activity as a whole, still holds no explanatory value within the exclusive DS approach (Witherington, 2007, 2011; Witherington & Heying, 2013). Such a *monistic* approach to explanation promotes a kind of foundationalism in which the higher-order, organizational properties of systems ultimately reduce to the real-time dynamics of system process (Witherington, 2011). To illustrate this explanatory monism and its implications for an understanding of development, the chapter now turns to a general overview of the dynamic field theory of embodied cognition from Thelen and Smith, Spencer, and their colleagues.

Explanatory Monism: Conflating Structural Reification and Holistic Structuralism

The dynamic field theory of embodied cognition takes as its central focus the question of how higher-order psychological constructs, such as cognition, are coupled to the real-time dynamics of physical activity in a physical world (Smith, 2005; Spencer, Perone, et al., 2009; Thelen et al., 2001). It answers this question by integrating perceptual, motor, and cognitive activity all within the same field of real-time movement dynamics, neurologically grounding cognition in the process (Spencer, Perone, et al., 2009; Spencer & Schöner, 2003). Cognition, in this light, concerns the real-time adaptive acts of organisms in relation to task contexts; more specifically, cognition manifests as memory and representational states, which take the form of time-dependent neural activation patterns associated with an event in the world being "re-presented to the nervous system in the absence of the input that specified that event" and creating self-sustaining organismic activity (Spencer & Schöner, 2003, p. 393). Cognition as a context-general characterization of a living system's organization, *abstracted* from the time-dependence of real-time activity in task-specific context, is wholly absent from consideration. From the standpoint of dynamic field theory, in fact, the only explanatory value of cognition (or of psychological constructs in general) lies in its being "bound to the real time bodily processes through which we act in a physical world" (Smith, 2005, p. 288), for such constructs are "only useful if . . . linkable in context to my real-time sensorimotor activity" (Spencer, Perone, et al., 2009, p. 88). Rendering psychological constructs meaningful, in other words, involves casting these processes in the same continuous, spatiotemporal terms as physical body movements and neurological functioning, because "the remembered and abstract inputs to the action must remain compatible with and continuously coupled to the motor decision field so that the inputs can be meshed together to specify the action" (Thelen et al., 2001, p. 74).

Dynamic field theory has yielded a general model for the processes that underlie "goal-directed actions to remembered locations" (Spencer & Schöner, 2003, p. 402). It has successfully captured the real-time variability of behavior both across a series of spatial search tasks—such as different forms of the Piagetian A-not-B task, spatial recall and position discrimination tasks—and across time scales of developmental organization—ranging from infancy to adulthood (e.g., Clearfield, Dineva, Smith, Diedrich, & Thelen, 2009; Schutte & Spencer, 2010; Simmering et al., 2008; Simmering & Spencer, 2008; Spencer, Austin, & Schutte, 2012; Thelen et al., 2001). Elaborations of the model also apply to other domains of functioning, such as habituation, perceptual learning, and visual cognition (e.g., Buss & Spencer, 2014; Johnson et al., 2008; Schöner & Thelen, 2006; Spencer et al., 2011; Spencer et al., 2012). These models exemplify a local-to-global focus, wherein the dynamic modeling of time-dependent relations among brain, body, and environment jointly produce patterning in organismic functioning, and have made critical contributions to the dynamics of wholeness focus as applied to developmental phenomena. However, proponents of dynamic field theory also cast their model as a *substitute* for what they consider the illegitimate explanatory frame that global-to-local approaches employ when viewing performance in tasks such as A-not-B from the standpoint of the *epistemic subject*—from the vantage point of the organism as a "subjectively *lived body*" (Colombetti & Thompson, 2008, p. 56) meaningfully engaged with its world through different levels of developmental organization (Witherington & Heying, 2013). In so doing, proponents show the privilege of one form of explanation over another and paint both levels of explanation as competing alternatives rather than as complementary parts of a unified whole.

Consider dynamic field theory's ontological approach to the Piagetian A-not-B error (e.g., Clearfield et al., 2009;

Smith et al., 1999; Spencer et al., 2011). In the A-not-B error, infants in Stage 4 of Piaget's 6-stage object concept sequence successfully retrieve an object completely hidden in Location A, but when the object is subsequently hidden in a new location (B), infants will persist in searching for the object in its original hiding location (A). Framed in traditional Piagetian terms, the A-not-B error indexes a certain level of organization in the development of infants' objectification of self and world—that is, the object concept—via progressive differentiation of their activity from the objects on which they act. Piaget articulated the formal properties of this activity—its formal explanation—in terms of partial but incomplete phenomenological objectification of self and world: objects, though now clearly differentiated for the infant from her or his activity, nonetheless remain wed to a particular spatial location and are therefore not fully objectified (Piaget, 1954).

Proponents of dynamic field theory summarily reject Piaget's formal explanation for the A-not-B error and substitute what they consider an "embodied" conceptualization of performance, consisting of an organism's general reaching and remembering skills, their particular history of reaching to and looking at A, issues related to the task space itself, and the timing of reaching relative to the object's hiding. Proponents further argue that shifting relations among these sensorimotor and representational parameters—unfolding in real-time within particular task circumstances—account for both errors and successes in reaching for occluded objects *irrespective of the level of developmental organization*, meaning that the same dynamics explain both the perseverative reaching errors of young infants and the absent-minded errors of adults (e.g., automatically reaching for your keys where you normally keep them) (Spencer et al., 2011; Spencer & Schutte, 2004; Thelen et al., 2001). In Spencer and Schöner's (2003) words:

> The same developmental insights that capture changes in infants' performance in the A-not-B task can account for both qualitative and quantitative changes in the stability of spatial working memory processes later in development. (p. 402)

Indeed, from the task-focused vantage point of the local processes involved, A-not-B performance can be captured in infants, children, and adults by the same activation field dynamics (Spencer, Dineva, et al., 2009; Spencer et al., 2011). Yet although the local dynamics of perseverative reaching errors in young infants and the absent-minded errors of adults look comparable when framed in terms of behavioral content in a task-specific context, contextualizing this activity more broadly in terms of its formal, organizational properties—embedding the activity in the organism as an integrated whole—reveals dramatic differences, reflected in different levels of developmental meaning and significance, both for the person and her or his observers, and different characteristic engagements between the person and her or his world. As a developmental scientist, one would be hard pressed to argue that an A-not-B error holds the same epistemic meaning for an 8-month-old as compared to a 2-year-old or an adult. From the wholeness of dynamics vantage point, the very meaning of the task itself, the organizational significance of the organism's action in the task context, and the likely ramifications of such action in context for future activity all differ as a function of an organism's particular level of developmental organization. But by grounding explanation of the A-not-B error at any point in development solely in terms of "the coupled dynamics of looking, planning, reaching, and remembering within the particular context of the task" (Thelen et al., 2001, p. 5), dynamic field theory denies the explanatory importance attached to embedding any given A-not-B performance within a developmental sequence of organizational forms reflecting the organism as an integrated whole across time.

Why do dynamic field theory proponents soundly reject Piaget's—or any holistic structuralist's—formal explanatory stance as a legitimate frame of reference for understanding A-not-B performance in infancy, rather than viewing their dynamic account as a complement to the organizational framework of Piaget? Their rejection stems from the exclusive DS approach's ontological adherence to an explanatory framework based solely in terms of bottom-up, here and now, temporally unfolding antecedents to behavior (Witherington, 2007, 2011; Witherington & Heying, 2013). Constructs like object concept—which capture the formal, organizational aspects of real-time activity from the standpoint of the organism as an integrated whole—simply hold no explanatory power precisely because they are "timeless" and abstracted; lacking temporal and concrete grounding, how could such constructs explain anything? Proponents of dynamic field theory couch their conceptualization of explanation firmly in the realm of *antecedents* to behavioral *content*, not in the realm of abstracted form, viewing all invocations of structural explanation in exclusive functional, "push-from-behind" terms rather than in organizational, constraint terms (Witherington, 2007). Failing to acknowledge that structural explanation operates by means of formal and final explanatory processes, they read any explanatory appeal to structural wholes as a case of structural reification, calling forth the specter of an instruction-filled homunculus that temporally precedes and controls the behavior it explains. This amounts to a conflation of *structural explanation*—which appeals to formal and final processes of constraint, not temporal antecedents—with *structural reification*—by which higher-order forms are divested of their status as abstractions and rendered instead as concrete, underlying determinants of behavior via the temporal precedence of efficient causal control.

The local-to-global, distributed efficient causal lens through which dynamic field theory operates is most thoroughly articulated in Thelen et al.'s (2001; see also Thelen & Smith, 1994) conceptualization of Piagetian formal explanation. Thelen et al. make the all-too-common mistake of construing Piaget's object concept account in functional, antecedent-consequent terms, as a concrete "entity" or cause that temporally precedes, exists independent of, and serves as the efficient causal force for the real-time performance of an organism in context (Müller & Carpendale, 2001; Staddon, Machado, & Lourenço, 2001; Witherington, 2007). Given that such an abstracted entity cannot readily account for the enormous context-dependent variability in infant responding to the task and that no reasonable account exists for how this abstracted entity could actually motivate real, physical activity in the real, physical world, Thelen et al. (2001) argue that the object concept is explanatorily vacuous; psychological concepts such as object concept "do not offer us any help in understanding the mechanisms and processes involved in succeeding or failing at the A-not-B . . . there is a gap between invoking such constructs and specifying how they actually operate to motivate real-life behavior" (pp. 71–72).

In response to commentaries by Müller and Carpendale (2001) and Staddon et al. (2001) that underscore Piagetian explanation as formal, not functional in nature, Thelen et al. (2001) exposed the explanatory monism of the exclusive DS approach by asking "[W]hat is the real use of a mental structure with only formal properties?" (p. 71) and "if Piaget meant for mental structures to be only formal descriptions, our foundational issue remains: [W]here are the mechanisms that produce behavior?" (p. 72). These questions reflect the exclusive DS approach's assumption that structural accounts offer explanation only insofar as they involve temporally based, distributed efficient causal mechanisms, concretely grounded in real-time movement dynamics. Because structures, as abstractions, cannot cause in that fashion, structural explanation cannot serve as true explanation. This argument fails to acknowledge that structure and organization can explain in their own right and on their own terms as frameworks via formal and final processes of constraint, within which the particular, real-time dynamics of activity are meaningfully contextualized (see Overton, Chapter 2, this *Handbook*, this volume). Thus, from the ontological perspective of an exclusive DS approach to development, the organizational explanation offered in Piaget's account cannot possibly complement a dynamics of wholeness analysis at the level of real-time activity in adaptive context, for appealing to an object concept does not make sense within an antecedent-consequent framework of temporal relations: "The A-not-B error is not about what infants *have* and *don't have* as enduring concepts, traits, or deficits but what they *are doing* and *have done*" (Thelen et al., 2001, p. 4). But by reducing the organism as a whole to its activity in context, dynamic field theory loses sight of the organizational whole that characterizes organismic functioning in its synchronic and diachronic totality.

Soft Assembly: Privileging Activity in the Here-and-Now

For dynamic field theory specifically—and the exclusive DS approach to development generally—explaining an organism's activity arrives *not* by abstracting higher-order synchronic and diachronic forms/organizational qualities from that activity and embedding that activity within those forms *but* by framing activity exclusively in terms of here-and-now adaptation to local contexts (Witherington, 2007, 2011). The "global order" that characterizes systems within any given level of developmental organization—across contexts and real-time activity—and the orderly sequence of organizational transformations that characterizes such systems across developmental-time are epiphenomenal abstractions that lose sight of the real-time processes unfolding in the particularities of local context (Thelen & Smith, 1994). These global orders are mere *appearance* masking a *reality* of real-time activity in adaptive context. Understanding development thus requires a grounding of all analysis in the variability that time-dependent activity demonstrates during adaptive encounters with everyday contexts, for "what happens on the local level in real-time experience determines the developmental trajectory" (Smith & Thelen, 1993, p. 165) as "developmental time is continuous with and indeed fabricated from real-time experience" (Thelen & Smith, 1994, p. 304; see also Spencer & Perone, 2008).

The adaptive context stands front and center in the explanatory monism of the exclusive DS approach to development, with *activity as adaptation to local contexts* becoming the defining feature of organism-environment transaction in real- and developmental-time. This adaptationist focus is reflected in the principle of *soft assembly*, "the core assumption of a dynamic view of development" (Thelen & Smith, 2006, p. 274) within the exclusive DS approach. Soft assembly means that the components of a system "can assemble in many ways" (Thelen & Smith, 2006, p. 274) to yield differential real-time patterns of behavior in conjunction with the exigencies of specific contextual demands. Within this framework, "the emphasis is on how people assemble behavior in the moment in context" (Spencer et al., 2011, p. 261), and the organism as system becomes identified with its real-time adaptive efforts in the world. This renders questions of organization and patterning in the organism qua system meaningful only when couched in terms of the instrumental, problem-solving qualities of the organism's activity, "the pragmatic dimension of action" (Overton, 2006, p. 23). Rather than being viewed as an integrated whole that actively maintains its own macroscopic organization in the face of microscopic flux, the organism, as a self-organizing system, reduces to "patterns of behavior 'softly assembled' from multiple, heterogeneous components exhibiting various degrees of stability and change" with its development "envisioned as a series of patterns evolving and dissolving over time" (Thelen & Smith, 2006, p. 276). Patterning only counts at the level of time-dependent behavioral content, not at the level of abstracted system form.

When coupled with its antistructuralist stance, the adaptationist focus of the exclusive DS approach treats organization as an outgrowth of adaptation *but not also* as a precondition for adaptation. Viewed through the exclusivist lens of an adaptation focus, organization always operates in the service of adaptation and, in fact, reduces to adaptation in local context. Real-time activity gains no meaning from being embedded within the higher-order wholes that characterize the organizational invariance of the organism qua organism, that *singular*, *instantaneous* totality of the system as a whole. Such patterning, capturing as it does the context-general characteristics of systems, abstracted from their real-time adaptive activity, is discounted as explanatorily vacuous because, as an abstracted rendering, it fails to account for variability in behavioral content: "details are messy and fluid because problem solving is dynamic by its very nature" (Thelen & Smith, 1994, p. 311). The organism consequently becomes a collection of local acts of problem solving, a collection of attractor states reflecting real-time behavioral states in a problem-solving state space.

In the exclusive DS approach, "attractor states are not sitting around; they are not competencies waiting to be tapped. Rather, attractors come and go in real time—the attractor landscape is dynamic and changing on the timescale of behavior" (Spencer & Perone, 2008, p. 1644). This in itself certainly holds from the vantage point of an inclusive approach, as well—at least under conditions that attractor states are used to model real-time behavior—but for inclusive DS proponents, the structural properties, or topological constraints, that characterize the attractor landscape as a whole are just as critical to explanatory efforts in a DS approach as the ever-changing behavioral attractor states. The structure of the system qua system frames the dynamic variability that operates within its boundaries, determining and lending meaning to the range of potential activity available within any given period of system stability at the level of its overall organization. Such structural constraint is reflected in the "competency" of a system—the stable topography of its landscape for any given period of developmental time—and provides a meaningful framework within which to embed our understanding of real-time adaptations to local context, making it indispensable to a full understanding of system patterning (Lewis, 2000b, 2002; van Geert, 1997b, 2006; van Geert & Steenbeek, 2008).

For inclusive DS proponents, the "action-in-context" level of analysis—though certainly critical for understanding in its own right—cannot substitute for the explanatory perspective yielded through an organism qua organism level of analysis, abstracted across attractor states to characterize the phase space as a topographical whole. Instead, both perspectives on system activity—the instrumental-communicative and the expressive-constitutive (Overton, 2006, 2010)—complement one another and offer different levels of explanation. For *exclusive* DS proponents, in contrast, competencies, as abstractions, are necessarily removed from the variability of specific activity in context and therefore superfluous to understanding (Spencer et al., 2011; Thelen & Smith, 1994, 2006). Knowing does not constitute an abstract, context-independent property of organismic functioning but instead becomes another real-time activity, always "in the service of a task" (Thelen & Smith, 2006, p. 303) and never a means by which the very "task" nature of a context is defined. Content to explain action solely in terms of its instrumental functions—as task-specific adaptation—proponents of the exclusive DS approach to development define the organization of a system in terms of adaptation to local context without entertaining the complementary vantage point, that of defining a system's adaptation to local context in terms of its organization (Witherington, 2007, 2011).

Such a repudiation of organization's explanatory role derails the wholeness of dynamics perspective and the unique lens of inquiry it brings to the study of development, resulting in the reduction of developmental time to real time. As an integral facet of developmental explanation for *inclusive* DS proponents, the wholeness of dynamics perspective embeds an organism's current level of organization within a transformational sequence of prior and subsequent levels of organization across developmental time (Mascolo, Pollack, & Fischer, 1997; Murray, 1991; Overton, 1991, 2010). This establishes the developmental context as one of *temporal sequence*, or *structured* time, in which an interpretive framework is established for organizing what organisms do in their real-time encounters with specific contexts. Developmental analysis begins, as a result, with formal and final processes of constraint. For *exclusive* DS proponents, however, "dynamic principles erase the gap between real-time assembly of behavior and its assembly over ontogenetic time" (Thelen & Smith, 1994, p. 129), meaning that "developmental stability and change is always connected to the local details of behavior" (Spencer & Perone, 2008, p. 1645). In the absence of complementary sentiment to the effect that the local details of behavior are always connected to the organism as a whole, both synchronically and diachronically, such a privileging of local-to-global processes grounds developmental time exclusively in real time and denudes the abstracted flow of developmental time of its explanatory significance. Development no longer involves abstraction across time as it does under the auspices of holistic structuralism; form across time, generalized from real-time content, is rejected for its abstraction, its structural reification and its divorce from the particulars of the here-and-now.

Bound to and defined by the task-specific context in the same way as real-time activity is, development in the exclusive DS approach resolves to little more than "a history of past here and nows" (Thelen & Smith, 1994, p. 216), an "accrual of real-time events" (p. 244), with the word *accrual* suggesting that development is forged through accumulation or addition. In other words, developmental-time amounts to little more than a quantitative accumulation of real-time actions in context, reducing to a series of adaptations to local contexts rather than also being a higher-order whole within which such real-time activity can be contextualized (Witherington, 2007). Developmental history is critical for the exclusive DS approach, but as a variable of influence, it is simply another part weighted equally with all other parts, not a higher-order whole, an interpretive, organizational framework within which current real-time activity must be embedded to fully understand such activity; though causally involved in real-time emergence, developmental history still reduces to a collection of real-time particulars (Witherington, 2007, 2011).

From the vantage point of adaptive action-in-context, every change from one act of an organism to another points to a new, emergent organization of the relation between the organism and its environment. Each act is unique and specific to a whole host of contextual parameters, both intra- and extraorganismic. Yet from the wholeness of dynamics vantage point of the organism qua organism, some changes in acts point to new, emerging levels of developmental organization in the organism itself—to a *developmental* transition between levels of organization—whereas other changes in acts point to an established, stable level of developmental organization—*real-time* transitions from one act to another within an organizationally invariant repertoire of acts. For example, a visually guided reach from a 3-month-old—for whom reaches that terminate in grasps are novel—signals a transformation and new level of emergent organization in the organism in a way that a visually guided reach from a 5-month-old—for whom reaches that terminate in grasps form a stable part of her/his action repertoire—does not. Such a distinction graces the inclusive DS approach but not its exclusive counterpart.

Any given act, when viewed from the level of action-in-context, will always constitute a new, emergent form—an adaptation to local, here-and-now context—but may or may not constitute a new, emergent form when viewed from the level of the organism qua organism, though its content relative to a context is newly emergent. Every act can thus exist both as a whole with respect to the adaptive relation of organism to environment and as a part within the whole that is the organism qua organism—both defined in terms of the organism and defining of the relation between an organism and its environment. For proponents of an inclusive DS approach, emergent form at one level of analysis is perfectly compatible with organizational stability at another level, and both represent distinct, equally legitimate ways of explaining the action of a system. Developmental transitions involve the framing of an individual's existing level of organization—abstracted from the specifics of action-in-context—within a sequence of that individual's previous level(s) of developmental organization and subsequent level(s) of organization. Abstracting such organizational sequences is foundational to the wholeness of dynamics perspective and establishes a critical frame of meaning within which to embed the particulars of any given action in any given context. When the wholeness of dynamics and dynamics of wholeness perspectives are treated as alternate views of the same whole, self-organization is as much about the organism maintaining its overall organization in the face of behavioral and contextual variability as it is about the adaptive qualities of the organism's emergent real-time activity in task-specific context. Such is the explanatory pluralism of circular causality as embodied in the inclusive DS approach to development.

By regarding as superfluous the characterization of organisms and their development in integrated whole terms, however, proponents of an *exclusive* DS approach delimit what it means for systems to manifest circular causality. Despite its centrality in the writings of those who espouse an inclusive DS approach to development, circular causality is conspicuously marginalized in exclusive DS writings, rarely warranting much mention if not altogether absent. When exclusive DS proponents do write of circular causality, they apply it to the here-and-now level of behavioral content, suggesting that emergent activities such as walking, reaching, and remembering feed back to the very components that give rise to them. But when "higher-order" constructs are not couched in the immediacy of the here-and-now—when, in other words, constructs are framed in formal and final explanatory terms as atemporal abstractions from behavioral content—these same proponents routinely dispense with the explanatory framework of circular causality, treating such constructs as mere products or as illusory by dint of their "timeless" divorce from real-time activity (Witherington, 2007, 2011). It is important to note that Thelen and Smith's (2006) mention of circular causality and Lewis's three scales of emotional development in the 2006 sixth edition *Handbook* chapter on dynamic systems showed evidence of a possible broadening in their conceptualization of the principle. However, their brief discussion remains ambiguous as to the whole-to-part nature of interlevel relations and stands out more as an aberration than a new rapprochement toward formal and final cause, especially in light of the steadily maintained antistructuralist stance evident both in their chapter and in the exclusive DS approach generally.

The exclusive DS approach to development's narrowed conceptualization of circular causality, and of development in general, engenders a dichotomous stance through its privileging of process over organization, local-to-global dynamic construction over global-to-local organizational constraint and real-time dynamics over developmental-time abstractions (Witherington, 2007). It treats fundamental explanatory principles of development, like directionality, teleology, sequence, and irreversibility, as *appearances* to-be-explained by the *reality* of real-time dynamics rather than as formal and final organizational frames within which to contextualize those very dynamics. Just as its antistructure stance marginalizes organization in process, so this stance severely undercuts the concept of development and ultimately undermines the explanatory potential in principles of nonlinear dynamics for uniting developmental science. Since "real time, context-specific behavior, generalized knowledge, and competence are all one" (Thelen & Smith, 1994, p. 179) and because the here-and-now is privileged relative to other levels of analysis, the unification of global order and local variability that exclusive DS proponents purport to achieve stems not from synthesis but from reduction, as the "appearance" of global order is reduced to the "reality" of local variability (van der Maas, 1995). Maintaining such a reductionist stance in the metatheoretical repertoire of the DS approach to development threatens to unravel the whole enterprise of understanding development in dynamic systems terms (Witherington, 2011).

CONCLUSION: IN SEARCH OF UNIFIED METATHEORETICAL GROUND

Despite their shared roots in the mathematical constructs and tools of NDS, proponents of the DS approach to development are metatheoretically divided with respect to what constitutes viable explanation in the understanding of development. Those who espouse an exclusive DS approach to development ground themselves in an *explanatory monism* by establishing the dynamics of wholeness perspective as foundational and primary to the understanding of organismic activity and its development. Those who espouse an inclusive DS approach to development ground themselves in an *explanatory pluralism* by embracing both a dynamics of wholeness and a wholeness of dynamics perspective as equal, complementary vantage points of understanding. Proponents of the inclusive DS approach fully commit to the perspectivist philosophy of von Bertalanffy's GST, embarking on a synthetic integration of NDS's temporal dynamics focus and GST's holistic structuralism. In contrast, proponents of the exclusive DS approach dispense with the timeless abstractions of GST's holistic structuralism in favor of championing the *real*, *legitimate* explanation of NDS's temporal dynamics focus. From the vantage point of a *dynamics of wholeness* perspective, these differences between inclusive and exclusive approaches vanish, yielding an ontologically unified framework for understanding development based around the principle of self-organization. However, from a *wholeness of dynamics* perspective, approach differences readily surface. Whereas inclusive approaches frame bottom-up processes of self-organization within a broader circular causal framework that accords equal explanatory status to the topological constraint of system organization *at all levels of organizational abstraction*, exclusive approaches summarily dismiss the explanatory importance of organizational abstraction, instead requiring that all explanatory efforts reduce to the real-time dynamics of action-in-context.

Such ontological differences reveal a fundamental divide in how DS proponents bridge the false dichotomies—for example, structure versus function, organizational stability versus dynamic process, global directional order versus local intraindividual variability—that have historically plagued developmental psychology (Witherington & Margett, 2011). For the inclusive DS approach, integrating the false dichotomies of development arrives through a perspectivist framework, wherein the organization/structure/form and the process/real-time functioning of organismic activity represent distinct but interdependent perspectives on the indissociable unity that is organized process. For the exclusive DS approach, integration arrives through the privileging of one vantage point over another, yielding a form of foundationalism at the level of the approach's explanatory efforts. The perspectivist framework of an inclusive DS approach—marked by an emphasis on the relativity of perspective and vantage point—embodies the metatheoretical tenets of the Relational-Developmental-Systems paradigm in which "synthesis and analysis, together with reason and observation, operate in an interpenetrating reciprocal fashion . . . in which each individual approach is valued not as a potentially privileged vantage point, but as a necessary line of sight on the whole" (Overton, 2010, p. 18). As relational metatheory, the inclusive DS approach bridges and ultimately transcends false dichotomies by framing them in *both-and terms*, transforming them into complementary pairs (Kelso & Engstrom, 2006). In contrast, the foundationalist framework of an exclusive DS approach—marked by an antistructuralist stance and privileging of the here-and-now adaptation of activity to local contexts—is ontologically incompatible with the perspectivist inclusivity of the Relational-Developmental-Systems paradigm. By narrowing its frame of legitimate explanation and by privileging certain vantage points over others, the exclusive DS approach more readily aligns with a Cartesian-Split-Mechanistic paradigm, reinforcing a dualistic, either-or approach to reality rather than transcending it (Witherington, 2011).

It is important to emphasize that from the vantage point of a *dynamics of wholeness* perspective, the exclusive DS approach to development is far removed from a Cartesian-Split-Mechanistic paradigm. In its emphases on system irreducibility, emergence without prescription, and the reciprocal, nonlinear relations among components of a system that fuel the emergence of novel system patterning, the exclusive DS approach—just like its inclusive counterpart and systems approaches generally—rejects the mechanistic "principle of *unidirectional, linear, and additive associative or causal sequences*" in which "elements must be related either according to their contiguous co-occurrence in space and time or according to simple efficient and material mechanical cause-effect sequences that proceed in a single direction" (Overton, 2013, p. 39). Recall that DS approaches, when looking at system organization within the bottom-up context of temporal precedence, view efficient causal processes as distributed across all of the fully interdependent parts of a system, none of which is privileged in the emergence of form. All DS approaches, whether inclusive or exclusive, reject the absolutist notions of cause and effect—antecedent and consequent—that underlie the Cartesian-Split-Mechanistic paradigm. Thus, within the confines of the dynamics of wholeness perspective, the exclusive DS approach fully entrenches itself in a *relational* focus, not in the analytically decomposable view of a mechanistic world view which treats parts and forces as independent elements "that preserve their identity regardless of context" and that combine in additive fashion to yield "simple complexity" (Overton, 2013, p. 38).

For the exclusive DS approach to development, however, "there is ultimately a rock bottom unchanging nature to Reality" (Overton, 2013, p. 38), as the Cartesian-Split-Mechanistic paradigm espouses, and that *Reality* is *temporally unfolding process*; the temporal dynamics of real-time process preserve their identity irrespective of developmental level of organization. The exclusive DS approach both privileges—and takes as foundational—*process over organization* (Witherington, 2011; Witherington & Heying, 2013). It privileges and takes as foundational the dynamics of wholeness perspective over the wholeness of dynamics perspective; real-time action-in-context over the organism as an integrated whole across time and context; nonrecursive change between levels of organization over circular causality. Process is prior to and constitutive of organization for proponents of an exclusive DS approach, but organization is *not* prior to and constitutive of process in their worldview. Thus, the exclusive DS approach embraces the splitting and foundationalism of the Cartesian-Split-Mechanistic paradigm *in its ontological approach to the nature of explanation itself.*

The specific *split metatheoretical* character of the exclusive DS approach to development has its roots in the contextualist focus that both inclusive and exclusive DS approaches share when articulating the dynamics of wholeness perspective. Under a contextualist worldview, the particularities of here-and-now time and context assume paramount importance for understanding action and its development (Witherington, 2007). "The event alive in its present" succinctly captures the fundamental mindset for this framework, with continuous change and novelty marking its core foci (Pepper, 1942, p. 232). In Pepper's (1942) words, "nothing is more empirically obvious to a contextualist than the emergence of a new quality in every event" (p. 256). Though contextualism is synthetic rather than analytic in its focus, its synthesis remains wed to the particularities of the here-and-now, to the level of specific action-in-context; as Overton (2007) has argued, "the holism of contextualism is about parts-whole relations of the adaptive act" (p. 158), not of the self-organizing system as an integrated totality. Understanding development within contextualism resolves to the study of variability in activity during real-time, adaptive encounters with everyday contexts.

Contextualism, however, is a dispersive rather than an integrative worldview. As its focus repeatedly narrows to specific action in specific contexts, contexualism avoids establishing an integrative framework abstracted from such particulars and establishes a view of reality as "multitudes of facts rather loosely scattered about and not necessarily determining one another to any considerable degree" (Pepper, 1942, pp. 142–143). Given its dispersive focus, contextualism "in its 'pure' state . . . cannot serve as an adequate metamodel for the study of human development" (Ford & Lerner, 1992, p. 10; see Lerner & Kauffman, 1985) and "consistently shows a tendency to lose its identity and to become a part of mechanism or organicism" (Overton, 1984, p. 219). When contextualism merges with mechanism, the contextualist focus on local-to-global dynamic construction becomes ontologically foundational, with the local, temporally bound dynamics of particular actions in real-time context—captured via distributed efficient causality—constituting the only basis for explanation. Under such a merger, the organization that emerges from the ceaseless flux of these real-time dynamics exists as little more than a momentary, epiphenomenal by-product of bottom-up causal forces. Although higher-order organization in the system is irreducible to lower-order organization, all organization is, in the final analysis, causally reducible to the local processes that give rise to it. The "appearance" of organization ultimately reduces to the "reality" of ceaseless flux, with pattern (the whole) serving as consequent to the antecedent of process (part-part relations). It is precisely this mechanism-contextualism blend that underlies the split metatheoretical character of the exclusive DS approach to development, invoking qualities of the Cartesian-Split-Mechanistic paradigm in the process (Overton, 2007; Witherington, 2007, 2011; Witherington & Heying, 2013).

The Relational-Developmental-Systems paradigm is forged not through a merger of contextualism and mechanism but through what Overton (2010) has termed a "principled synthesis" (p. 11) of contextualism and an *organismic* worldview (see also Overton, 1984, 2007; Overton & Ennis, 2006). The organismic worldview or organicism (Pepper, 1942) lies at the heart of GST's *wholeness of dynamics* vantage point, its holistic structuralism. Organicism takes as its basic metaphor the organism as active constructor of reality through interaction with the world (Reese & Overton, 1970). By this perspective, any living, organized system constitutes an irreducible, integrated whole, and its development is marked by irreversible, progressive, and qualitative changes in the formal properties of that whole (Overton, 1984; Pepper, 1942). Organicism, in other words, grounds its explanatory framework in formal and final explanations, in the abstraction of formal properties from real-time system activity in the ever-changing present (Lerner & Kauffman, 1985).

The Relational-Developmental-Systems paradigm preserves the distinct explanatory foci of both organicism and contextualism through its principled synthesis of the two, establishing each worldview as a unique but complementary frame of understanding with respect to the other rather than as an *absolute* mode of truth in its own right. Within this explanatory pluralism, the issue of local-to-global dynamic construction is addressed through contextualism's focus on the "grass-roots" particularities of real-time acts adapting to their contextual settings—a dynamic interplay of organismic system components constrained instrumentally by local context—yielding, in turn, the continuous emergence of new action qualities, or wholes. Similarly, the issue of global-to-local organizational constraint is addressed through organicism's formal and final explanatory outlook, with higher-order forms—reflecting the abstracted organization of a system that characterizes functioning across a variety of contexts—necessarily framing the lower-order local dynamics on which they depend. Both organicism and contextualism—as different but simultaneous levels of explanation—constitute necessary lines of sight for our understanding of system activity and development, with neither assuming ontological privilege or precedence (Overton, 2007). It is precisely such a principled synthesis of organicism and contextualism that underlies the explanatory pluralism of the inclusive DS approach to development, fully establishing it as a representative of the Relational-Developmental-Systems paradigm.

Through its grounding in the mathematical and conceptual principles of nonlinear dynamics, the DS approach to development has revolutionized the study of temporal dynamics and championed the importance of *intraindividual variability* and real-time activity in developmental science. The principal strength of the approach lies in the rigorous methodological and analytic framework it establishes for addressing the question of process in development. However, the approach's greatest strength can also turn into its greatest weakness. When focus on the temporal dynamics of process—the dynamics of wholeness perspective—becomes all-consuming and rendered as ontologically foundational to the organization and wholeness it seeks to explain, the approach's promise "to bring theoretical coherence" (Thelen & Smith, 2006, p. 307) to developmental science ushers in an explanatory monism that simply privileges one side of a polarity, *process*, over the other, *organization*. Such a monistic take on explanation, revealed in the exclusive DS approach, undermines the very synthesis that the approach attempts to provide and promotes a split metatheoretical frame for understanding development. Realization of the approach's potential as a Relational-Developmental-Systems paradigm at all levels of the research process requires the explanatory pluralism of an inclusive DS approach to development.

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CHAPTER 4

Dynamic Development of Thinking, Feeling, and Acting

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People are different. The differences are pervasive. Humans act differently in different contexts. There is no average person, and only under some very special conditions (see Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2010) can means or averages adequately represent any individual's performance. These ideas constitute the fundamental starting point that is omitted in most frameworks for explaining human action. Analysis should *begin* with analysis of the role of context, and with an appreciation that variability is fundamental to human action—that we human beings naturally vary our actions based on context and support for skilled performance. People do not follow narrow models of ability that force them into little boxes such as *intelligence* or *learning style* (Fischer & Bidell, 2006; Fischer, Knight, & Van Parys, 1993).

Human action is integrative. Despite the differences between people and differences in how people act in various contexts, action in the world necessarily involves some sort of integration of cognitive, motivational, affective, evaluative, and motoric processes. We do not act as a series of separable or isolated modules; rather, we act as whole organisms, even if the particular patterns of cognition, conation, and affect differ from context to context and from person to person. Further, the development of structures of thinking, feeling, and acting is the result of an open-ended *probabilistic epigenetic* process (Gottlieb, 2007) that brings together in a relational matrix multiply embedded biological, psychological, and sociocultural systems. A person's behavior cannot be parsed into separable genetic and environmental components. To understand human action and its development, it is necessary to understand how the persons as integrative relational systems operate in particular physical and sociocultural contexts.

In other words, human activity is both organized and variable, dynamically changing according to systematic principles. The primary goal of cognitive, affective, and developmental science is to characterize these principles: How are cognition, emotion, and action organized? What principles are required to describe the ways that people naturally vary their performances? How do organized patterns of thinking, feeling, and acting take shape over time? Taken together, these principles—person-in-context and variability-as-information—represent the backbone of dynamic systems theory.

Children and adults are flexible and inventive in their action and thought, adapting old ideas to new situations, inventing concepts, formulating plans, and constructing hypotheses in the course of participating in a wide variety of cultural practices. These statements make sense to psychologists and educators, who see evidence everywhere of the relational, constructive, self-organizing, self-regulating, and culturally contextualized nature of human psychological processes. Yet the most widely used conceptions of psychological structure and its development have not reflected this relational, dynamic, constructive, and contextualized picture of psychological processes. In fact, the opposite is true. In the past, the major models of development have described psychological structure in static, formal terms, with concepts such as linear growth, universal stages, innate (i.e., strictly biologically determined) linguistic modules, and static cognitive competencies; portraying psychological organization as fixed and unchanging.

The task of developmental science is to capture organized patterns in this variability and to propose models to account for both the variability and the stability (Nesselroade & Molenaar, 2010) of behavior and development. In this chapter we demonstrate how the concepts and methods of *dynamic systems theory* (see also Witherington, 2011, Chapter 3, this *Handbook*, this volume) provide a framework and tools for analyzing this variability and detecting the order within it. This framework is consistent with what others (e.g., Lerner, 2006; Lerner & Benson, 2013; Overton, 2006, 2010, 2013, Chapter 2, this *Handbook,* this volume; Overton & Lerner, 2012) refer to as the *Relational-Developmental-Systems* model. One set of key findings associated with dynamic systems theory is that qualitatively new cognitive abilities emerge naturally in learning and development, transitioning from one form of action or representation to another. Humans are self-creating, self-organizing, and self-regulating systems grounded in meaning through the action of our bodies and our cultures.

Tools from dynamic systems analysis provide ways of embracing the variability in order to find the order within it (see Witherington, Chapter 3, this *Handbook*, this volume). In this chapter, we present a framework for conceptualizing psychological structure as dynamic self-organizing systems constructed by human agents. We begin with an introductory overview of dynamic systems theory as a way to describe learning and development through dynamic organization of self-constructed, socially embedded skills and activities (actions, thoughts, and emotions). This position contrasts with traditional static views of psychological structure based on reductionist scientific theory inherited from the Cartesian-Split-Mechanistic tradition in philosophy (see Overton, 2013, 2014, Chapter 2, this *Handbook*, this volume, for a discussion) and producing systematic but inadequate understandings of psychological structure, including failures to explain the scope of developmental variability. The dynamic framework and research tools crafted for analyzing development and learning provide a methodology for the study of psychological structures, including both their variability and the order in the variation (Molenaar, Lerner, & Newell, 2014). These concepts and tools explain both long-term macrodevelopment and short-term microdevelopmental variability in dynamic structures. These models and methods illuminate analysis of relations among cognitive, social, emotional, and neurological development. All these parts work together to explain how we humans act in all our rich complexity.

THE DYNAMICS OF HUMAN ACTION: THE PERSON ←→ ENVIRONMENT SYSTEM

The first step toward studying learning and development using dynamic systems principles is to articulate a dynamic account of human psychological functioning. There has been what might be called a *relational turn* in many areas of the social sciences (Overton, 1998, 2013, Chapter 2, this *Handbook*, this volume). To analyze human psychological functioning, it is often necessary to decompose complex activity into its component parts and systems. Over the past decades, however, theory and research has shown that understanding the complexities of human functioning requires that we understand how behavior emerges from *relations between coacting* (←→) *systems* rather than as products of independent aggregates functioning in isolation from one another (Gottlieb & Halpern, 2002). The relational turn is evident in theory and research across the human spectrum, including analyses of the epigenetics of human development and evolution (Lickliter & Honeycutt, 2010, Chapter 5, this *Handbook*, this volume); emotion-cognition interaction (Dolcos, Iordan, & Dolcos, 2011; Turiel, Chapter 13, this *Handbook,* this volume); the possible role of a mirror resonance system in underwriting social relationships (Spunt & Lieberman, 2013); and the cultural mediation of thinking, feeling and acting (Cole, 1996; Mistry & Dutta, Chapter 10, this *Handbook*, this volume; Wertsch, 2007; see Overton, Chapter 2, this *Handbook*, this volume, for other examples). The relational turn does not simply call for more powerful ways to assess how diverse variables influence behavior. Instead, it calls for models that explain how psychological acts are constituted in real time by coactions among biological, psychological, and sociocultural processes operating within and between persons.

A parallel aspect of emerging developmental models is an appreciation for the *embodied* nature of psychological processes and their development (Gallagher, 2005; Overton, Chapter 2, this *Handbook*, this volume). The concept of embodiment proceeds from a rejection of the traditional Cartesian-Split-Mechanistic paradigm that postulates the functioning of a separate and distinct mental sphere that lies behind behavior and controls it autonomously from within. From the perspective of embodiment, thinking, feeling, and acting are products of the dynamic intercoupling of the brain, body, and world. Thinking and feeling are ongoing *processes* that arise from the ways in which bodies operate within concrete physical, social, and cultural *environments*. Thinking is not a disembodied process of manipulating abstract symbols in an incorporeal mind; instead, thoughts have their developmental origins in sensorimotor-affective activity in the concrete physical, social, and cultural world.

THE HOW OF DEVELOPMENT: THE EPIGENESIS OF PSYCHOLOGICAL STRUCTURES

Over the past decades, epigenesis has become an increasingly prominent core concept in developmental science's understanding of developmental processes (see, e.g., Lerner & Benson, 2013; Overton, 2006). As Overton (2013) points out:

> Epigenesis is conceptualized as "probabilistic epigenesis" (Gottlieb, 1992), which designates a *holistic* approach to understanding developmental complexity. Probabilistic epigenesis is the principle that the role played by any part of a relational developmental system—DNA, cell, tissue, organ, organism, physical environment, and culture—is a function of all of the interpenetrating and coacting parts of the system. It is through complex *reciprocal* bidirectional and *circular reciprocal interpenetrating* actions among the coacting parts that the system moves to levels of increasingly organized complexity. Thus, epigenesis identifies the system as being completely *contextualized* and *situated*. (p. 53)

Broadly, probabilistic epigenesis refers to the idea that anatomical and psychological structures emerge over time through embodied actions in the world, and are neither preformed nor predetermined (Gottlieb, 2007). It is this epigenetic process that nullifies any attempt at explaining any action, prenatal or postnatal, as "strictly biologically determined" (i.e., "innate").

At the molecular biological level, the related term *epigenetics* is used to designate the "study of . . . [processes] that determine which genome sequences will be expressed in the cell, . . . [processes] that control cell differentiation and give the cell an identity that is often passed on through mitosis" (Griffiths & Tabry, 2013, p. 75). Thus, processes beyond the level of the genes (e.g., RNA, cytoplasm, DNA methylation) play a role activating gene expression at points of development (Danchin et al., 2011; Meaney & Ferguson-Smith, 2010; Nugent & McCarty, 2011). Epigenetics and the processes of epigenesis it entails challenge what has been termed the "*central dogma* of the *modern synthesis*" (Huxley, 1942/2009) in evolutionary theory. This central dogma states that the direction of causality between genetic and nongenetic processes in the creation of proteins is unidirectional (from DNA → RNA → mRNA . . . → Protein). Within this scheme, genes orchestrate the building of proteins, but are themselves unaffected by the processes involved in protein synthesis. However, research has shown that nongenetic biological processes, particularly DNA methylation and histone modification, function to activate and inhibit gene expression during protein synthesis (Meaney, 2010; Šerman, Vlahović, Šerman, & Bulić-Jakuš, 2006; Sun, Sun, Ming, & Song, 2011). As such, the epigenetic model embraces the idea of bidirectional rather than unidirectional causality between genetic and extra-genetic processes (DNA ↔ RNA ↔ mRNA . . . ↔ Protein).

Processes that regulate gene expression are sensitive to changes that occur at multiple levels of organismic functioning. In a multiply nested epigenetic system, no single part of the relational developmental system (e.g., genes, extra-genetic biological processes, behavior, sociocultural experience) is autonomous or primary in human psychological development. Psychological structures are emergent products of coactions among both horizontal (gene-gene, cell-cell, organism-organism) and vertical (gene-cytoplasm, cell-organ, organism-ecosystem) aspects of the relational developmental system. For example, the offspring of rat mothers who show high levels of maternal care during a pup's first week of life (i.e., grooming, pup licking, nursing) show lower levels of stress as adults than offspring of less nurturing mothers. These maternal behaviors produce a suite of biological changes in rat pups, some of which are involved in the silencing and expressing of genes (Weaver et al., 2005). Research has identified epigenetic processes involved in the construction of psychological structures in humans as well. These include the development of attachment (Lickliter, 2008; Schore & Schore, 2008); emotionality and stress regulation (Champagne, 2010); suicidality among adult survivors of maltreatment (Weaver et al., 2005), and other domains (Jablonka & Lamb, 2005).

THE STRUCTURE OF ACTION

Given that development proceeds according to the principle of probabilistic epigenesis, the next issue concerns the embeddedness of this process in the coactive person ←→ environment system as development proceeds across life span. Figure 4.1 provides a schematic representation of the coactive person ←→ environment system. As indicated in the figure, the person ←→ environment system is composed of five categories of coacting processes. These include: (1) individual *acts*; (2) the physical and psychological *objects* toward which acts are directed; (3) *other people*; (4) some form of *mediational means*—that which we act *with*; and (5) physical and sociocultural *contexts*. The foundational assertion of *dynamic coactive systems* approach is that what we *do* and how we *develop* are *emergent* products of *coactions* that occur between and among component parts of the *person ←→ environment system*. The parts of the person ←→ environment system are inseparable (i.e., the system is holistic) as causal processes in the production of action and experience.

The first part or component of the system consists of the structure and functioning of individual acts and their objects, indicated at Figure 4.1 at Points A and B. A *psychological act is a goal-directed integration* of meaning, movement, and phenomenal experience. To act is to experience. As indicated by Overton (2006):

> Experience manifests its relational dialectical as well as its embodied character in being what James terms a "double-barrelled" (1912, p. 10) concept. "It recognizes in its primary integrity no division between act and material, subject and object, but contains them both in an unanalyzed totality" (Dewey, 1925, pp. 10–11). *Experience* refers to *both* the action of the subject (i.e., the subject's embodied active exploration, active manipulation, and active observation of the object world) *and* the object world's active impingement on the subject. "It includes *what* men [sic]do and suffer, *what* they strive for . . . and endure, and also *how* men [sic] act and are acted upon (p. 10)." (p. 68)

Actions have several properties:

- Acts are *intentional* processes in the sense that they are either performed *on* something, directed *toward*

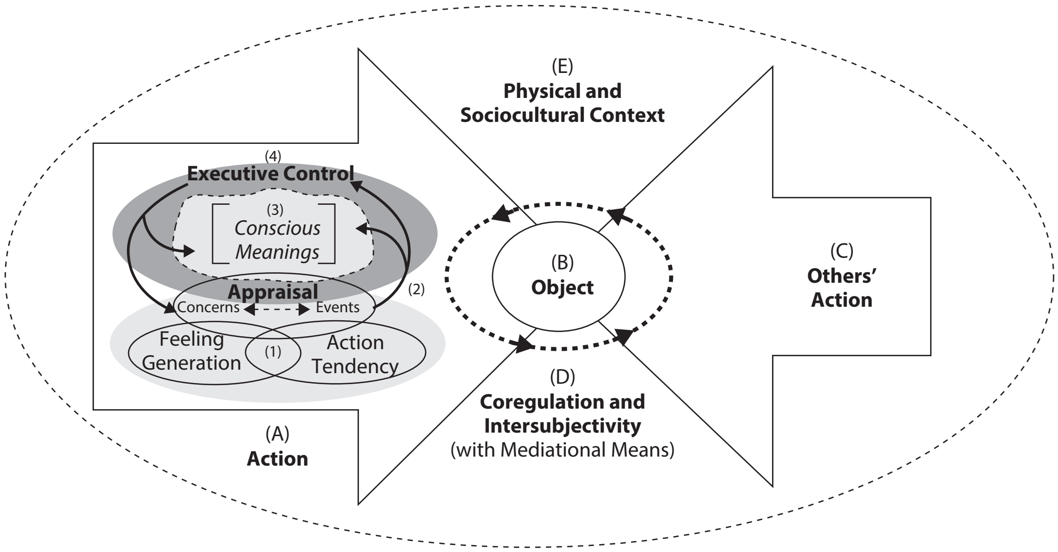


Figure 4.1 The coactive person-environment system.

something, or are *about* something, real or imagined (Fischer, 1980; Searle, 1983). For example, when hitting a baseball, the act of *hitting* is performed *on the ball*; the ball is the *object* of the act of *hitting*.

- Psychological acts are *meaning-mediated* processes. Persons act on the basis of the meaning events have for them. *Meaning* is a central psychological category: to the extent that a process is mediated by meaning, that process is a psychological one (Bruner, 1990). The patellar reflex (knee jerk) is mediated by activity at the level of the spinal cord and operates without participation of higher-level meaning. In contrast, inhibiting a knee jerk is mediated by the goal of keeping the knee still, knowledge of when the hammer will strike, and so forth. Inhibiting a reflex is thus a psychological act. There are as many forms of meaning as there are forms of acting. Meanings have their origins in patterns of *embodied* (sensorimotor-affective) activity in the physical and social world (Noë, 2004; Piaget, 1952) and develop through successive differentiation and integration (Overton, Müller, & Newman, 2008; Piaget, 1952; Werner & Kaplan, 1963). The role of meaning in action is indicated at Point (4) in Figure 4.1.
- Psychological actions are *goal-directed* operations on the world. This implies that persons have some degree of *agency* or control over their representational, experiential, and motoric processes (Fischer, 1980). Research clearly indicates that infants exhibit a capacity for primitive forms of agency and goal-directedness from birth (DeCasper & Carstens, 1981; Trevarthen & Reddy, 2007). In development, intentional acts become organized into hierarchically nested symbol systems (Mascolo, Fischer, & Neimeyer, 1999). Higher-order meanings—especially valued images of self—operate as goals that drive action. Goal-directed agency is represented at Point (4) in Figure 4.1.

Psychological acts are integrative processes. There is no such thing as a simply cognitive or emotional or conative or behavioral process; any action that affects the world necessarily involves some integration of meaning, feeling, needing, and motor action. For example, when playing baseball, action, object, means, and meaning operate as a dynamically coupled and unified system. A change in any single part can result in a change in the action itself. The form of a batter's swing varies depending upon whether he is attempting to hit a fast-moving hardball or a large and looming softball.

THE EMOTIONAL GROUNDING OF INDIVIDUAL ACTION

At its core, psychological functioning is an *embodied* system that has its basis in sensorimotor-affective activity. Emotions are fast-acting experiences that arise from (initially nonconscious) motive-relevant transformations in a person's relation to the world. The core emotional parts of psychological functioning are indicated in Figure 4.1 at Point (1). Drawing on current emotion theory (Mascolo, Fischer, & Li, 2003), any given emotional state is composed of at least three coacting categories of processes. These include *motive-relevant appraisals*; *affect (feeling) generating processes*; and *motive-action tendencies*.

- *Appraisals* consist of the nonconscious assessment of relations between perceived events and an individual's goals, motives, desires, or concerns (Frijda, 2012). Although many models of emotion view appraisal as a form of cognitive process (Ellsworth & Scherer, 2003), this is misleading. Although appraisals may involve cognition, they are primarily *motivational* processes; they reflect relational registrations of the fate of a person's motives (Roseman, 1991).
- *Affect-generating processes* consist of syndromes of central nervous system (Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012), peripheral nervous system (Kreibig, 2010), and bodily changes (Dunn et al., 2010) that bring about the phenomenal experience of a particular class of emotional feeling. Theorists, researchers and laypersons alike have suggested that different emotional states are associated with different sensory qualities (*qualia*) (Bermond, 2008). However, because people tend to find phenomenal experience difficult to describe, they often resort to the use of metaphor to describe feelings (Ortony & Fainsilber, 1989).
- *Action tendencies* refer to classes of voluntary and involuntary *action* that function in the service of a person's goals, motives, and concerns within any given context (Frijda, 2012). Different emotional states are defined in terms of different appraisal-affect-action configurations. For example, fear arises in the context of appraised danger (Nezlek, Vansteelandt, Van Mechelen, & Kuppens, 2008), and involves a phenomenal tone that people experience as a state of hyperactivation (Davitz, 1969). In fear, persons are motivated to *remove the danger*, which can be achieved in diverse ways (e.g., fight/flight; tend/befriend; freezing) (Bracha, Ralston, Matsukawa, Williams, & Bracha, 2004).

In any given context, emotions emerge over time as a product of coactions that occur among component appraisal, affect, and action systems. Appraisal processes continuously and nonconsciously monitor relations between perceived events and the entire range of a person's goals, motives, desires, and concerns. Appraised changes in the relations between events and motives continuously (and nonconsciously) modulate emotion. Changes in affect and emotional experience *select, amplify, and organize these same appraised events for conscious awareness* (Lewis, 1996; Mascolo et al., 2003). Appraisal and affect coact in the construction and organization of conscious awareness. For example, experienced drivers often find that they are able to operate motor vehicles without conscious awareness for long periods (Charlton & Starkey, 2011). However, if a child were to run into the road, the driver, immediately aware of the danger, takes evasive action. The transition from *nonconscious* driving to *conscious awareness* implies that the processing of road conditions must occur continuously, albeit outside of awareness. This example demonstrates how *conscious awareness arises as the product of nonconscious processes*. The nonconscious, fast-acting effects of emotional activation orient attention and organize both intentional and unintentional action (Freeman, 2000). The emotional construction of conscious awareness is indicated in Figure 4.1 at Point (E).

INTERSUBJECTIVITY AND THE COREGULATION OF THINKING, FEELING, AND ACTING

The third aspect of the coactive person ←→ environment system consists of the actions of *other people* (Point C in Figure 4.1). Psychological inquiry has traditionally operated within a Cartesian-Mechanistic framework that embraces strong dichotomies such as *individual/social*, *self/other*, *subject/object*, *inner/outer*, *mind/behavior*, and related dualities (Overton, 2006, Chapter 2, this *Handbook*, this volume). From the Cartesian view, psychological life is understood as a subjective and internal process that is set off against an objectively external world of objects and people. Viewed in this way, the problem of other people—how we come to know and be known by "other minds"—becomes a difficult one. From the Cartesian view, individuals have no direct access to the minds of others. Infants begin life as separate (and egocentric) entities who must somehow break into the world of social relationships. To address this problem, theorists have suggested that individuals must either project their own subjectivities onto others (Goldman, 2006; Gordon, 1986), or they must construct theories of mind to infer the types of mental states that lie behind the external behavior of others (Gopnik & Meltzoff, 1997; Stich & Nichols, 1992).

Theory and evidence calls into question the traditional Cartesian conception. A large and growing number of phenomenological (Gallagher, 2008), linguistic (Racine & Carpendale, 2008; Wittgenstein, 1980), and embodied systems perspectives (Overton, 2006; Thompson, 2007) hold that infants and adults are embodied beings who are able to experience their physical and social worlds directly. Several implications arise from these approaches. First, from an embodied view, there is no such thing as a separate, internal sphere of mind that *lies behind* action. That which is often called *mind* is a form of *action* in the world (Overton, 2006, Chapter 2, this Handbook, this volume; Wertsch, 1998). Second, as a form of embodied activity, psychological action is not something that necessarily operates within a hidden interior. Overt acts are not separate external somethings regulated by a hidden internal something. Instead, observable action is the external *manifestation* of psychological activity; the *internal* and *external* are private and public manifestations of common processes (Ter Harke, 1990). In face-to-face interaction, there is ordinarily no need to *infer* the experiential states of others; instead, we read such states directly from the other's expressive actions. Wittgenstein (1980) states:

> "We *see* emotion."—As opposed to what?—We do not see facial contortions and make the inference that he is feeling joy, grief, boredom. We describe a face immediately as sad, radiant, bored, even when we are unable to give any other description of the features .... In general I do not surmise fear in him—I see it. I do not feel that I am deducing the probable existence of something inside from something outside; rather, it is as if the human face were in a way translucent and that I were seeing it not in reflected light but rather in its own. (§570, p. 170)

This does not imply that experience is *never* hidden; it is only to say that experience is not hidden *a priori*. Humans can hide their psychological states. When they do, they hide the *external* manifestations of experience—not a private interior (ter Hark, 1990).

Research corroborates an embodied-relational conception of development in infancy and beyond. First, research suggests that infant-caregiver dyads are capable of establishing rudimentary forms of intersubjectivity soon after infants are born. Intersubjectivity can be defined in terms of the capacity for shared or coordinated action or experience within episodes of joint action (Foolen, Lüdtke, Racine, & Zlatev, 2012; Matusov, 1996). Support for this view comes from many sources. Meltzoff and Moore (1977, 1983) have shown that neonates are capable of matching facial actions modeled by others. By 2 months of age, infants and their caregivers engage in emotionally charged turn-taking involving sequences of smiling, cooing, and related coordinated acts (Trevarthen, 1979; Trevarthen & Hubley, 1978). In these exchanges, infant and caregiver not only coordinate their facial and vocal action, but they coordinate the emotional *experiences* that arise within the affective dance that occurs between them (Gallagher & Hutto, 2008).

The idea that young infants are capable of primitive forms of intersubjectivity is bolstered by the discovery of *mirror neurons* (Cattaneo & Rizzolatti, 2009; Gallese, Eagle, & Migone, 2007; see also Marshall, Chapter 7, this *Handbook*, this volume). Mirror neurons consist of neurons, initially discovered in the prefrontal lobes of monkeys, which become activated both when observing behavior in others and when executing the same action by the self. There is some controversy about whether mirror neurons exist in humans. Some studies suggest that functions that attributed to mirror neurons in monkeys exist in humans (Kilner, Neal, Weiskopf, Friston, & Frith, 2009); others suggest otherwise (Lingnau, Gesierich, & Caramazza, 2009). The possibility that mirror neurons (or similar such systems) operate in humans suggests that a common neurological system may underlie both the observation and production of certain classes of motor behavior. Such common pathways provide a foundation for understanding how infants are capable of entering into emotionally mediated social interactions from the start of life: Although individual persons are separate and distinct organisms, the mirror resonance system may provide the means for experiencing correspondences—however primitive at first—between experience of others and similar experiences within the self (Meltzoff, 2011).

These arguments suggest a dramatic revision of traditional conceptions that depict individuals as prior to social relationships or that identify cognitive development as a precondition for social development (Kohlberg, 1994; Piaget, 1932). Whereas some approaches suggest that intersubjectivity is a *derivative product* of cognitive development, the relational perspective suggests that psychological development *builds on* a primordial capacity for intersubjectivity. The capacity for intersubjectivity is what makes face-to-face communicative exchanges between infants and caregivers possible.

Intersubjective communication is not a matter of passing discrete messages back and forth between interlocutors. Face-to-face communication operates as a *continuous process system* (Fogel, 1993) in which both partners are simultaneously active as "senders" and "receivers." As one individual speaks, her partner is continuously active as both "receiver" (interpreting verbal and nonverbal meaning) and "sender" (providing nonverbal and sometimes verbal feedback). Thus, unlike in discrete state communication systems (e.g., email, snail mail), the "message" communicated in intersubjective interaction is neither fixed nor discrete. As interlocutors continuously adjust the structure and content of their communications to each other in real time, the "message" itself changes in the process of its "transmission." When thinking about communication as a dynamic, continuous, and intersubjective process, discrete concepts like "sender," "receiver," "message," and "transmission" lose their meaning.

If social interaction operates as a continuous process, it follows that within face-to-face interaction, social partners *coregulate* each other's action and experience. Coregulation refers to the process by which social partners continuously adjust their actions, thoughts, and feelings to the ongoing and anticipated actions of their social partners (Fischer, 1980; Fischer & Bidell, 2006; Fogel, 1993; Lerner, 2006; Mascolo, 2013; Semin & Cacioppo, 2008). In coregulated interaction, each partner's ongoing actions operate as *part of the process* of the actions of the other. If this is so, it is not possible to understand the production of action by focusing only on what occurs within the heads of solitary individuals.

SOCIOCULTURAL CONTEXT AND SEMIOTIC MEDIATION

The final components of the person ←→ environment system include the *sociocultural context* (Figure 4.1/Point E) and the use of *cultural tools* (Point D) to mediate higher-order action (Cole, 1996; Wertsch, 1998). Like individual actors, culture operates as a network of dynamic processes rather than as a fixed or monolithic entity (see Mistry & Dutta, Chapter 10, this *Handbook*, this volume). Cultures function as systems of dynamic meanings, practices, values, and artifacts distributed throughout a linguistic community. Symbol systems play a central role in the constitution and dissemination of culture. As forms of representation, symbols are used to make one thing (i.e., a signifier, e.g., the word "friend"; a picture of a person) stand for or represent something else (i.e., the signified; e.g., an actual person; the meaning of *friend*). The *semiotic function* allows individuals to create meanings that go beyond the information given (Bruner, 1990; Burke, 1966).

Among the symbolic processes that constitute cultural activity, language is perhaps the most important. Language operates as a generative and rule-governed system of signs (words). Signs are *generative* vehicles that mediate the construction of *arbitrary* meanings *shared* within a given community. These properties make language a quintessential tool in the construction and dissemination of culture. Signs are *arbitrary* in the sense that their meanings are derived from social practice rather than from the physical or perceptual qualities of their referents. For example, the term *friend* identifies a socially structured way of defining how people relate to each other; its meaning is not determined by the perceptual qualities of any particular individual.

Second, signs allow meanings to be easily shared among members of a linguistic community. Anyone who understands the English language can be taught the meaning of the word *friend* almost instantly. It is difficult to communicate novel meanings using nonlinguistic symbolic forms (e.g., pictures, pantomime). Finally, sign systems are *generative* in the sense that they allow persons to construct an infinite number of meanings from a finite number of linguistic rules and elements. For example, one can generate novel conceptions of "friend" simply by adding modifiers (e.g., *best friend*, *girlfriend*, *friend with benefits*). Thus, when a child learns how to use a term like *friend*, he gains access to a world of meanings, practices, and values that have their origins in culture (Damianova & Sullivan, 2011; Vygotsky, 1978).

Psychological functioning is a coactive product of processes that operate within and between individuals. No single aspect of the person ←→ environment system is primary in the constitution and regulation of action. As a result, it is not possible to understand the origins and development of psychological activity simply by examining individual actors (or isolated parts of individual actors). Instead, to understand psychological development, it is necessary to examine how integrative structures of thinking, feeling, needing, and acting undergo differentiation and integration as products of multiply nested coactions that operate throughout the person ←→ environment system.

DYNAMIC SKILL THEORY: TOOLS FOR TRACKING THE DEVELOPMENT OF INTEGRATIVE PSYCHOLOGICAL STRUCTURES

Psychological structures functioning according to epigenetic processes are integrated systems of thinking, feeling, and acting that operate within particular sociocultural contexts. Skills are types of psychological structures. Skills are control structures; they reflect a person's capacity to exert control over elements of thinking, feeling, and acting within particular sociocultural contexts. Skills are not inherently generalized structures. Instead, they are tied to particular psychological domains, tasks, and physical and social contexts. Skills are dynamically coupled properties of persons-in-contexts. The structure of running, for example, differs depending on whether a person is running on a rubberized track, a beach, or an inclined plane. Similarly, a skill developed in one psychological domain (e.g., arithmetic) will not necessarily generalize for use in other psychological domains (e.g., music, storytelling) or even in highly related domains or tasks (e.g., subtraction). Skills develop slowly over time as individuals coordinate lower level elements of acting, thinking, and feeling into higher-order wholes within and between domains and contexts.

A COMMON SCALE OF SKILL MEASUREMENT

Our research has established a scale of hierarchical complexity that children and young adults move through as they learn and develop. This scale provides a key advance for developmental science—a *common ruler* (scale) for measuring change and variation in activity. This discovery is similar to creation of the centigrade or Fahrenheit scales for temperature, and to the meter or foot for length. Unfortunately, psychological measurement has produced mostly arbitrary scales based on a single psychological characteristic, such as intelligence, achievement, or personality. These scales have been grounded in statistical models assuming stable (static) ability and so-called normal distributions (for critique, see van Geert & van Dijk, 2002; Wahlsten, 1990), and they assess behavior in one situation. A more useful scale allows measurement of different skills in various situations and is not tied to one situation or assessment instrument.We have discovered a consistent pattern of cognitive/emotional/cortical transformations in development, with periods of reorganization occurring at regular intervals during development (Fischer, 1980; Fischer & Bidell, 2006; Stein, Dawson, & Fischer, 2010). This pattern is illustrated in Figure 4.2. At regular intervals (e.g., at approximately ages 2, 4, 6, and 10 years) children reorganize their embodied actions to form more complex capabilities. Along with the reorganizations, these changes are marked by spurts in performance. We have found these reorganizations to follow a sequence of 13 levels of skill that develop through four broad tiers with a series of three levels within each tier. The four tiers include *reflexes* (i.e., action patterns, present at birth, that require environmental affordances as a necessary condition for their activation and use), *sensorimotor actions* (i.e., controlled actions performed on physical and social objects), *representations* (i.e., signs and symbols), and *abstractions* (i.e., representations of generalized, intangible meanings). Each successive change from one tier to another constitutes a qualitative transformation—that is, a fundamental shift in the structure of thinking, feeling, and activity that is exhibited within particular domains and contexts. The capacity to exert control over action patterns that are present at birth (i.e., reflexes) is different from the capacity to intentionally execute novel actions and to construct action-based meanings in the context of objects and other people (sensorimotor actions). Similarly, the capacity to make on set of things, actions, or experiences *stand for* another object, thing, or experience in its absence (i.e., representations) differs from the capacity to construct action-based meanings in the context of objects, persons, and events (i.e., sensorimotor acts). Finally, the capacity to construct representations of intangible, hypothetical, and generalized meanings (i.e., abstractions) differs substantially from the lower-level capacity to represent the concrete aspects of observable events (i.e., representations).

Within tiers, skills develop through an iterative cycle of levels. Similar structures recur in each tier, reflecting a dynamic cyclical growth process. Within each tier, a person first differentiates a series of individual *single sets* (i.e., single reflexes, acts, representations, or abstractions). Over time, after an individual differentiates multiple single sets, the person gains the capacity to coordinate at least two sets to form *mappings*. Thereafter, with further development, individuals become able to differentiate multiple mappings and organize them together to form *systems*. At the fourth level of each tier, the person differentiates multiple systems to form a higher-order *system of systems*, which is the equivalent of a new kind of unit that begins the next tier—a *single set* of a new type. The broad growth cycles (tiers) of reflexes, actions, representations, and abstractions are identified in the left column of Figure 4.2. Levels of skill—the specific clusters of discontinuities that arise within tiers—are indicated to the right of each tier.

DEVELOPMENTAL CHANGES IN PSYCHOLOGICAL SKILLS

In this section, we illustrate the use of the common scale through an analysis of developmental changes in integrative structures of thinking, feeling, and acting from birth to adulthood. Although we focus primarily on the structure

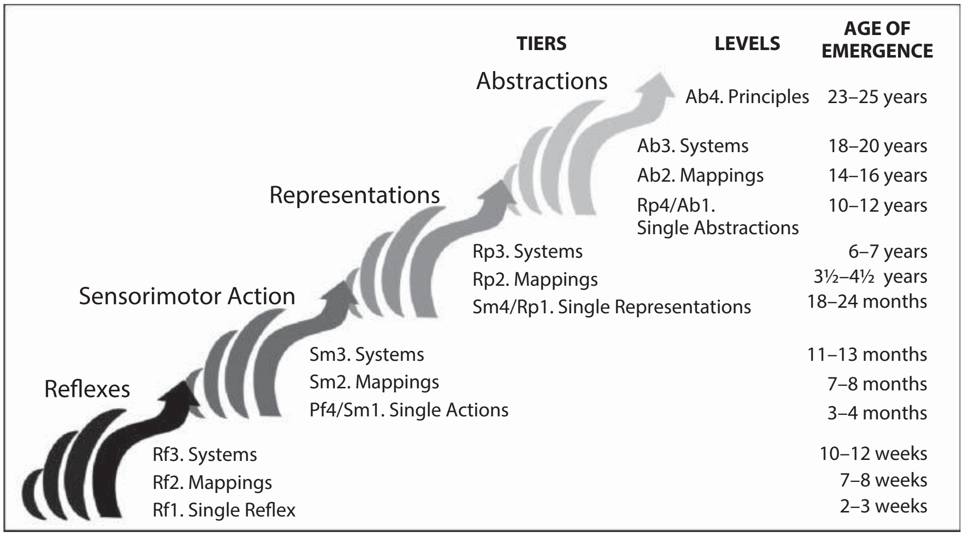


Figure 4.2 Levels and tiers in the development of psychological skills.

of the child's participation in physical and social activity, whenever possible, we also identify how individual functioning operates within coregulated sign-mediated social interaction.

DEVELOPMENTAL CHANGES DURING INFANCY: FROM REFLEX PATTERNS THROUGH SENSORIMOTOR ACTION SYSTEMS

Psychological development builds on primordial forms of intersubjectivity that already exist in the interactions between newborns and their caregiver. The first evidence of such activity can be found in the form of neonatal matching of a number of adult facial actions (e.g., tongue protrusion, lip protrusion). Because infants cannot directly observe their own facial expressions, they cannot use vision to coordinate their own facial activity with the seen facial actions of their caregivers. One explanation of this finding is that similar biological systems (e.g., a mirror resonance system) mediate the processes of both performing an action (e.g., tongue protrusion) and seeing someone else perform an action (e.g., seeing an adult stick out the tongue). From this view, when an infant observes an adult's facial action, the biological processes that mediate the act of seeing the adult's facial action simultaneously activate parallel (matching) states of affect and action readiness in the infant. These primordial experiences of intersubjective attunement between caregiver and infant provide the foundation upon which further social development builds.

Tier 1: Reflexes

Beginning around 2 to 3 weeks, infants begin to operate within the reflexive tier of development. At this point, infants are capable of constructing *single reflexes* (Rf1). They start to exert control over simple elements of action that are both present at birth and that arise in the context of direct physical and social contact. Single reflexes are not like knee jerks or eye blinks. They involve the active control of action patterns that are available at birth and function within the context of direct environmental affordances (e.g., grasping a blanket placed in the infant's hand). In the social sphere, infants exhibit simple reflexes by looking at the mother's face when it is directly in front of the child or by cooing back to a smiling mother looking and cooing toward the baby (see Figure 4.3a).

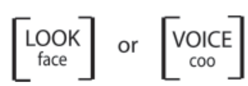


Figure 4.3a

By 7 to 8 weeks, infants begin to coordinate at least two reflex acts into a *reflex mapping* (Rf2) (see Figure 4.2). For example, in contexts in which a caregiver engages infants in direct facial and vocal interplay, infants can begin to exert coordinative control over simple acts of looking at mother and cooing (see Figure 4.3b).

Figure 4.3b

By 10 to 11 weeks, with the onset of *reflex systems* (Rf3) (see Figure 4.2) infants begin to coordinate multiple such mappings together in the context of direct social stimulation. For example, holding a precocious 2-month-old baby in his arms, with a smile and animated voice, a father repeatedly and slowly says “I love you” to his infant. In this context, the infant coordinated acts of looking at the father, hearing the father’s utterance, and with smiling and positive affect, reflecting the prosody and sound of her father’s voice into a vocalization sounding strikingly similar to “I love you” (see Figure 4.3c). This form of affective attunement and reciprocity between infant and caregiver corresponds to what Trevarthen (1979) termed *primary intersubjectivity*.

Figure 4.3c

Tier 2: Sensorimotor Actions

Beginning around 3.5 to 4 months of age, skills undergo transformation as infants gain the capacity to construct skills in the sensorimotor tier of development (see Figure 4.2). At this point, infants begin to gain the capacity to coordinate multiple reflex systems into a single *system of reflex systems*, which is the equivalent of the first level of the *sensorimotor tier*—single *sensorimotor actions* (Rf4/Sm1). Using sensorimotor actions, infants begin to exert spontaneous control over single goal-directed acts. For example, a 4-month-old can *reach for a seen ball* while accommodating the act of reaching to slight changes in the trajectory of the ball; alternatively, an infant can begin to control acts of looking in order to *track the movement of a seen ball* as it moves through a trajectory in space. In social interaction, drawing on expectations acquired over a history of responsive caregiver-child interaction, an infant can coordinate multiple sensorimotor acts (e.g., smiling, vocalizing, looking, hand movements) to initiate social exchanges with others (see Figure 4.3d).

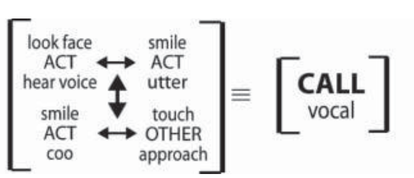


Figure 4.3d

By 7 to 8 months of age, infants begin to coordinate sensorimotor actions into a sensorimotor mapping. Using such mappings, an infant can coordinate looking and reaching into a single seamless controlled skill. She can *reach* for an object *in order to look at it*; or actively *look at an object* in order to *reach for it* as it moves through space. By 9 months, infants are capable of establishing what Trevarthen and Hubley (1978) termed *secondary intersubjectivity*—the capacity to engage in shared reference with an adult. This involves a capacity to coordinate an understanding of what others see or want with what the self sees or wants (see Figure 4.3e).

Figure 4.3e

Using sensorimotor mappings, an infant is able to coordinate acts of *looking at a toy* with a separate act of *seeing his caregiver* look at the same toy. *Social referencing* arises as infants coordinate *looking* at a caregiver’s emotional facial actions (happy, mad, or sad) with the child’s own act of *approaching* an object in the world. For example, an infant can use the mother’s positive or negative facial expression as an indicator to touch or not to touch a particular seen toy.

By 12 to 13 months of age, infants can coordinate two or more sensorimotor mappings into a *sensorimotor system* (SM3). In the realm of acting on objects, a sensorimotor system corresponds to Piaget’s *tertiary circular reactions*. At this level, children can coordinate multiple acts of reaching, moving, and manipulating a new toy to see its various sides and observe how it works in action. In the social sphere, children begin to develop the capacity to use gestures to make rudimentary requests (i.e., pointing; Gros-Louis & Wu, 2012; Tomasello, Carpenter, & Liszkowski, 2007). At the very least, pointing requires an infant to coordinate his own sight of a wanted object (e.g., looking at a toy) with his caregiver’s gaze at the same object (i.e., seeing mother look at the toy), while simultaneously making movements directed toward both the object (e.g., extending the arm) and the caregiver (e.g., alternating looking at mother and object). Over time, the child is able to make refinements in his expectations of the mother (i.e., that she will bring the object) and the gestures used to enlist her support (using the index finger, etc.) (see Figure 4.3f).

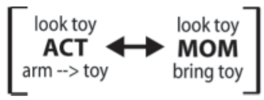


Figure 4.3f

DEVELOPMENTAL CHANGES, TODDLER TO ADULTHOOD: FROM REPRESENTATIONS THROUGH ABSTRACTIONS

The next major transformation a child's capacity to construct novel skills occurs between 18 and 24 months of age. Here we find the emergence of the semiotic function entailing the use of symbols and signs. Using the semiotic function, children are able to make one thing stand for another. Following Saussure (1983; see also Cassirer, 1944; Piaget & Inhelder, 1969), genuine semiotic capacities require the capacity to separate *signifier* (i.e., representational vehicle) from *signified* (i.e., the meaning, referent or object of the signifier). Thus, symbols and signs are genuine semiotic vehicles in the sense that they both *stand for* something else and are *detached* from their referents (e.g., using the word "mother" in the absence of the mother). *Signs* (e.g., the word "mother") differ from *symbols* (e.g., using the vocalization "mumee" to refer to mother) in the sense that they represent conventional rather than personal meanings. Although the shift from sensorimotor action to representations is a dramatic one, the transition occurs gradually and takes a variety of forms. Prior to the emergence of signs and symbols, children are capable of forms of representational activity that are dependent upon the local sensorimotor context. For example, an 8-month-old can take the opening of a door as a *signal* or *index* that the mother will soon be present (Namy, 2009; Piaget, 1951).

Tier 3: Representations

With the onset of construction of skills in the *representational* tier of development, children gain the capacity to coordinate multiple complex action patterns at the level of sensorimotor systems into a higher-order system of sensorimotor systems, which is the equivalent of a *single representation* (see Figure 4.2). Using single representations, children are able to make one thing (e.g., a sound sequence; a picture) stand for another (e.g., an object; the meaning of a word). Single representations allow children to form images and ideas of objects and meanings that have no immediate basis in sensorimotor experience. Children are able to spontaneously control the constructive formation of a mental image; they can use words to stand for absent objects, or to represent the concrete meanings of such objects.

At this level, children can represent concrete ideas in the form of a simple declarative sentence, such as "Eating candy is good" or "Mommy is nice." They begin to use objects to represent absent qualities in pretend play. For example, a child can pretend that a stuffed animal is a teddy bear and pretend to make it walk. In the social sphere, children begin to construct single representations of self (e.g., "I am a girl"; "I have a mommy") and to assign value to those representations (e.g., "I am a good girl") (see Figure 4.3g). Rochat and Passos-Ferreira (2009) refer to shared symbolically mediated evaluations as a form of *tertiary intersubjectivity* between child and caregiver.

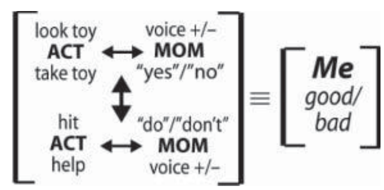


Figure 4.3g

Beginning around 3½ to 4 years of age, children gain the capacity to coordinate at least two single representations into a representational mapping. Using representational mappings, a child is able to represent the relationship between two concrete ideas. At this level, children are capable of representing relations involving *reciprocity* (e.g., "Daddy gave me a present because I drew him a picture"), *quantity* (e.g., "Mommy is tall and I am small"), *cause-and-effect*, (e.g., "Jack fell down because Jill pushed him"), and so forth. Here are three mapping relations depicted in Figure 4.3h.

Figure 4.3h

Beginning around 6 to 7 years of age, in supportive contexts, children coordinate two or more representational mappings into a single *representational system* (Rp3). Using representational systems, children can construct a concrete but systematic logical line of reasoning. In the classical Piagetian conservation task, for example, children are able to understand that changes in the height of the

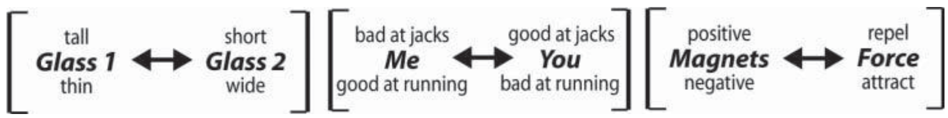


Figure 4.3i

water when it is poured from a tall glass into a short one are compensated by changes in the width of the glasses. In so doing, children are able to represent the relation between two relations, namely, that changes in height *from tall to short* are *compensated for* by changes in width from *thin to wide*. In social relationships, a child can begin to defend against negative feelings that arise from social comparisons. "Jake is better than me at playing jacks, but I'm better at running than Jake." Three illustrations of representational systems are shown in Figure 4.3i.

Tier 4: Abstractions and Principles

Beginning around 10 to 11 years of age, in high support contexts, preteens can begin to construct skills at the next broad tier of development—*abstractions* (see Figure 4.2). Using abstractions, an older child can begin to represent generalized, intangible, and hypothetical aspects of events, people, things, and processes. Abstractions arise as older children gain the capacity to coordinate at least two lower-order representational systems into a *system of representational systems* (see Figure 4.2, Rp4), which is the equivalent of a higher-order *single abstraction* (Figure 4.2, Ab1). For example, at this level, in contexts that support their construction, a preadolescent can begin to coordinate at least two lower-level conceptions at the level of representational systems into a higher-order single abstraction. For example, a 10- to 11-year-old could construct an abstract concept of conservation by generalizing over what is common to two or more concrete examples of conservation—say, conservation of liquid and conservation of mass. In so doing, a child might use the following line of reasoning:

> In general, conservation means that the amount of something stays the same even though there is a change in what it looks like. In the water task, there is the same amount of water in the tall and thin glass as there is in the short and wide one. When the water is poured from the tall glass into the short one, changes in the height are made up for by changes in the width of the glass. So, even though it looks different, there's the same amount of water in both glasses. This is kind of the same as what happens in the sausage task. The two balls of clay are the same at the beginning. When you roll one out to make it into a sausage, the clay becomes long but thin. The changes in the length of the clay are made up for by changes in the thickness. So, the ball of clay has the same amount as the sausage. In both situations, the amount of the thing is the same even though what it looked like changed.

The coordination of two or more concrete representational systems into a single abstraction can be represented as follows:

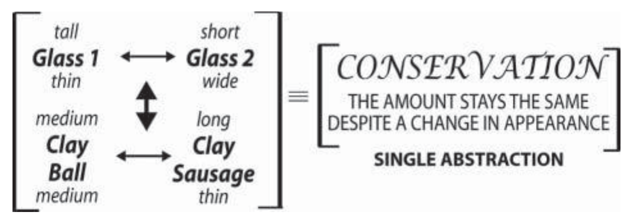


Figure 4.3j

Beginning around 14 to 16 years of age, adolescents gain the capacity to coordinate two or more single abstractions into an *abstract mapping* (see Figure 4.2, Ab2). Using abstract mappings adolescents can represent the relation between two abstract ideas (see Figure 4.3k). For example, a 15-year-old can represent what is meaningful in her life in terms of the relation between two core goals: "The two most important things in my life are my family and my school. I need a good education for my future, and my family is always there to support me in school and other areas."

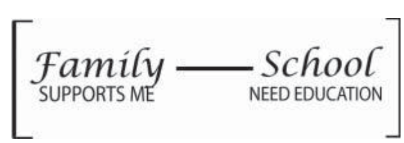


Figure 4.3k

As teenagers approach young adulthood, they gain the capacity to coordinate at least two abstract mappings into a single coordinated *abstract system* (Figure 4.2, Ab3). In so doing, 18- to 20-year-olds are able to construct highly differentiated relations between multiple abstractions, each of which is grounded in the coordination of multiple systems of lower-level concrete representations of events. For example, a young adult can begin to represent the relation between two aspects of his career and two aspects of his personal life (see Figure 4.3l).

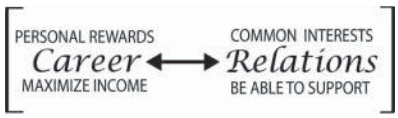


Figure 4.3l

Beginning around 22 to 23 years of age, among individuals with deep experience or advanced training in particular careers or domains, a person is capable of coordinating two abstract systems into a single integrated *abstract principle*. Abstract principles reflect an extremely high level of differentiation and integration of abstract ideas, each of which organize a wealth of lower level abstract and concrete knowledge. For example, as represented in Figure 4.3m, highly reflective individuals can organize a series of abstract systems from various aspects of life into a higher-order principle that defines one's personal theory of a good life (Mascolo & Fischer, 2010). Evidence strongly supports the existence of the first 12 levels of skill proposed by dynamic skill theory, and there is now initial evidence showing growth spurts among highly accomplished individuals during early adulthood (Dawson-Tunik, Commons, Wilson, & Fischer, 2005).

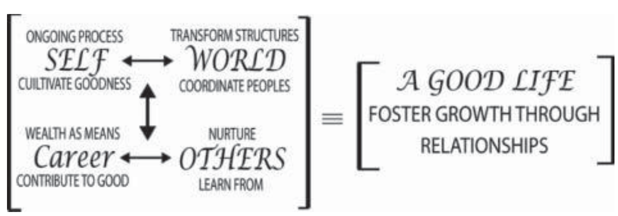


Figure 4.3m

DYNAMIC SKILL THEORY AND THE COMMON SCALE: A SUMMARY

The common scale for behavioral complexity captures both long-term development and short-term learning (Dawson & Wilson, 2003; Fischer, Bernstein, & Immordino-Yang, 2007). It is marked by clusters of discontinuities, such as abrupt changes in growth patterns and clusters of items in scaling (Fischer & Rose, 1994; Fischer & Silvern, 1985; van Geert, 1998). Rasch (1980) scaling of interview and test data have provided consistent evidence of common patterns of discontinuities (Dawson & Wilson, 2003; Dawson, Xie, & Wilson, 2003), forming a scale of 13 levels of hierarchical complexity. The scale also relates to the outline of developmental stages that Piaget (1983) described, but performance is not fixed at one age but instead varies across the scale, marked by clusters of behaviors demarking discontinuities. The scale has important similarities to those suggested by Case (1991), Biggs and Collis (1982), Halford (1982), and McLaughlin (1963). Interestingly, discontinuities in growth of brain activity seem to follow the same scale (Fischer & Rose, 1994).

THE SHAPES OF DEVELOPMENT: RANGES, WEBS, AND PATHWAYS

As we stated at the beginning of this chapter, the pervasive variability of human behavior is essential to the dynamics of human behavior. People act differently in different situations, with different people, in different emotional states. *Variability* is everywhere in human activity and development. Although there is great order in human action and development, people are not stable, and exhibit no fixed patterns of intelligence or learning styles. A child who can solve an arithmetic problem one day or in one situation frequently cannot solve the same problem the next day or in a different but apparently similar situation. Contexts and emotions change who we are. Different children of precisely the same age frequently cannot perform the same cognitive tasks. Variability in the level of psychological performance is the *norm,* not the exception (see Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2010).

Variation in the complexity of an individual's skills is manifested in different ways. First, at any given point in time, individuals do not function at a single level of development. Instead, the complexity of a person's actions fluctuate within a *range* of levels depending on a broad set of variables, including context, psychological domain, time of day, the behavior of social partners, task, emotional state, and so forth. Second, psychological development does not occur in monolithic stages of general abilities. Instead, development assumes different forms in different psychological domains, tasks, and sociocultural contexts. Psychological structures do not develop through a single pathway. Instead, both within and between individuals, skills in different contexts (e.g., arithmetic, social relationships, storytelling, science, self-understanding) develop along diverse pathways that both converge and diverge over time. In this way, developmental change looks more like a multidirectional web than a unidirectional ladder. In what follows, we examine sources of both order and variability in the development of psychological structures within and between individuals.

DEVELOPMENTAL RANGE

An important feature of skill development is that individuals do not function at any single level at any point in development. Skills are context-sensitive control structures; they reflect a person's capacity to exert control over thinking, feeling, and acting within particular sociocultural contexts, psychological domains, and tasks. At any given point in development, the form and level of a person's skills vary as a function of local conditions, including the nature of the task or task domain, the emotional state of the person, and the degree of support and assistance provided by the social context. In this way, in development, a person does not operate at any single point along the common scale; instead, individuals function with a *range* of different possible levels. This is called the *developmental range*.

The developmental level, content, and emotional valence of a person's psychological structures vary dramatically as a function of priming and immediate social support, emotional state, and cultural experience (Fischer & Heikkinen, 2010). A child's *optimal* level of performance refers to the level of skill within a particular domain that she is capable of producing under conditions of *high contextual support*. A child's *functional* level of performance occurs under everyday conditions that provide *low contextual support*. High-support (e.g., providing examples of higher-order performance, or providing rubrics or other forms of structured assistance) contexts direct children's attention toward relevant aspects of a task. An individual's optimal level of functioning under conditions of high support is typically higher than his or her functional level in the absence of such support.

To understand the concept of developmental range, consider the wide variation documented in the structure of children's stories or narratives about positive and negative social interactions (Ayoub & Fischer, 2006; Fischer & Ayoub, 1994; Raya, 1997). To illustrate, in one study 5-year-old Susan watched her counselor use dolls to act out a pretend story about social reciprocity. In the story, a child doll named Susan makes a drawing of her family, and gives it to her father. Then the daddy doll hugs the girl doll, thanks her, and gives her a toy in return. At this point, Susan was immediately able to act out a story involving positive social reciprocity at the same level of complexity as the counselor's story. However, 10 minutes later, when the girl was asked to act out the best story she could about people being nice to each other, she acted out a much simpler story, simply making the Daddy doll give lots of presents to the child doll, with no reciprocal interaction between them.

Further changes in complexity occurred after a shift in the child's emotional state. Soon after the above interactions, Susan spontaneously began to engage in aggressive doll play. At this point, the counselor showed her another story involving reciprocal nice interactions between father and child. This time, when Susan acted out the story, she switched the content from positive to negative and organized it around an aggressive exchange between the father and daughter. However, despite the shift to negative emotion and aggression, Susan nonetheless sustained the level of complexity of her story.

In this example, the level of complexity of the child's storytelling shifted dynamically with changes in the immediate situation, the child's emotional state, and the form of social support provided by her counselor. It is thus incorrect to characterize an individual's skills as simply being at one developmental level at any given point in development. Instead, the level of complexity of individual action fluctuates within a *developmental range*. Different contexts for assessment routinely entail such substantial variations. Children (and adults) show distinct levels of competence under different conditions, even for a single domain such as stories about nice and mean social interactions between peers (Ayoub & Fischer, 2006; Brown & Reeve, 1987; Fischer, Rotenberg, Bullock, & Raya, 1993). Figure 4.4 documents changes in the age of emergence of successive levels of psychological skill levels under a series of different conditions, including conditions of high and low support. As indicated in Figure 4.4, a person's optimal level typically functions one or more levels higher than his or her functional level. Further, the distance between an individual's optimal and functional levels of performance (developmental range) typically expands with development. Skills at higher levels of functioning (e.g., abstract mappings and above) may never emerge in some people.

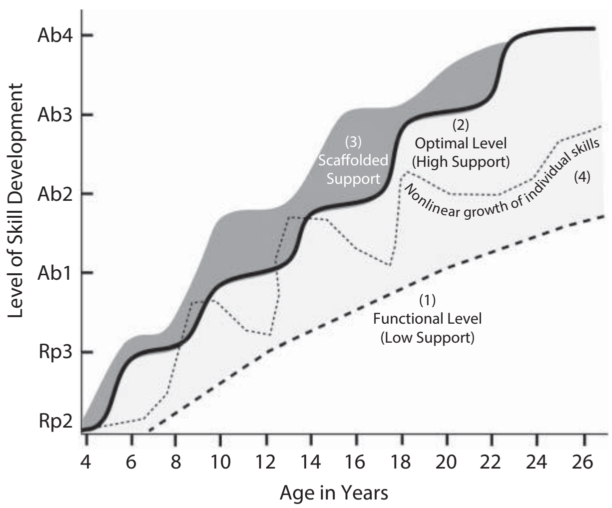


Figure 4.4 Four growth curves showing low, high, scaffolded, and variable support.

HOW COACTIVE SCAFFOLDING PRODUCES HIGHER-LEVEL SKILLS

It is helpful to differentiate an individual's *scaffolded* level of performance from his *optimal* level of performance under conditions of *high support*. Scaffolding occurs when more expert others assist an individual in the performance of any given activity (Gauvain, 2005; Wood, Bruner, & Ross, 1976). Scaffolding differs from high support in that when scaffolding, a more expert person tends to perform part of the task for the child, or otherwise provide instruction that directs the child's actions in ways that the child could not accomplish alone. In contrast, under conditions of *high support*, an individual is able to complete an activity by him or herself, without the intervention of someone else during the process of executing the task. A child who is able to imitate a story modeled by someone else, but does so without further assistance beyond the modeling itself, is operating at her optimal level under conditions of high support. Scaffolding occurs when this child requires instruction or cueing during the process of telling or retelling a story. Under scaffolded conditions, a child's higher level of performance is dependent on the continued intervention of another person. Under conditions of high support, beyond the support itself a child is able to complete the task alone.

In any given task, an individual's scaffolded level of performance tends to be higher than his *optimal* level. This is because control over elements of the task is distributed between teacher and learner. Scaffolding functions to raise an individual's level of functioning to levels beyond that which he can achieve alone. In this way, as Vygotsky (1978) suggested, the level of skill produced when a child is learning a new skill with the assistance of others operates in advance of the level of skill a child exhibits when working alone.

Social scaffolding, however, is not the only type of scaffolding that organizes development and learning. We use the term *coactive scaffolding* to refer to the ways in which aspects of the person ←→ environment system outside of an individual's direct control function to raise the individual's performance beyond that which he or she can sustain alone (Mascolo, 2005). Social scaffolding is one form of coactive scaffolding. Other forms of scaffolding include *task scaffolding*, *ecological scaffolding*, and *self-scaffolding*. *Task scaffolding* occurs when aspects of the task itself (or the objects of action) operate in ways that support higher levels of performance. For example, when playing Scrabble, the simple act of moving tiles around suggests different letter combinations that a player can use (intentionally or otherwise) to identify novel words. *Ecological scaffolding* occurs when the relationship between the actor and context functions to support high-level performance. For example, when a mother holds an infant in her arms, the baby is optimally positioned to gaze toward the mother's face. The distance between the infant's face and the mother's face is approximately equal to the limits of a neonate's visual acuity. In this way, the ecology of the holding environment supports the act of looking into the mother's face. *Self-scaffolding* (Bickhard, 1992) occurs when the actor herself creates her own conditions for supporting higher-level functioning. Self-scaffolding occurs in the context of problem solving, for example, when a person uses an already known way of solving a problem to solve a similar but novel problem.

DEVELOPMENTAL ANALYSIS OF JOINT ACTION

Scaffolding directly contributes to the moment-by-moment formation of psychological structures. We have developed a series of tools for conducting developmental analyses of joint action as it occurs in moment-by-moment interactions between individuals. This system allows empirical analysis of the micro- and macrodevelopment of psychological structures as they emerge between people in joint action. The process of assessing changes in the structure of joint action involves several steps. These include (a) *performing task analyses* of the actual or optimal endpoints of development within particular domains; (b) *analyzing the* *structure of joint action* (how individuals organize patterns of acting, thinking, and feeling in relation to each other in particular contexts); and (c) *tracking changes in the structures and processes of joint action* over time. A developmental analysis of the role of coactive scaffolding in organizing a developing skill is depicted in Figure 4.5. The top panel of Figure 4.5 contains a task analysis for *manipulating a handheld jack-in-the-box*. As indicated in the figure, to manipulate a jack-in-the-box successfully, it is necessary to understand the goal of the task as *making the jack pop: hold the box*, *turn the crank up and down*, and *sustain turning* until the *jack pops*.

The operation of a handheld jack-in-the-box is beyond the capacity of a 15-month-old child. However, with assistance, most 15-month-olds can perform at least part of the task. The middle panel of Figure 4.5 depicts a *dyadic action structure* that identifies the ways in which control over components of the jack-in-the-box tasks is distributed between a 15-month-old boy and his mother at a particular moment in time. The left portion of the diagram identifies the configuration of acts over which the *child* was able to exert control (i.e., looking at the box while turning the crank up and down for several jerky turns); the right portion identifies those parts over which the *mother* exerted control (i.e.,

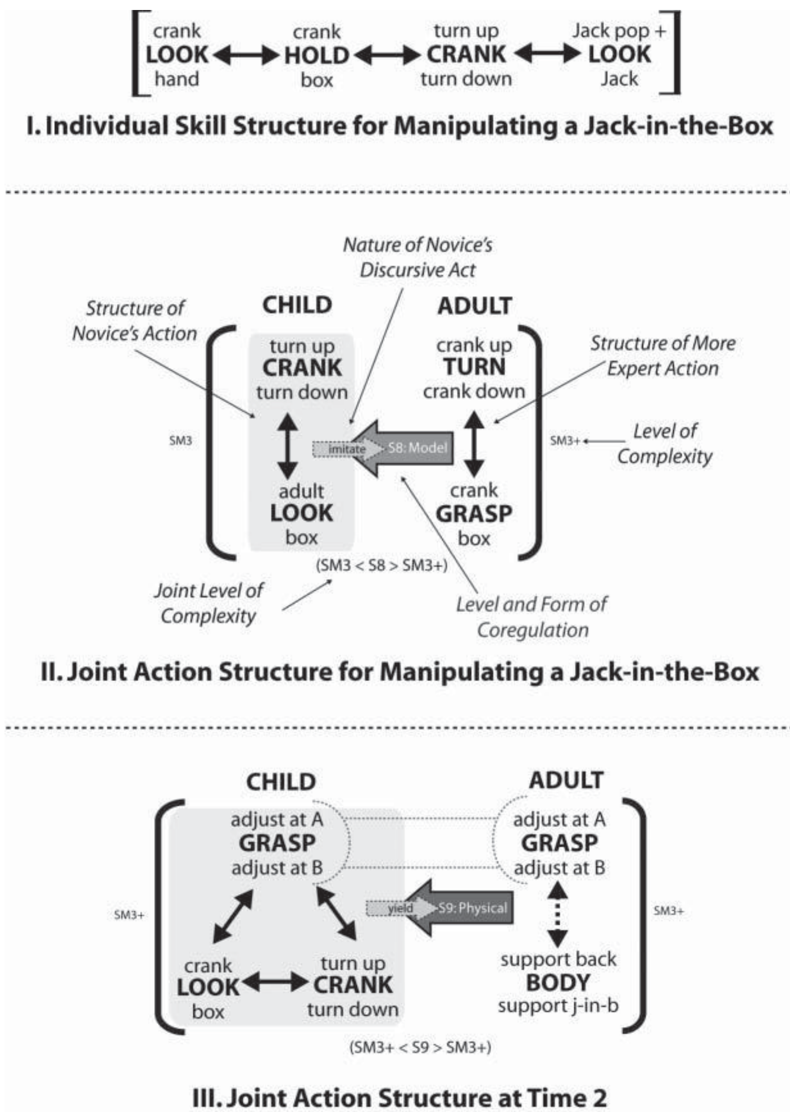


Figure 4.5 Tools for the developmental analysis of joint action.

Source: From "The Dynamic Development of Thinking, Feeling, and Acting Over the Life Span" (pp. 149–194), by M. P. Mascolo and K. W. Fischer, in *Cognition, Biology, and Methods*, W. F. Overton (Ed.), Volume 1 of *The Handbook of Life-Span Development*, R. M. Lerner (Editor-in-Chief), 2010, Hoboken, NJ: Wiley.

TABLE 4.1 Levels and Forms of Social Scaffolding

Level and Form	Example
9. Physical Guidance. E uses physical contact, directly or indirectly, to direct N's task activity.	Uses hand-over-hand contact to guide N in crossing laces.
8. Model. E demonstrates or shows N how to perform a task or action.	Cross your laces like this.
7. Direct. E directs, instructs, or otherwise indicates how to perform a task or action.	First cross your laces, then put your left lace through the opening.
6. Interpret/Explain. E draws on authoritative understanding to interprets or explains event.	When you cross your laces, it looks like the letter "X"
5. Hold. E offers or agrees to perform part of a task or carry part of the emotional burden of a task.	Don't worry; if you don't finish it all, I'm here to help.
4. Distance. E asks questions or makes statements intended to prompt constructive activity on part of N in order to meet the challenge.	N: "What makes it nighttime?" E: "What is the difference between night and day?"
3. Restate/Expand. E repeats, reframes or adds additional information that extends the meaning of N's statement.	N. It gets dark at night. E. It gets dark at night when the sun goes down.
2. Encourage. E reassures or modulates N's self-evaluation in order to support ongoing activity.	You can do it; it's just like you tied your laces yesterday.
1. Prompt. E cues N to deploy existing skill.	Okay, tie your shoes!

Note. Higher levels of scaffolding indicate increasing degrees of support.

holding the box while modeling the turning of the crank). The symbol in the middle of the diagram identifies the form of *coregulated action* that occurs between parent and child. Table 4.1 identifies a series of nine levels of social scaffolding. Each level is defined in terms of the degree of structuring assistance provided to a learner by a teacher. In this situation, the child is able to turn the crank for several turns after his mother *models* (Scaffolding Level 8) the action and *encourages* (Level 2) the child to perform it.

The bottom panel of Figure 4.5 identifies the structure of action between the parent and the child only minutes later. In this situation, the child sits on his mother's lap, his back leaning against his mother, while his mother uses hand-over-hand guidance (Scaffolding Level 9) to assist the child in both turning the crank and holding the box. The scaffolded structure of the child's behavior in this situation is different than it was just moments before. In this situation, without her physical support and hand-over-hand guidance, the child would have been unable to exert any degree of control over the process of turning the crank and holding the box. The dyadic action analysis shows precisely how particular relations among components of the person ←→ environment system (e.g., hand-over-hand guidance ←→ child holding the box ←→ mother's bodily support ←→ child's posture in relation to the box) support higher order action. By tracing changes in the structure of dyadic action over time, one can illuminate how children gradually seize control and master configurations of thinking, feeling, and acting that have their origins in coactions that occur within the person ←→ environment system.

NONLINEARITY AND THE SHAPES OF DEVELOPMENT

Along with optimal level and functional level, Figure 4.4 shows four growth curves that are indicative of the dynamic variability in the shapes that development takes over time. An individual's functional level (Curve 1) performance in any given skill tends to increase slowly over time. Changes in functional level tend to occur only after individuals have had time to consolidate lower-level skills into more stable higher-level skills that can have broad application beyond their contexts of acquisition. In contrast, changes in optimal level performance (Curve 2) tend to follow spurts in brain development (Fischer & Rose, 1994) and are revealed primarily under conditions of high support. As a result, growth curves tend to follow a scalloped pattern reflecting a spurt in growth, followed by a period of consolidation. Repeated high-support assessments over time reveal the earliest age of emergence of new levels of skill. Under scaffolded support, an individual-with-assistance is capable of performing at levels that extend beyond his or her optimal level. This is indicated in the shaded area beneath Curve 3. In most cases, it is best to view a child's scaffolded level as reflecting activity at the dyadic rather than individual level of performance.

Everyday development occurs across a wide variety of contexts, conceptual domains, tasks, and conditions. Psychological structures tend to show wide variations in level of complexity from one point in time to another. As a result, psychological development tends to be profoundly *nonlinear* rather than linear. Curve 4 in Figure 4.4 depicts a typical nonlinear growth curve. Particular skills tend to develop in fits and starts, and exhibit both forward progression and backward transition (Granott, 2002). Backward transitions (i.e., temporary regressions) occur for many reasons, many of which have to do with variations in local conditions (degree of support, type of task, etc.). However, backward transitions also serve important developmental functions (Bassano & Van Geert, 2007). Backward transitions often occur as individuals build a novel skill.

This occurs for several reasons. It is often necessary for individuals to return to lower levels of functioning in order to consolidate (form increasingly integrative connections among) component parts of newly formed skills (Feldman & Benjamin, 2004). Backward transitions also occur when, after completing the construction of one part of skill (e.g., when learning to tie shoes, building the skill to cross the laces), children return to a lower level of functioning to begin construction of a second part of the developing skill (e.g., learning to loop one lace around another). Nonlinear growth of skills is the rule rather than the exception in the development.

WEBS AND DEVELOPMENTAL PATHWAYS

In the standard metaphor for development, children are tracked along a single, unidirectional *developmental ladder,* and educators assume that all children move along the same ladder. The *constructive web* framework provides tools for rethinking variability to capture patterns of variation in skill development. Different groups of children commonly move along alternative developmental pathways. When children (and adults) are seen as moving along different pathways, the teacher's work is changed from forcing students to learn in one way to finding the best pathways for children to follow. There is not only one learning sequence but many alternatives. Different children learn along different pathways.

Figure 4.6 depicts a constructive web exhibiting a variety of different converging and diverging paths. The pathways that make up the web can represent different strands of development within a single individual, different individual strands, or different groups of individuals. The pathways of construction vary in their degree of stability as one moves to higher levels of development. In Figure 4.6, bold lines that form the base of a developmental pathway indicate the automatization of skills that occurs with over-learning and routinization. *Automatized* skills (e.g., reading words with reading proficiency) require little or no attentional resources for their execution (Usoof-Thowfeek, Janoff-Bulman, & Tavernini, 2011). Functional level skills are those that require conscious control and attentional resources, but are effectively stable for everyday activities (e.g., reading a picture book for a 7-year-old). Optimal level skills are those that individuals can sustain under high support conditions (e.g., modeling a simple story for a 7-year-old), whereas scaffolded levels occur as adults assist children in constructing skills currently under

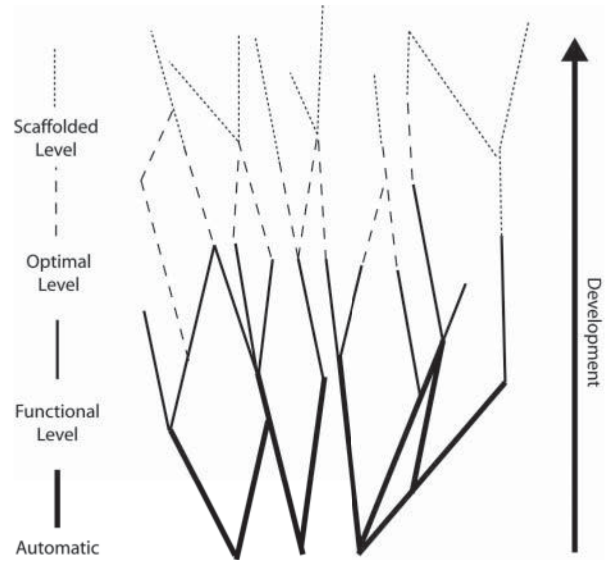


Figure 4.6 Constructive developmental web.

development. Within a developmental web, an individual's developmental range corresponds to the area through which an individual's skills fluctuate with changes in context, emotional state, instruction, domain, and so on.

ILLUSTRATING THE CONSTRUCTIVE WEB: PATHS IN THE DEVELOPMENT OF READING

Young children can begin to read words at an early age. Most curricula treat all children as if they learn in the same way. However, that is not true: Different children learn differently, taking distinctive pathways to learn how to read words. This is true even for children learning one language, such as English, and it is even more pervasively true when all the many human languages are considered. Children learning Mandarin have to master four tunes or melodies that mark each word, and they have to learn Chinese characters that do not represent the sounds of the words. Their tasks are vastly different from reading Spanish or Rumanian or even English. For example, Knight and Fischer (1992) found three different pathways to reading that were hidden in the variability of early readers. As shown in Figure 4.7, different readers actually followed *distinct* pathways for reading. Many readers showed one pathway (A), but others showed the two alternative pathways (B and C). The first pathway occurred among readers who were readily able to integrate sight, sound, and meaning when learning to read. The other pathways occurred in children who had difficulty integrating sight, sound, and meaning. The second pathway was marked by

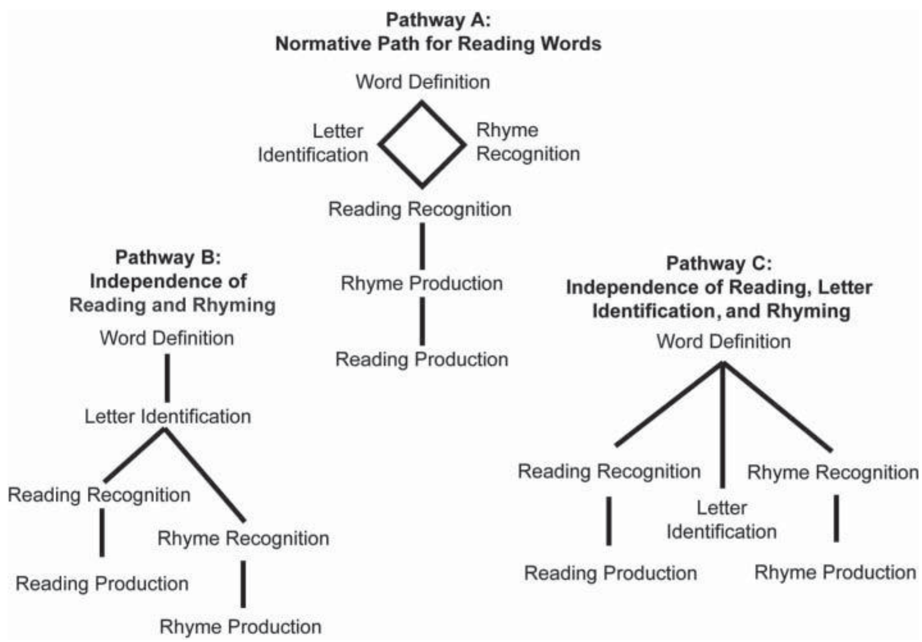


Figure 4.7 Pathways in the development of word reading.

Source: From "Dynamic Development of Action and Thought" (pp. 313–399), by K. W. Fischer and T. R. Bidell, in *Theoretical Models of Human Development*, R. M. Lerner (Ed.), Volume 1 of the *Handbook of Child Psychology*, 6th ed., W. Damon and R. M. Lerner (Editors-in-Chief), 2006, Hoboken, NJ: Wiley.

an independence of visual (e.g., word identification and reading production) and auditory (rhyme recognition and rhyme production) aspects of reading. The third pathway involved even further independence in the development of the subskills of reading. For this group, letter identification developed independent from word recognition and reading production, which developed independent from rhyme recognition and production. Most children in the second and third groups learned to read; however, they followed a different path from the "normal" one (Fink, 2007; Fink & Samuels, 2007).

In another series of studies we found strong evidence that different kinds of readers show distinct organization of their visual field. It turns out that astronomers can benefit from having a different organization of their visual field, which is distinct from the normative pattern that eye specialists describe: Instead of having a rapid drop-off in the sensitivity of the visual field moving away from the fovea (central visual area) and toward the periphery, some astronomers demonstrate instead a heightened sensitivity in their periphery. They benefit from this sensitivity, as evidenced by greater success at identifying patterns across wide areas of the visual field, such as the complex patterns that are shown by black holes. Astronomers with dyslexia were more successful at identifying black holes from patterns of waves (Schneps, Rose, & Fischer, 2007).

An implication of these findings is that people develop along alternative pathways, and teachers can help different kinds of readers learn in ways that embody the most effective remedial educational strategy for them. That is, instead of attempting to speed up "normal" development in ineffective readers, teachers can seek ways of helping to channel children along pathways that work well for them to converge on the goal of skilled reading (Fink, 2006; Wolf & Katzir-Cohen, 2001). By trying different methods of teaching reading, teachers can channel development, providing environmental support to build bridges to effective reading. Children with difficulty reading can experiment to find ways of learning to read and write skillfully for them. Fink (2007) found that many dyslexic adults had found their way to becoming skill readers and writers despite their dyslexia. This approach is being realized in educational efforts for many dyslexic children (Fischer et al., 2007; Rose & Meyer, 2002) and also in work with maltreated and aggressive children (Ayoub & Fischer, 2006; Kupersmidt & Dodge, 2004; Watson, Fischer, Andreas, & Smith, 2004).

FORGING A PATH BY WALKING

It is important to note that the pathways embedded within a developmental web are neither preformed nor predetermined. Instead, developmental pathways, like the development of psychological structures themselves, are emergent products of coactions that occur among component parts of the person ←→ environment system over time. The developmental web is itself a product of constructive process. Thus, instead of thinking of developmental trajectories as already existing pathways that preexist the developmental process, it is better to think of the process of development as akin to the process of *making a path through walking* (Thompson, 2007).

The developmental web provides a framework for understanding the development of differing socioeconomic groups, cultures, ethnicities, or races, and children with learning or psychological problems. Against the backdrop of a developmental ladder based on European American, middle-class norms, children from different social groups are frequently seen as exhibiting deficits in development. Within the web metaphor, many developmental differences become alternative pathways instead of deficits; and curricula, interventions, or therapies can be created based on these alternative pathways. Research methods should allow detection of alternative sequences instead of forcing all children to either fit or not fit one sequence. Remarkably, much research on development has treated sequences not as variable phenomena to be explained but as fixed milestones in a ladder. In the early 1970s, Flavell (1971) and Wohlwill (1973) called for more research on variation in sequences, but only recently has this call been taken seriously. Most neo-Piagetian analyses ignore evidence for variation and branching and overgeneralize the uniformity of cognitive and emotional development. Given the pervasive evidence of cognitive variability, why do the most prominent models of psychological structure continue to be static conceptions such as stage, competence, and biologically determined core knowledge? It is time to rebuild the study of learning and development based on dynamic systems.

DEVELOPMENT IN INFANCY: CHANGES IN SKILLS FOR RELATING TO PERSONS AND THINGS

Infant development from the reflex tier through the sensorimotor action tier demonstrates all the hallmarks of dynamic development discussed earlier including dramatic developmental transformations over time; the dynamic coconstruction of sensorimotor skills within intersubjectively mediated social interaction; development along diverse pathways; and dynamic variations in the form of sensorimotor action as a function of context. In this section, we examine structural changes in the development of sensorimotor skills through an analysis of the pathways over the course of infancy. Thereafter, we extend our discussion of development in infancy to an analysis of claims made about the capacities of young infants to understand objects and people.

THE DEVELOPMENT OF REACHING IN INFANCY

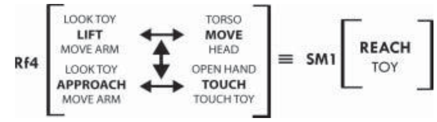
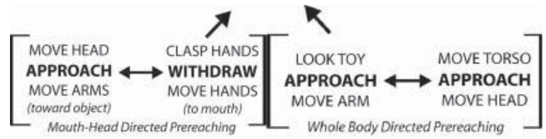
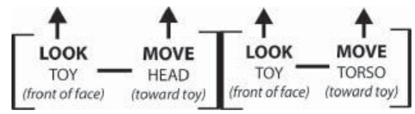
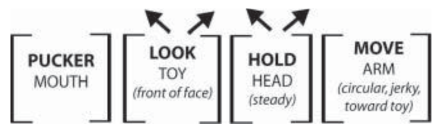
Analysis of the development of how infants reach-to-eat provides a rich illustration of structural change in skills through the reflex and sensorimotor action tiers of development (see Figure 4.2). In this section, we track developmental changes in reaching in infancy using the common skill scale, with particular attention to the development of the everyday skill of *reaching to eat*.

FROM NEONATAL PREREACHING TO SELF-DIRECTED REACHING

The development of reaching has its early origins in the *prereaching* acts of neonates (Rader & Stern, 1982; von Hofsten & Ronnqvist, 1993). From birth, when a seen object is placed within reach, infants attempt with effort to extend their arms toward the object. Prereaching is highly dependent on the relation between the infant's posture and social context. The infant's body must be supported and oriented toward a seen object that is placed within the infant's reach. Movements of the two arms are generally undifferentiated, leading to bimanual rather than unimanual arm extension. As the arms extend, the hands—which normally assume a fisted position—fan out reflexively. Acts of prereaching are typically jerky, uncoordinated, and inaccurate. When an arm does reach its target, neonates do not spontaneously grasp the touched object. For a neonate to grasp an object, it must be placed directly in the hand. Over the first 2 months of life, the rate of neonatal prereaching declines (Rader & Stern, 1982). During this time, when infants extend their arms, their hands remain fisted rather than flexed. The breakdown of the extension-flexion reflex begins to give way to more differentiated forms of reaching.

Table 4.2 depicts alternative trajectories in the development of prereaching and reaching over the course of infancy. In their analysis of infant reaching, Foroud and

TABLE 4.2 Developmental Changes From Prereaching to Reaching

Form of Reaching	Description	Structure of Reach
5. Self-Directed Reaching. Single sensorimotor acts (Rf4/Sm1, 3.5–4 months)	Reflex systems are coordinated into a single, self-directed sensorimotor act of reaching. Object must be within reach and placed in front of child. Accuracy improves substantially.	
4. Differentiated Head/Mouth and Whole Body Directed Prereaching. Reflex systems (Rf3, 10–11 weeks)	Child directs either (a) multiple bodily movements or (b) more differentiated whole body movements toward object. Accuracy increases, but remains poor.	
3. Head/Mouth and Whole Body Directed Prereaching. Reflex systems (Rf2, 7–8 weeks)	Child directs either (a) head and mouth or (b) whole body toward seen object. Accuracy is poor.	
2. Diffuse Prereaching. Single reflexes (Rf1, 2–3 weeks)	Extension-flexion reflex dissipates. Single elements of action directed toward object. Hands fisted rather than flexed. Movements remain jerky. Accuracy is poor.	
1. Neonatal Prereaching.	With object placed in front of neonate, both arms extend jerkily toward object as fingers fan out. Accuracy is poor.	

Note. Arrows in right column indicate patterns of differentiation and integration in development over time.

Whishaw (2012) identified three early levels of prereaching. The first, *diffuse prereaching*, was observed between the first and third month of life. This form of prereaching operates at the level of *single reflexes*. Diffuse prereaching involves the activation of fragmented and incomplete movements of the hands, limbs, head, and mouth in the direction of a seen target (a toy or piece of food). These motor movements are typically uncoordinated, stopping and starting at different times, and fail to reach their targets. For example, presented with an object while sitting in an inclined position, one infant alternatively shifted her eyes toward the target; opened and closed her hands; extended her torso; and made circular movements with her hands.

The second form of prereaching involves *head and mouth directed prereaching*. Step Rf2 in Table 4.2 depicts the structure of this skill at the level of reflex mappings (i.e., coordinations of two single reflexes). For example, one infant moved her head and mouth in the direction of a wanted object placed in front of her. A more developed form of head/mouth prereaching occurs at the level of reflex systems (Table 4.2/Step Rf3). (Reflex systems are integrations of two reflex mappings.) For example, another infant, looking at the wanted object, puckered her mouth, and moved her hands in a circular fashion toward the object. Failing to reach it, she clasped her hands together and brought them to her mouth—as if she were actually bringing the object to her mouth! A third form of prereaching involves *whole body prereaching*. In this version of prereaching, an infant directs her entire body toward the object as a single unit (Table 4.2/Rf3). These observations indicate that prereaching shows a variety of dynamically shifting forms as it develops in very young infants.

Table 4.3 shows changes in the structure of action within the sensorimotor tier of development. With the development of single sensorimotor actions (Table 4.3/Sm1), an infant is capable of executing single fully coordinated actions such as *reaching for a seen object*, *grasping a touched object*, or *bringing an object to the mouth*. Although 4-month-olds are capable of performing single actions, it is not until 7 or 8 months of age that infants are able to coordinate two sensorimotor actions into a *sensorimotor mapping* (Table 4.3/Step Sm2). At this level, reaching becomes more coordinated. By integrating two sensorimotor actions, an infant can adjust her reach around an obstacle in order to reach for and grasp an object. Alternatively, from the outset of a situation, an infant

TABLE 4.3 Developmental Transformations in Adaptive Reaching

Form of Reaching	Description	Structure of Reach
5. Fully Integrated Reach-to-Eat. Sensorimotor systems (12–13 months)	Infant is able coordinate both gross (e.g., extend/withdraw arm) and fine motor movements (e.g., pincer movement) within a three-dimensional space. Child fully able to pronate (i.e., rotate wrists in anticipation of grasping) and supinate (e.g, rotate hands) with movement relative to targets.	LIFT FOOD / REACH / SUPINATE ⟷ PRONATE / GRASP / WITHDRAW
4. Transition to Seamless Reach-to-Eat. Compounded sensorimotor mappings (Sm3, 9–10 months)	Reach-to-eat becomes more differentiated (infant initiates reach by flexing elbow rather than shoulder) and integrated (arm initiation immediately coordinated with wrist rotation in anticipation of object).	REACH FOOD — GRASP FOOD; WITHDRAW TO MOUTH
3. Intercoordinated Reaching and Grasping. Sensorimotor mappings (Sm2, 7–8 months)	Infant is able to coordinate fully differentiated reaching and grasping actions. Reaching and grasping are fully intercoordinated and adjust to each other.	REACH OBJECT — GRASP OBJECT
2. Undifferentiated Reach-to-Eat. Complex sensorimotor actions (4 months +)	Infant is able to reach, grasp food from mother's hand, and transport it to the mouth. Movements are undifferentiated both within (e.g., child uses whole hand rather than pincer) and between (grasping food is part of sliding action) actions.	REACH FOOD ~ PRE-ADJUST GRASP ~ GRASP (diffuse); SLIDE FOOD TO FACE ~ "MOUTH" FOOD
1. Self-Directed Reaching. (Single sensorimotor acts, 3.5–4 months)	Infant is able to control single actions (reaching, grasping, transporting) at a single time; objects must be within child's sight and reach.	REACH TOY or GRASP TOY (diffuse) or MOVE TOY TO MOUTH

can coordinate previously separate acts of reaching and looking in order to *reach for an object in order to look at it,* or *look at an object in order to reach for it*. By 12 to 13 months, using *sensorimotor system,* infants are capable of seamlessly coordinating multiple actions in elaborated acts of exploring and manipulating objects (Table 4.3/Sm3).

THE DEVELOPMENT OF REACHING TO EAT

In addition to these broad transformations, there are also a series of subtle changes in reaching and grasping during this time. Sacrey, Karl, and Whishaw (2012) analyzed the structure of *reach-to-eat* (reach-grasp-eat) movements both in adults and in developing infants between the ages of 6 to 12 months. Table 4.3 identifies developmental changes in the structure of the infant's reaching and reach-to-eat skills between the ages of 6 and 12 months of age. At 6 months, infants exhibit a set of uncoordinated reach-to-eat actions. Unlike adults, 6-month-olds initiate reaching by flexing the shoulder rather than the elbow. Although they open their digits as they extend their arms, they fail to position the fingers over the food (pronation) or to rotate their wrist to orient to the food (supination). To grasp, infants open the entire hand and close it around the food. Instead of lifting their wrists, infants tend to slide the food from the hand of the caregiver. Bringing the food to the mouth, the infant mouths it in order to eat it (Table 4.3/Sm1+).

The 9-month-old's reach-to-eat skill shows marked advance. Similar to the adult, the infant begins the reach by flexing the elbow. The primary advance involves coordinating the movement of the arm with initial skill in rotating the wrist toward the seen target. Accuracy increases, as infants are able to correct diverging paths of movement in relation to the object (Table 4.3/Sm2+). By 12 months, the child's reach-to-eat skill approximates that of the adult. Operating at the level of sensorimotor systems, an infant can coordinate both gross (e.g., extending/withdrawing arms) and fine motor movements (e.g., the pincer) within a three-dimensional space (e.g., rotating wrists toward/away from the food/mouth in approach/withdrawal phases).

DYNAMIC VARIATION IN THE DEVELOPMENT OF REACHING

Like most actions, the structure of reaching varies as a function of object, posture, context, the individual child, and other important variables (Clearfield, Feng, & Thelen, 2007; Lobo & Galloway, 2008; Schöner & Dineva, 2007). For example, research has demonstrated that the structure of anticipatory grasping of objects changes over infancy. Before 4 months of age, infants accommodate their hands around an object placed in the hands, but show minimal preadjustment to objects prior to physical contact. At 5 months, infants differentially adjust their grasping movements prior to physical contact in response to visually salient features of objects (Barrett, Traupman, & Needham, 2008). Between 5 and 12 months, infants become more adept at adjusting their grasp to the physical orientation of objects. Infants preadjust their grasp to horizontally presented objects beginning around 5 months; to vertically presented objects at 7 months (Witherington, 2005); and to diagonally presented objects by 11 to 12 months (Wentworth, Benson, & Haith, 2000). Further, infant reaching is highly sensitive to postural constraints. Among infants under 5 months of age, the quality of reaching is diminished when infants assume a supine (0°) rather than seated (70°) or reclined (45°) position (Carvalho, Tudella, & Savelsbergh, 2007)

Research has demonstrated that the developmental course of reaching varies in different children. Thelen and her colleagues have identified diverse, richly textured trajectories in reaching behavior in individual children (Corbetta & Thelen, 1996; Corbetta, Thelen, & Johnson, 2000; Spencer, Vereijken, Diedrich, & Thelen, 2000). As a group, infants tend to shift from bimanual reaching to unimanual reaching beginning around 4 months, and briefly return to bimanual reaching around the time that they begin to walk (Corbetta & Bojczyk, 2002). Corbetta, Thelen, and Johnson (2000) examined how infants between 5 and 9 months of age adjust their reaches (unimanual versus bimanual) as a function of variation in object size. They identified three groups of infants: One group consistently matched the form of their reach to the size of the ball, shifting from bimanual reaches with larger balls to unimanual reaches with smaller ones. A second group was inconsistent in their matching, and a third never altered their reaching.

THE POWER AND LIMITS OF SENSORIMOTOR ACTION: WHAT DO INFANTS “KNOW” ABOUT OBJECTS AND PERSONS?

In the past decades, research has documented the capacity of infants to construct knowledge in a variety of social and nonsocial areas. The literature assessing infant cognition is enormous. Researchers have studied infant understanding of number (de Hevia & Spelke, 2010), objects (Baillargeon et al., 2012), space (Keil, 2008), concepts and categories (Oakes, Horst, Kovack-Lesh, & Perone, 2009), causality (Newman, Choi, Wynn, & Scholl, 2008), language (Gervain & Mehler, 2010), imagery (Moore & Johnson, 2011) and other minds (Meltzoff, 2011; Wellman, 2011). Some infancy researchers have proposed that infants are equipped with domain-specific innate (i.e., strictly biologically determined) knowledge, which allows them to reason about objects and people from early in infancy. For example, Carey and Spelke (2008) suggest that “human reasoning is guided by a collection of innate domain-specific systems of knowledge. Each system is characterized by a set of core principles that define the entities covered by the domain and support reasoning about those entities” (p. 169). In the case of number, Carey and Spelke suggest that such strictly biologically determined knowledge includes “core principles of one-to-one correspondence and succession (every number has a unique successor)” (p. 176). Similarly, in the domain of knowing about persons, Wynn (2008) states,

> I propose three innately given components of understanding as our entree to understanding the social world: First: . . . Infants reason about inanimate objects in terms of naive physics, while they reason about social beings in terms of mental attributes such as goals, desires, and attitudes . . . . Second: The goals, desires, and attitudes that young infants ascribe to social beings, and via which they interpret their behavior, are inherently mentalistic attributions . . . . Third: Infants are not interpreting interactions among agents and assigning attitudes dispassionately, but are judging these social interactions. The actions of one intentional being toward another are viewed in valenced terms, as “good” or “bad,” from early infancy. (p. 303)

These are bold claims and, in employing the term *innate*, in its sense of being strictly biologically determined, rather than its correct meaning of “present at birth,” (see Bateson, Chapter 6, this *Handbook*, this volume; Overton, Chapter 2, this *Handbook*, this volume) they totally ignore the *probabilistic epigenetic* development that occurs prenatally (Gottlieb, Wahlsten, & Lickliter, 2006; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume). Nevertheless the claims have found a receptive audience because they have led to robust findings from a large and growing number of cleverly designed and well-controlled experimental studies. We examine but two examples of these studies. Izard, Sann, Spelke, and Streri (2009) familiarized newborn infants with auditory sequences containing different numbers of syllables (e.g., “ra-ra-ra-ra” or “ra-ra-ra-ra-ra-ra-ra-ra-ra-ra-ra-ra”). After familiarization, as the auditory presentation of the syllables continued in the background, infants were presented visually with four different stimulus displays containing either a congruent (the same number of shapes as syllables) or incongruent (a different number of shapes from syllables) number of shapes. To determine whether infants could differentiate number across different kinds of stimulus characteristics, each of the four test arrays was composed of a different type of geometric shape with a different fixed color. Three ratios of congruent to incongruent shapes were used: 4:8, 4:12, 6:18, with large and small numbered arrays presented equally in congruent and incongruent conditions. Results indicated that newborn infants looked longer at stimulus displays in which the number of objects was congruent rather than incongruent with the number of auditorally presented syllables. The researchers interpreted these findings to indicate that newborns are capable of perceiving abstract number.

In a study on social knowledge, Luo and Baillargeon (2010) reported a series of studies suggesting that young infants are capable of reasoning about psychological states. Six-month-old infants were habituated to trials in which a female agent sat between two objects (A and B) and consistently reached for A. Both objects were always visible to the infants. In the hidden-object condition, only A was visible to the agent; a screen occluded B from the view of the agent. In a sighted object condition, B was only partially occluded from the agent's view. After eight familiarization trials of the agent reaching for A, the positions of the objects were reversed and the screen was removed. At this point, the agent reached for either A (old object event) or B (new object event). In the sighted object condition (in which the agent could see both A and B before the test phase), infants looked longer at the new object event, suggesting that they expected the agent to exhibit her earlier established preference to reach for A. However, in the hidden object condition (where the agent could not see B prior to the test), looking time was equal for both the new event and the old event, suggesting that, faced with an entirely new choice, the agent would have no preference for A or B. From these data, the researchers concluded that the infants "realized" that the agent's repeated actions on Object-A during the familiarization trials could not be interpreted as revealing a preference for Object-A over Object-B if she could not see Object-B.

These are remarkable findings. The interpretation of these findings, however, has proven highly controversial (Mix, Huttenlocher, & Levine, 2002; Oakes, 2010). Some developmental scientists caution against making claims about complex mental processes based on habituation procedures that require minimal responsiveness on the part of infants (Bremner, 2000; Kagan, 2008). Others note that the phenomenon of habituation remains poorly understood (Schöner & Thelen, 2006). Still others underscore the continued need to ensure a high level of control over nontarget variables when using habituation (Cohen, 2002). Against this backdrop, we nonetheless take these data to indicate something meaningful about infant development. However, we also raise issues regarding their interpretation. Some approaches to infancy research seem to proceed under the assumption that infants are fundamentally little adults. Operating under this assumption, research is designed with the goal of identifying the earliest moment in development at which infants can perform adult-like tasks. Evidence of successful performance at very young ages is then interpreted as indicating that infants possess core, adult-like abilities. However, advocates of such positions often do not consider (a) the rich, structuring role that perceptual input plays in mediating infant abilities; (b) how presumed infant abilities undergo developmental change; and (c) alternative interpretations that do not require invoking complex psychological processes.

Carey (2009) has suggested that infants are born with innate (i.e., strictly biologically determined) systems for representing number, including an "object file" system for discriminating among small numbers of objects (e.g., one, two, and three objects), and an analogical system for representing larger numbers of objects. The distinction between these two systems comes from research suggesting that although infants can make fine distinctions between one-, two-, and three-item displays, their capacity to make distinctions between stimulus displays containing larger numbers of objects is less refined. By 6 months of age, infants can discriminate stimulus displays that differ by a 2:1 ratio (e.g., infants can differentiate 8-dot displays from 16-dot displays). Over time, infants become capable of discriminating stimulus displays containing increasingly more refined ratios. By 9 months of age, infants can discriminate 3:2 comparisons. However, it is not clear why there is a need to invoke biologically determined knowledge to explain these results. One might suggest that working memory capacity provides a more parsimonious explanation for small set discrimination. Zosh, Halberda, and Feigenson (2011) have shown that infants (like adults) are able to represent two or three subsets of information in perceptual working memory at any given time. If this is so, perceptual changes in stimulus displays involving small numbers of items are likely to be highly salient to infants and adults. As the number of items in a stimulus display increases beyond an infant's working memory, the ability to make fine distinctions among stimulus displays would diminish. At this point, however, the infant would still be able to make comparisons among stimulus displays containing a small number of phenomenally distinguishable groupings of larger numbers of items.

Thus, the most parsimonious explanation of the infant's capacity to discriminate among these diversely numerated stimulus displays is that infants are comparing perceptually salient groupings of object ensembles. Performance is constrained by the *phenomenal aspects of perception* with a minimum of surplus activity. Although it is reasonable to refer to such discriminations as *analog* (Carey, 2009), it is highly unlikely that "innate" knowledge is necessary to explain the data. Similar interpretations apply to other examples of seeming complex cognitive manipulations in infancy. McCrink and Wynn (2004) reported a study in which 9-month-olds were shown five objects that move behind a screen, followed by another five objects. When the screen was removed, infants looked longer if they saw 5 objects than if they say 10, suggesting that the infants expected to see the larger rather than smaller group. Again, the most parsimonious explanation of these data is that infants are able to hold in mind the phenomenal aspects of larger and smaller arrays of objects in highly structured perceptually based tasks that require little indicative activity on the part of the infant. The data do not suggest that infants can add, subtract, or manipulate representations of objects independent of perceptually salient events.

Interpretation of the results of infant performance on the social tasks described above raises similar issues. In the Luo and Baillargeon (2010) study concerning reasoning about psychological states, in the sighted object condition (in which an agent consistently chose Object A over Object B before the test phase), during the test phase infants looked longer when the agent reached for B over A, suggesting that infants expected the agent to reach for Object A. However, in the hidden object condition (where the agent reached for A but could not see B prior to the test phase), looking time was equal in the test phase regardless of whether the agent reached for Object A or B, suggesting that infants had no expectations of where the adult would reach. However, Luo and Baillargeon (2010) argue that these data indicate that the infant is capable of *reasoning* about the internal *mental* states of the agent—in particular, that "infants recognize that an agent's representation of a scene may be incomplete relative to their own" (p. 304). Adopting Luo and Baillargeon's (2010) interpretation would unnecessarily support the idea that preverbal infants are able to form representations of the behavior of others as the product of intentions, beliefs, and desires; all understood as internal mentalistic states. And this interpretation would suggest that if young infants are able to form internal mentalistic representation, then the foundation for social knowledge and reasoning must be strictly biologically determined.

From the standpoint of an embodied, coactive model of psychological development, an infant's sense of the intentionality of another person's action does not proceed as an act of mind-reading (i.e., one mind attempting to penetrate the hidden contents of another). Rather than mind-reading, an infant's sense of the intentionality of other's actions arises in embodied coactions with others within richly textured social worlds. As Gallagher (2008) points out,

> We do not ordinarily need to go further than what is already the rich and complex comprehension that we gain through the perception of a situated agent—that is, of an agent who is situated in an environment which also tells us something about what that person is doing and thinking. (p. 168)

Thus, in social encounters, infants and adults alike do not need to make inferences about the contents of another person's mind. Instead, goals, intentions, emotions, and perception of events can be perceived directly from the other's actions and how those actions are deployed in the physical and social world. From this view, to understand how infants perform tasks that seem to call for complex social reasoning, one must identify the full range of the infant's embodied perceptual experience within a given social encounter. Thus, for example, in the study by Luo and Baillargeon (2010) just discussed, information about the adult's goals and perceptions is directly available in the infant's perceptual experience of the adult's actions. The infant does not have to infer something that is *hidden in the mind* of the adult; the infant perceives the adult's intention in the adult's repeated act of reaching itself. The infant does not have to construct an image of what the adult is seeing *within the adult's private experience*; the infant sees directly what the adult sees.

Luo and Baillargeon (2010) also argue that their results suggest that the infants were able to recognize that the adult had an "incomplete representation" (p. 303) of the stimulus situation. However, there is a difference between saying that infants know *what is in the mind of the other* (can reason about the mental states of others) and saying that infants are able to construct a sense of what an adult can or cannot *see* in the context of direct perceptual experience. From an embodied systems perspective, the infant does not have to have an understanding of the *mental states* of the adult; the infant only needs to discriminate how the adult's intentions-in-action in the test phase are predicated on whether or not she was able to *see* one object or both objects in the familiarization phase. In this way, the infant need not adopt the *internal perspective* of the adult; the infant only has to view the task from her *physical position*. Although such a capacity might seem like a complex accomplishment, research suggests that mirror resonance processes may operate as part of the neuronal processes that mediate social perception. In social coactions with others, subpersonal mirror neurons may be activated when one individual sees another person performing an intentional action (Molenberghs, Cunnington, & Mattingley, 2012). Research suggests that the mirror resonance system may distributed throughout many places in the brain, including the motor cortex, Broca's area, and the parietal cortex, the primary visual cortex, cerebellum, and areas within the limbic system (Catmur, Mars, Rushworth, & Heyes, 2011; Molenberghs et al., 2012). The activation of the mirror resonance system may function as the neurological substrata that mediates the immediate but nonarticulated perception of the other person's intentional actions (Gallagher, 2008). In this way, in perceptually and emotionally rich social encounters, the intentional states of the other may become immediately available to the infant, even in the absence of a *theory of mind* or skills for simulating the experiences of others.

Research on early infant abilities holds out the promise of transforming our understanding of the foundations of psychological development. However, to fulfill this promise, there is a need to examine how such capacities emerge and function within the larger coactive person ←→ environment system (Mascolo, 2013). The sensorimotor-affective world of the infant is richly structured and deeply informative (Ray & Heyes, 2011). Cognitive processes that operate in infancy are constrained and informed by intermodally organized *perceptual* processes that operate within sensorimotor action in the world (Bremner, 2000; Vaillant-Molina & Bahrick, 2012). Such perceptually based meanings stand in contrast to the genuinely *symbolic* representations that toddlers and older children construct in the absence of direct experience (Johnson, Younger, & Furrer, 2005; Namy, 2009). To appreciate how the phenomenal world of the infant differs from that of toddlers and young children, it is necessary to assess *developmental changes* in structure of meaning over time (Campos et al., 2008) and to identify the ways in which *specific physical and social contexts* contribute to the organization of those structures (Campbell & Namy, 2003). It also requires that theorists and researchers avoid the temptation to study infant cognitive processes in isolation. As Oakes (2009) points out,

> [T]o understand the nature of infant cognitive skills, it is necessary to understand how . . . the field has focused on dissecting cognitive abilities in infancy; our task now is to put those abilities back together again so that we can understand how they work together in development. (p. 352)

Thus, without considering how early cognitive skills operate as parts of a larger person ←→ environment system, we risk misrepresenting the nature of infant abilities.

PATHWAYS IN THE DEVELOPMENT OF PSYCHOLOGICAL STRUCTURES FROM CHILDHOOD THROUGH ADULTHOOD: THE CASE OF EVERYDAY MORAL ACTION

In the following, we examine development that occurs beyond infancy in the representational and abstract tiers of development (see Figure 4.2). In examining these later emerging tiers, we explore the development of integrative structures of sociomoral action from early infancy through the life span. The study of moral development has undergone profound changes. The field has shifted from moral reasoning (Kohlberg, 1981; Lapsely, 2006) as a primary concern toward articulation of the role of emotion, social context, and culture in moral judgment, action, and identity (Turiel, Chapter 13, this *Handbook*, this volume). Researchers have suggested morality has its origins in prelinguistic evaluative judgments in infancy (Hamlin, Wynn, & Bloom, 2007) in empathy and sociomoral emotions emerging during the second year of life (Mascolo & Fischer, 2007; Roth-Hanania, Davidov, & Zahn-Waxler, 2011); and in the socialization of conscience and self-regulation in early childhood (Kochanska, Koenig, Barry, Kim, & Yoon, 2010; Thompson & Newton, 2010). Scholars and educators have called for a renewed emphasis on the development of moral character (Damon, 2011; Lapsley & Yeager, 2013). Thus, the study of moral development has ushered in a renewed emphasis on character and conscience that is reminiscent of the work of Hartshorne and May (1928–1930).

These are important advances. We note three central issues related to the study of moral development (see also Nucci & Gringo, 2011). First, in abandoning broad-based stage models of moral reasoning, many investigators have abandoned the goal of analyzing *structural transformations* in the development of moral activity (Gibbs, Moshman, Berkowitz, Basinger, & Grime, 2009). For example, although hundreds of important studies examine individual differences in temperament, socialization practices, and moral/prosocial behavior, only broad classes of aggregated behavior—often abstract across contexts—are assessed (Eisenberg, 2000; Grusec, 2006; Kochanska & Aksan, 2006). Changes in the *form* of moral and prosocial behavior have been neglected. Second, although investigators have acknowledged the multiplicity of moral orientations (e.g., justice, care, duty), the orientations are sometimes treated as if they were separate and distinct domains (Juujärvi, 2006). However, evidence suggests that although different moral concerns (e.g., rights, care, virtue) are partially distinct, they tend to overlap and codevelop over time (Walker, 2006; see also Rose, Rouhani, & Fischer, 2013). Finally, in rejecting the primacy of moral reasoning in the study of moral development, there has been a proliferation of studies on the role of automatic moral judgment, emotion, conscience, and socialization in the production of moral and prosocial behavior. With exceptions (e.g., Turiel, 2002, 2010, Chapter 13, this *Handbook*, this volume), theory and research in these areas proceeds largely in isolation from each other. There is a need to develop ways to understand how moral cognition, emotion, and action develop in relation to each other within individuals and particular sociocultural contexts.

Instead of privileging any single aspect of moral functioning, we suggest that there is a need to understand moral development as the study of changes in integrative patterns of moral cognition, emotion, and action as they arise within individuals in particular sociocultural contexts. In what follows, drawing on dynamic skill theory, we illustrate ways to track developmental changes in (a) the *integrative structure* (cognition-affect-action) of moral activity; (b) in *everyday* rather than interview contexts (c) with regard to *contextualized* rather than abstract moral issues. In so doing, we illustrate how moral functioning undergoes transformation as children construct increasingly differentiated and integrated structures of moral thinking, feeling, and acting. This approach offers the promise of bringing together theory and research from structural-developmental, socialization, and sociocultural approaches to moral development.

FROM AFFECT TO IDENTITY: PATHS IN THE DEVELOPMENT OF STRUCTURES OF MORAL ACTION

A moral action is one that is mediated by standards that specify conditions that *ought* to (or ought not) exist. In invoking this definition, we adopt a broad view in which the realm of everyday morality incorporates what Taylor (1989) calls *strong evaluation*. This encompasses not only judgments of *right or wrong* but also judgments of *care for others, worth, virtue,* and *goodness* (Blasi, 1990; Sabini & Silver, 1982; Taylor, 1989). Emotion plays a central role in the organization of moral behavior; however, moral emotions (guilt, shame, jealousy, etc.) are moral because they are mediated by some sort of evaluative standards, however implicit (Blasi, 1999). As suggested in Figure 4.1 (Point 1) and as articulated in our relational perspective, there is no reason to privilege affect over cognition, automatic over controlled processes, or nonconscious over conscious processes (Haidt, 2001; Hassin, Uleman, & Bargh, 2005; Mlodinow, 2012) in the construction of action, moral or otherwise. From the relational perspective, debates about the primacy of fast-acting affective judgments versus deliberative reasoning in moral development are fruitless. Instead, there is a need to understand how diverse psychological processes work together in the construction of moral action (Decety, Michalska, & Kinzler, 2012).

Figure 4.8 presents a developmental web identifying trajectories in the construction of integrative structures of moral action from preschool through adolescence. The web charts developmental changes within three domains of moral actions: *autonomy/rights*, *virtue/character*, and *harm/care*.

- *Autonomy/rights* domain. This reflects the predominant Western concern with the primacy of individual freedom. Development in this domain moves initial concerns about individual interests in principles of individual rights, respect, fairness, and reciprocity (Shweder, Much, Mahapatra, & Park, 1997).
- The *virtue/character* domain. This is organized around attempts to live up to particular values and virtuous ways of being in the world (Blasi, 2005). Development in this domain moves from the socialization of committed compliance (Kochanska & Aksan, 2006) to the development of virtue, moral character and identity, and a commitment to moral purpose (Carr, 2006; Damon, 2011; Frimer & Walker, 2009). Actions organized with

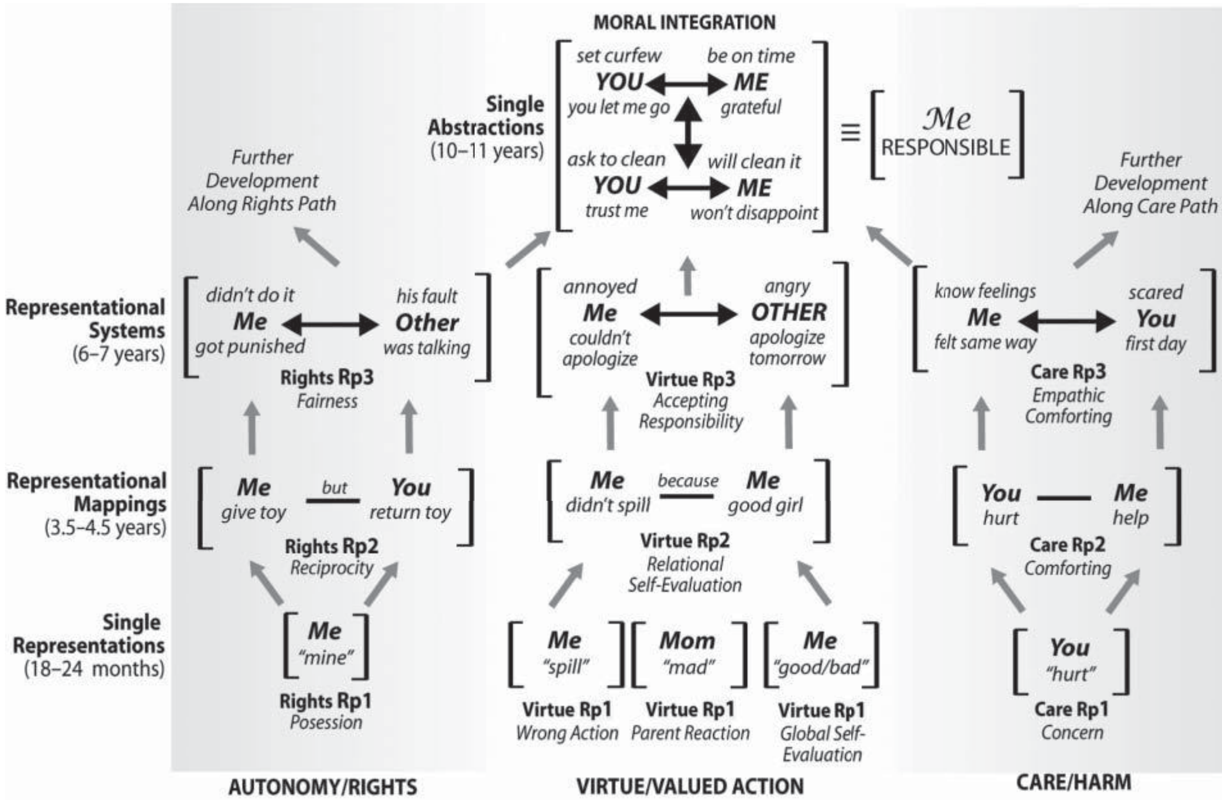


Figure 4.8 Trajectories of moral action: Autonomy, virtue, and care.

respect to concerns about *harm/care* domain. Development in this domain has its early origins in sympathy and empathy toward others (Svetlova, Nichols, & Brownell, 2010) and moves toward the higher-order principles of care and compassion (Ottoni Wilhelm & Bekkers, 2010).

The developmental web presented in Figure 4.8 indicates multiple starting points, pathways, and endpoints in the development of integrative structures of moral action. The actual paths through which moral skills develop differ both within and between individuals. Depending on differences in temperament, parenting, and other circumstances, the developmental course of children's moral skills may be biased along divergent autonomy-, virtue-, or care-based pathways. Within persons, individuals vary according to the mode and developmental complexity of their moral actions depending on the nature of the problem at hand (Walker, 2006), emotion (Fischer, Shaver, & Carnochan, 1990), the presence of others (Thornberg, 2007), and other variables. Thus, individuals who, at one moment, act on a principle of care for someone in distress can, at another, invoke an autonomy orientation to defend a threat to property.

AUTONOMY, RIGHTS, AND THE ETHOS OF FAIRNESS: FROM INDIVIDUAL INTEREST TO INDIVIDUAL RIGHTS

The left pathway of Figure 4.8 describes the emergence and development of moral action mediated by standards of moral autonomy, fairness, and rights. As indicated in Step Rp1 of the RIGHTS pathway, 18- to 24-month-olds use single representations to defend their property (e.g., "mine!"). Around this age, children begin to offer simple spontaneous and solicited apologies (i.e., "sorry") to their siblings, although they are more likely to do so when requested by a parent (Schleien, Ross, & Ross, 2010).

By 3 years of age, children are able to identify and intervene in transgressions against third parties (Vaish, Carpenter, & Tomasello, 2010). The toddler's emerging moral sense is a double-edged sword: Using single representations, they also begin to lie about wrongdoings.

In a study in which preschoolers were asked not to peek at a toy while the experimenter was not looking, 25% of 2- and 3-year-olds lied about peeking at the toy when asked (Evans & Lee, 2013).

Beginning around 3½ to 4½ years of age, children's moral sense undergoes transformation as they gain the capacity to form *representational mappings*. At this level, children begin to develop a rudimentary sense of fairness and reciprocity. For example, at this level, children begin to demonstrate an awareness of simple reciprocity norms. For example, as indicated in Step Rp2 (Figure 4.8), one 4-year-old girl, when asked to share her toy horse, responded, "Here he is. But I want him back soon" (Markström & Halldén, 2009, p. 119). At this level, children are able to invoke a range of concrete strategies for managing rules for both strategic and normative purposes. At this level, children are also able to construct simple representations of fairness and indirect reciprocity. For example, children witnessed a puppet who struggled to achieve the goal of climbing a ladder. The struggling puppet was helped by a second puppet and hindered by a third. When distributing scarce rewards to the puppets, 4½-year-olds almost always gave more rewards to puppets who helped over those who hindered (Kenward & Dahl, 2011). These findings suggest that at this level, children engage in *indirect reciprocity* when making judgments about the bad behavior of others. When rewards were plentiful rather than scarce, 4½-year-olds distributed the rewards equally to helpers and hinderers, indicating a preference for equality.

Beginning around 6 to 7 years of age, with the capacity to construct *representational systems*, children are able to construct more stable representations of fairness, reciprocity, and rules for regulating autonomous relations between people. Children often invoke standards of fairness for their own strategic gain. For example, as depicted in Step Rp3 (Figure 4.8), in a study assessing children's criticism of school rules, Thornberg (2007) described how one 7-year-old girl protested against her teacher's reprimand: "Gabriel was talking very much to me and tried to take my rubber [eraser], and then our teacher sent us both out. It wasn't my fault; it was his fault . . . I didn't do anything" (p. 423). Children often use self-serving arguments to justify their behavior in situations in which they extend care for others. For example, when asked why she helped another student in distress, one 7-year-old girl responded, "Well if I helped him [when he needed help], he'd help me when I need help." This is not to say that all invocations of fairness and reciprocity are self-serving. In situations involving distributive justice, unlike younger children, 7-year-olds begin to take personal need into account when distributing scarce resources (Kienbaum & Wilkening, 2009).

CULTIVATING CONSCIENCE: FROM COMMITTED COMPLIANCE TO MORAL CHARACTER (VIRTUE)

The middle pathway in Figure 4.8, broadly considered, describes developmental changes in the cultivation of conscience and moral virtue from early childhood through adolescence. Movement through this pathway develops from the early socialization of committed compliance (Kochanska et al., 2010) through to the internalization and appropriation of social standards (Hardy, Padilla-Walker, & Carlo, 2008), and culminates in the moral identification of the self in terms of appropriate moral standards (Patrick & Gibbs, 2012). Kochanska & Aksan (2006) define *conscience* as an "inner guidance system" for regulating behavior and emotion in terms of everyday sociomoral standards. In a series of remarkable research investigations, Kochanska and her colleagues (Kochanska, Barry, Jimenez, Hollatz, & Woodard, 2009; Kochanska, Philibert, & Barry, 2009), Eisenberg and her colleagues (Eisenberg, 2010; Spinrad et al., 2012), and others (Thompson, 2012) have examined how children's dispositions interact with socialization in the construction of moral self-regulation.

The development of conscience develops in the context of mutually responsive relationships between infants and their caregivers (Kochanska & Aksan, 2006). Kochanska has shown how individual differences in dispositions toward fearfulness and effortful control interact with socialization processes to produce individual differences in children's conscience over the first 6 years of life. For example, in children with a disposition toward fearfulness, gentle parenting strategies that deemphasize power assertion are associated with higher levels of moral self-regulation. Pathways to the development of conscience in fearless children are more complex. According to Kochanska, for fearless children, gentle parenting strategies are unlikely to produce the level of emotional arousal required to induce rule following and internalization. However, power assertion also undermines rule following by fomenting anger and resentment toward the parent. The development of moral self-regulation in fearless children is dependent on the formation of a mutually response relationship that mitigates the emotional effects of discipline

(Kochanska, 1995; Kochanska & Murray, 1997). Children's dispositions toward effortful control facilitate the development of moral self-regulation (Kim & Kochanska, 2012; Spinrad et al., 2012). However, even here, the capacity for effortful control interacts with other variables in the production of prosocial behavior (Eisenberg et al., 2010; Kim & Kochanska, 2012). Kochanska, Barry, et al. (2009) showed, for example, that individual differences in the capacity for effortful control were unrelated to variations in future disruptive behavior in guilt-prone toddlers. However, higher levels of effortful control were associated with less future disruptive behavior in less guilt-prone toddlers. Thus, there are multiple paths toward the development of conscience.

Along with describing the development of conscience and moral virtue, in a more detailed sense the middle pathway in Figure 4.8 describes changes in the child's capacity to represent and regulate actions in terms of everyday social rules and standards of value. During the second year of life, infants gain the capacity to bring their behavior in line with parental requests ("do's") and prohibitions ("don'ts") when they are prohibited from touching toys (Kochanska & Tjebkes, 1998), and even when tempted to do otherwise by a malicious puppet (Emde & Buchsbaum, 1990). Beginning around 18 to 24 months of age, as a result of the history of interaction between children and their caregivers, toddlers are able to *represent single concrete meanings* (e.g., simple rules) in the absence of direct sensorimotor experience. For example, as indicated in Step Virtue/Rp1 (Figure 4.8), 2-year-olds can form single concrete representations of their wrongdoings (e.g., "I spilled the milk") and of caregiver reactions to wrongdoing (e.g., "Mommy mad"). They can also evaluate both themselves and others positively or negatively (e.g., "I a good girl").

Over the third year of life, children are able to begin to make connections among multiple single representations, but these connections tend to be relatively global and undifferentiated. For example, in their analysis of moral language use in two children, Wright and Bartsch (2008) reported several such statements produced by young children: "I bad get bump [spanking]" (2;6); "Oops! I splashed and that's not very good" (3;2); "My cousin hit me and she's a bad girl" (3;2); "I wasn't good. I was going to fight" (3;8). It is not until 3½ to 4½ years of age, when children are able to form representational mappings, that they are able to represent explicit relations among two or more single concrete ideas. Wright and Bartsch (2008) reported the following moral utterances that function at the level of representational mappings: "I'm picking up mine because I want you to be happy" (3;4), "If I be real good at the community center, will you get me a prize?" (4;2), and, as indicated in Step Virtue/Rp2 (Figure 4.8): "I didn't spill it last night uh huh Mommy? Because I'm a good girl last night" (4;2).

With the onset of the capacity to coordinate two or more representational mappings into a higher-order representational system, 6- and 7-year-olds can position themselves using more stable and nuanced representations of moral rules. Children begin to position themselves in flexible ways in relation to moral infractions. Perregaard (2010) provides an example of how moral rules are socialized and how a 9-year-old girl and her parents resisted an exchange. Julie had revealed that her teacher asked her to leave class for talking during a lesson. Discussing the event with her parents, Julie flexibly assumed a series of moral positions in which she alternatively deflected, denied, acknowledged, and ultimately took responsibility for her transgression. Julie initially attempted to portray herself as a victim of her teacher's arbitrary use of power (i.e., "I *had* to leave class . . . I *happened* to talk only *once*"). Several moments later, Julie attempted to *deny* that her teacher asked her to stop talking: "She did not ask me to stop . . . and then the first time I talked I was kicked out." In response to her parent's questioning, Julie then acknowledged that her teacher did, in fact, tell the whole class to stop: "No. Well yes. She had said several times to the whole class that we should be quiet." Finally, when pressed further, hiding part of her face behind a napkin, Julie shifted to the complex strategy of *overcorrecting* for her misdeed, "I really have been thinking about it . . . but it annoys me, because I didn't get a chance to apologize to Ida, and I can't apologize tomorrow." Julie's shifting moral positions evolved at the level of compounded representational systems (multiple systems linked together over time). The structure of her overcorrection is indicated in Step Virtue Rp3 (Representational Systems in Figure 4.8).

DEVELOPING CONCERN FOR OTHERS: FROM EMPATHY TO THE RULE OF CARING

The right pathway in Figure 4.8 depicts developmental changes in expressions of concern for others over the course of childhood. Infants begin to develop a concern for others even before the first birthday. Roth-Hanania et al. (2011) demonstrated that 10- to 12-month-old infants begin to show signs of concerned affect as indicated by facial and vocal indicators of sadness or a sympathetic face (lowered eyebrows; raised brow; downturned lips) in the context of a person exhibiting overt signs of pain. Between 12 and 18 months, infants increasingly attempt to comfort another person who is in pain (Roth-Hanania et al., 2011; Vaish et al., 2010; Zahn-Waxler, Radke-Yarrow, Wagner, & Chapman, 1992). By the end of the second year, acts of comforting become more sophisticated, and begin to reflect the needs and desires of the distressed individual.

As indicated in Step Care Rp1 (Figure 4.8), beginning around 18 to 24 months of age, toddlers construct single symbolic representations of circumstances related to another person's distress. Vaish et al. (2010) have shown that 18-month-olds show sympathetic concern to others who are the victims of harmful events, even if the victim does not show signs of emotion. In naturalistic contexts, children's empathic concern for others becomes increasingly representational over time. This is illustrated by the observations that appear below. The first three observations are from Zahn-Waxler (1990); the last are from Wright & Bartsch (2008).

- A child is pounding with a cup and accidentally hits father hard in the nose. (Father gives loud "ouch.") Child drops cup, looks very serious, leans forward to father for a kiss (14 months).
- A child bangs head against mother's face in an excess of affection. (Mother restrains, verbally prohibits and explains, "that hurts.") Child says "kiss, kiss" and kisses mother. Then bangs head on mother again and says, "hurting, hurting" (18 months).
- A child pulls cousin's hair. (Mother tells her not to.) Child crawls to cousin and says, "I hurt your hair; please don't cry," then gives her a kiss (24 months).
- "He got yellow feets and toes and I don't want to hurt him" (28 months).
- "Poor Donna crying" (30 months).

With the emergence of the capacity to form representational mappings between 3½ and 4½ years of age, children's caring actions can be mediated by an increasingly explicit awareness of the relation between their own experiences and those of others. In a study on the development of friendship, Avgitidou (2001) described a poignant example of a caring action at this level involving two 4-year-old boys. One boy, Chris, reluctant to be interviewed, stared at the floor in response to a researcher's invitation to play. Observing the encounter, the boy's friend Thanasis "came and stood next to him and leaning his face towards him in order to look him in the eyes he said 'Go Chris,' I did that (the interview). Chris became distressed and ready to cry and then Thanasis held his hand and said 'Would you like me to come with you?' . . . I obtained two chairs while Thanasis kept hold of Chris' hand and looked at his face" (p. 150). The structure of this caring act is depicted at Step Care Rp2 in Figure 4.8.

At this level, empathic children are capable of a variety of rather surprising comforting strategies. For example,Warming (2011) described an interaction between two 4-year-old boys attending a daycare center. One boy, having bloodied his knee, began to cry. Seeing the first boy's knee, in a happy voice, second boy said, "Congratulations! I've hurt my knee too!" In this situation, the second boy engaged in an act of "emotional solidarity." By forming an emotional alliance with the hurt boy, the comforter not only signaled that the hurt child was not alone in his suffering, but also that the boy's pain could even be seen as a sign of honor. Still further, the comforter was able to communicate that the boy's pain could be endured and would soon pass.

With the emergence of representational systems at 6 to 7 years of age, children's expressions of care become still more stable and consolidated. Children begin to use a variety of comforting strategies involving increasingly coordinated representations of the internal perspectives of self and other (Burleson, 1982). Clark, MacGeorge, and Robinson (2008) described a variety of comforting strategies used by older children and adolescents, including *accounting* (i.e., offering an explanation), *minimization* (playing down the magnitude of the event), expression of *sympathy*, providing *advice*, expressing *optimism*, and providing *companionship*. For example, at this level, as indicated in Step Care Rp3 (Figure 4.8) a child might comfort a friend who is anxious on the first day of school by saying, "I know how you feel. It's scary on the first day of school. I cried on my first day too" (Hoffman, 2000). This comforting strategy contains a combination of *sympathy* and *accounting*.

CONSOLIDATING MORAL IDENTITY THROUGH ADOLESCENCE: THE RECONCILIATION MODEL

One aspect of moral development involves the construction of a *moral identity* (Hardy & Carlo, 2011). An identity refers to the ways in which an individual answers the question, "Who am I?" A moral identity is one in which *moral commitment* plays a central role in the constitution of identity (Frimer & Walker, 2009; Krettenauer, 2011). Frimer and Walker (2009) proposed a model of moral identity defined in terms of the coordinative reconciliation of *agency* and *communion* motives. Their approach provides a relational alternative to conceptions of morality that represent agency and communion as opposing values. Building upon the work of Colby and Damon (1993) and Blasi (2004), Frimer and Walker (2009) maintain that "doing the right thing manifests in mature people not *in spite of* but *because* of who they are as persons—because of their identity" (p. 1669, emphasis added). Frimer and Walker (2009) suggest that in development, values of agency and communion will necessarily come into conflict with each other. Such conflict generates disequilibrium that can be resolved in two basic ways: one can either abandon one motive in favor of the other or *reconcile* the values into an increasingly integrated identity. The choice to reconcile agency and communion goals transforms the self into a moral identity that guides sociomoral action in the world. The formation of a moral identity is not inevitable; it represents but one of several pathways that moral development can take in adolescence.

Using an extended self-understanding interview, Frimer and Walker (2009) examined the relations between moral centrality (the importance of moral concerns in one's self-understanding) and a variety of measures of morally relevant behavior in young adults. They found that communal values positively predicted moral behavior, whereas values organized around self-interest negatively predicted moral behavior. Narratives that contained an interweaving of agency and communal values also predicted moral behavior. Frimer, Walker, Lee, Riches, and Dunlop (2012) found that in contrast to a comparison group, protocols of moral exemplars contained integrative structures in which agency was seen as a means to communion (see also Hart and Fegley, 1995). Matsuba and Walker (2005) demonstrated that young adult moral exemplars differed from comparison individuals in the centrality of agency and communal values in their self-narratives. The life stories of moral exemplars exhibited a concern for societal betterment, ideological depth, and feelings of empowerment. Themes related to redemption and contamination were more characteristic of nonexemplars. This suggests that an integrated moral identity organized around agency and communion can properly be seen as an optimal endpoint of moral development.

As children approach adolescence, they often begin to make requests for increased autonomy and responsibility (Daddis, 2011). During this time, progress toward the construction of a moral identity occurs as children begin to *identify* with their responsibilities. As shown in Figure 4.8 (Moral Integration) using single abstractions, preteens can identify themselves in terms of generalized responsibilities to others (e.g., living up to parental expectations). For example, one 10-year-old girl identified responsibility as a dilemma between autonomy and duty: "They [parents] ask you to do something; they don't tell you to do something, they say, 'oh, can you do this?' and if you don't it just feels like you're sort of letting them down a bit" (Such & Walker, 2004, p. 236). As indicated in Step V4, such an abstraction is formed by generalizing across multiple concrete acts of choosing to comply with parental requests (e.g., choosing to respect a parent's curfew; choosing to clean one's room).

As indicated in Figure 4.9, at the level of abstract mappings, 14- to 16-year-old teens can represent the relation between two abstract ideas. With respect to moral identity, teens can begin to represent the relation between moral selfhood and one's obligations to others. For example, one 16-year-old male identified as a moral exemplar describes his ideal identity as one in which he would: "be there for people, for my kids, not to leave them or anything like that. I'm responsible for what I do. Even I know now I will stick to what I say is to be responsible for what you do" (K. S. Reimer, unpublished data, 2013). This abstract mapping is represented in Figure 4.9a. This individual defines himself in terms of an abstract relationship between his sense of personal responsibility and his sense of care for others. In so doing, he defines his moral identity not in opposition to social obligations, but instead *through* them.

As 18- to 20-year-olds gain the capacity to coordinate at least two abstract mappings into an abstract system, they can represent higher-order relations between autonomy and

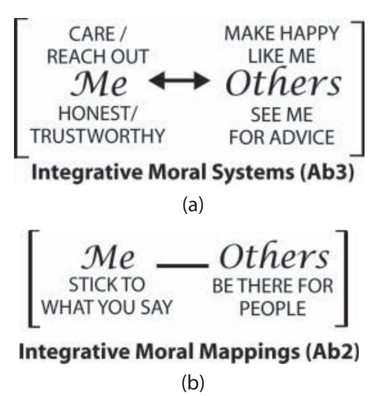


Figure 4.9 Abstract structures of integrative moral identity in late adolescence.

communion. For example, a 16-year-old moral exemplar said the following about the moral centrality of *care* in his sense of self: “I’m the kind of person that *really cares about people*, and I really *want to see people be happy*, because I’m very *positive and I want people to be as positive as I am*. And so I, like, reach out to people so they know that life isn’t as bad as people make it out to be. And I’m pretty *generous and pretty honest*. But I try to be pretty *trustworthy* and I’m the kind of person that *lots of people can look to for advice or whatever*” (K. S. Reimer, unpublished data, 2013). This precocious teen’s sense of moral identity is represented in Figure 4.9b.

Among the motives that direct human action, perhaps none are more powerful than a desire to live up to valued images of self (Kagan, 1996). An integrated moral identity serves as a kind of moral guide for social action (Tangney, 2002). Not all adolescents develop a sense of self structured around agency and communion. Moral identity can develop toward unmitigated self-interest, unmitigated care, or toward an integrative reconciliation between them. When moral concerns play an integrating role in identity, they gain the ability to transform who we are and how we act in the world (Blasi, 2005).

CONTINUING THE MORAL TRAIL: FROM ADOLESCENCE THROUGH ADULTHOOD

We play out our lives against the backdrop of inescapable moral frameworks (Taylor, 1989). Psychologists have identified a series of different moral frameworks that give meaning and structure to human lives. These include frameworks organized around *autonomy, justice* and *rights*, *care/community*, *divinity/spirituality*, *virtue/character*, *duty/authority*, and *contamination/sanctity* (Carr, 2006; Graham et al., 2011; Shweder et al., 1997). One way to approach the study of moral development over the course of life is to examine changes in the ways in which categories of moral concerns structure what adults take to be *important* in their lives. We refer to an individual’s representations of what is most important in life as his or her *core goal structure* (Mascolo & Fischer, 2010). Consistent with research on moral identity (Frimer & Walker, 2009), one might expect that core goal structures are rarely organized in terms of any single moral orientation. Instead, with development, individuals draw from multiple sociomoral orientations, both implicitly and explicitly, to frame their sense of what is important in life. In particular, one might expect that core goal structures would incorporate increasingly integrated representations of agency and communion themes over the course of development.

To test this proposition, we conducted a cross-sectional study assessing developmental changes in core goal structures (one’s sense of what is important in life) over the course of adulthood. On an online questionnaire, 338 adults between the ages of 18 and 75 were asked to enter written responses to the question “What do you experience as the most important thing in your life right now?” They were asked to explain why the issue was important to them, and to provide concrete examples. Responses were examined for the presence of a series of moral themes. These included *agency* (references to personal goals and projects), *care/community* (references to the desire to care for specific others or society), *divinity* (statements referring to the role of God or spirituality in life), *virtue* (references to moral qualities that can be held by individuals), and *duty* (references to obligations to others or deference to authority). References to duty and virtue were rare in this sample, and were not explored further.

Figure 4.10 shows the differences in the presence of autonomy, care, and divinity themes in core goal structures as a function of both age (Figures 4.10a and 4.10b) and level of education (Figures 4.10c and 4.10d). Figure 4.10a shows changes in the proportion of individuals whose protocols made reference to autonomy, care, and divinity themes across age. Autonomy themes were highest in the youngest age group, and declined steadily with age until the 55-plus age group, at which point they increased slightly. In contrast, care themes were less prevalent among 18- to 25-year-olds, but increased and followed the same age-related pattern as autonomy themes beginning with the 26- to 35-year-old group. Divinity themes occurred in a minority of the protocols at each age, and showed no age-related changes. A fourth theme—dependence upon others—decreased steadily over the life span. These data suggest an age-related pattern. Young adults were most concerned with the pursuit of autonomy goals in the presence of support by loved ones (i.e., parents, family). Over the course of young adulthood, care themes increased and autonomy themes decreased in prominence, converging at Age 26 to 35 and following the same age-related trajectory after that point.

Figure 4.10b shows changes in the proportion protocols organized around singular moral orientations (e.g., autonomy alone; care alone or divinity alone). As indicated in Figure 4.10b, pure types were rare in the sample, and showed no age-related difference. In contrast, the

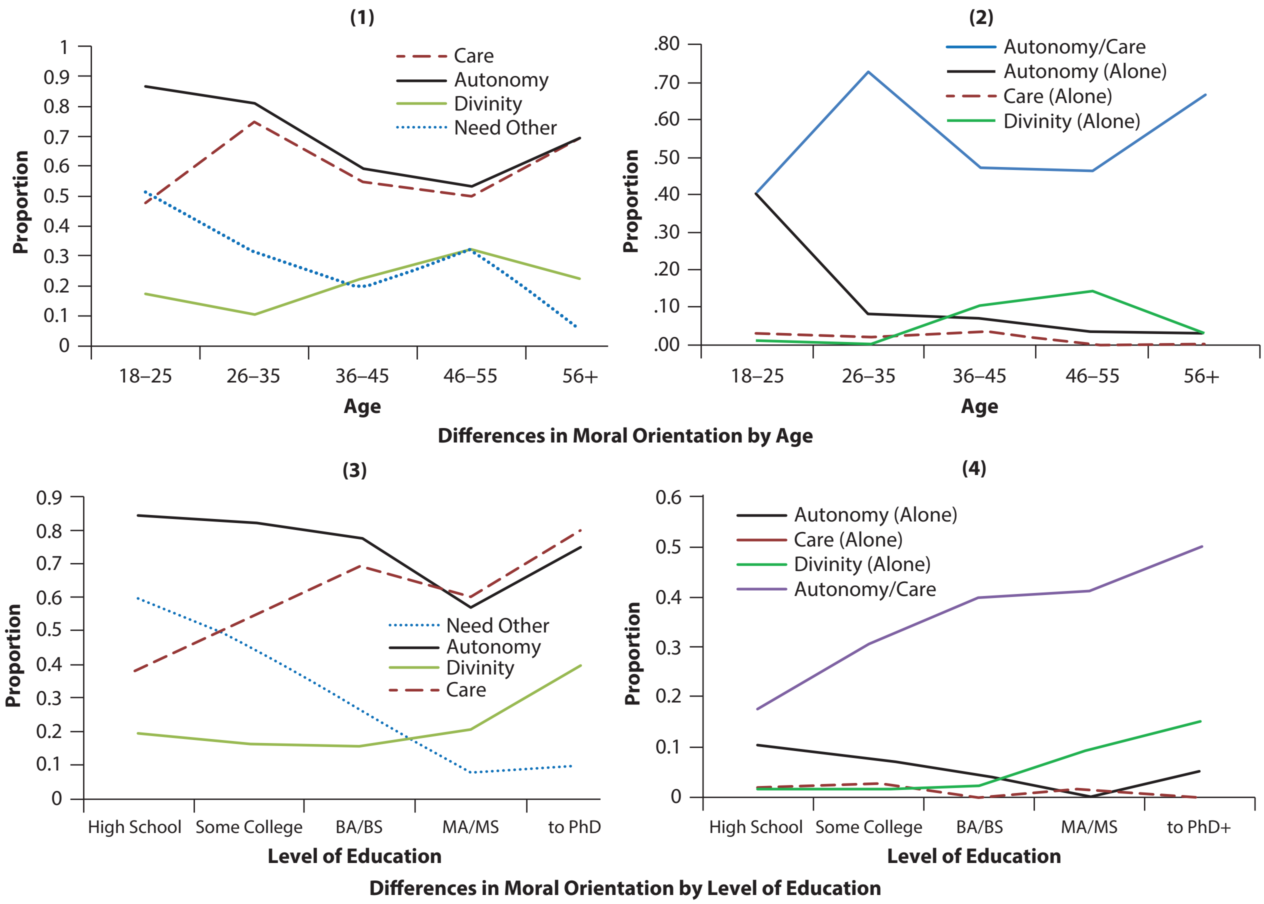


Figure 4.10 Changes in moral themes across the life span.

proportion of core goal structures containing references to both agency *and* care concerns increased between 18 and 25 years to 26 and 35 years, and then fluctuated between .50 and .70 throughout the remaining life course. Figures 4.10c and 4.10d depict these same data as a function of level of education instead of age. As indicated from the figures, although similar, the pattern of changes is more pronounced when analyzed across level of education. As indicated in Figure 4.10c, the presence of divinity/spirituality themes increased among individuals with the highest level of education. Figure 4.10d, shows a steady increase in the protocols containing both autonomy and care themes with increasing levels of education.

The developmental level of core goal structures for each individual was determined using dynamic skill theory. Core role structures showed developmental variation as a function of both age and educational level. The correlation between developmental level and age was .64 (partial correlation controlling for educational level was .34); between developmental level and level of education .65 (partial correlation controlling for age was .34. The correlation between age and level of education was .67 (all $p < .001$).

The study of moral action provides a microcosm for understanding the development of integrative structures of action. It brings together thinking, feeling, strong evaluation, socialization, and culture. The development of structures of moral action shows both order and variability. Order in the development of moral structures is indicated by increasing differentiation and integration in configurations of moral thinking, feeling, and acting. Variability is indicated in the form of diverse trajectories in developmental pathways, such as those that we have described in the development of moral activity. The moral world reflects a variegated landscape of concerns about autonomy, virtue, care, and other areas involving strong evaluation. However, there are no pure pathways in the development of moral action. Although moral development moves in the direction of increased differentiation and integration, structures of moral action integrate multiple themes depending upon local circumstances.

A MICRODEVELOPMENTAL ANALYSIS OF THE COACTIVE CONSTRUCTION OF EVERYDAY SKILLS

At its core, the concept of *constructive processes* is richly coactive, multiply nested, and fundamentally interdependent. In the following, we focus on coactive processes that operate at the individual and social levels of functioning. Using tools for analyzing the development of joint action (described earlier), we will examine the microdevelopment (Granott & Parziale 2002) of shoe-tying skills as they emerge through richly coactive exchanges between a boy and his nanny. To perform an analysis of how shoe-tying skills develop within joint action, we begin by performing a *task analysis* (Fischer, 1980) of the developmental outcome in question (i.e., tying a bow knot). We then track developmental changes in the differentiation and integration of component acts involved in learning to tie shoes and how these changes arise through the process of coactive scaffolding within the person ←→ environment system.

A task analysis involves (a) breaking down a given task or skill into its part actions and processes and (b) identifying the particular ways in which individual parts are coordinated or related to compose the task in question. Figure 4.11 provides a *task analysis* of the structure of the sensorimotor actions involved in tying shoes. As indicated in Figure 4.12, one can parse the structure of tying a bow knot into a series of part steps, each of which is composed by an integrated configuration of actions.

Having performed a task analysis and identified the parts of a developing skill, the next step is to track the *formation* and *integration* of the parts as they emerge in moment-by-moment social interaction over time. These steps are illustrated by the results of a study assessing the microdevelopment of shoe-tying skills in a 5-year-old boy and a 22-year-old caregiver. Over the course of several days, the caregiver was videotaped as she taught a 5-year-old boy to tie his shoes. For each episode (segment of coordinated activity), (a) the nature and number of task parts successfully and unsuccessfully attempted by the child and (b) the type and level of coregulated scaffolding provided by the teacher were identified. Figure 4.12 tracks changes in the developmental scaffolding of the child's shoe-tying skill over time.

Inspection of Figure 4.12 reveals several important points. First, as indicated in the top panel, the developmental trajectory is nonlinear. Although the developmental

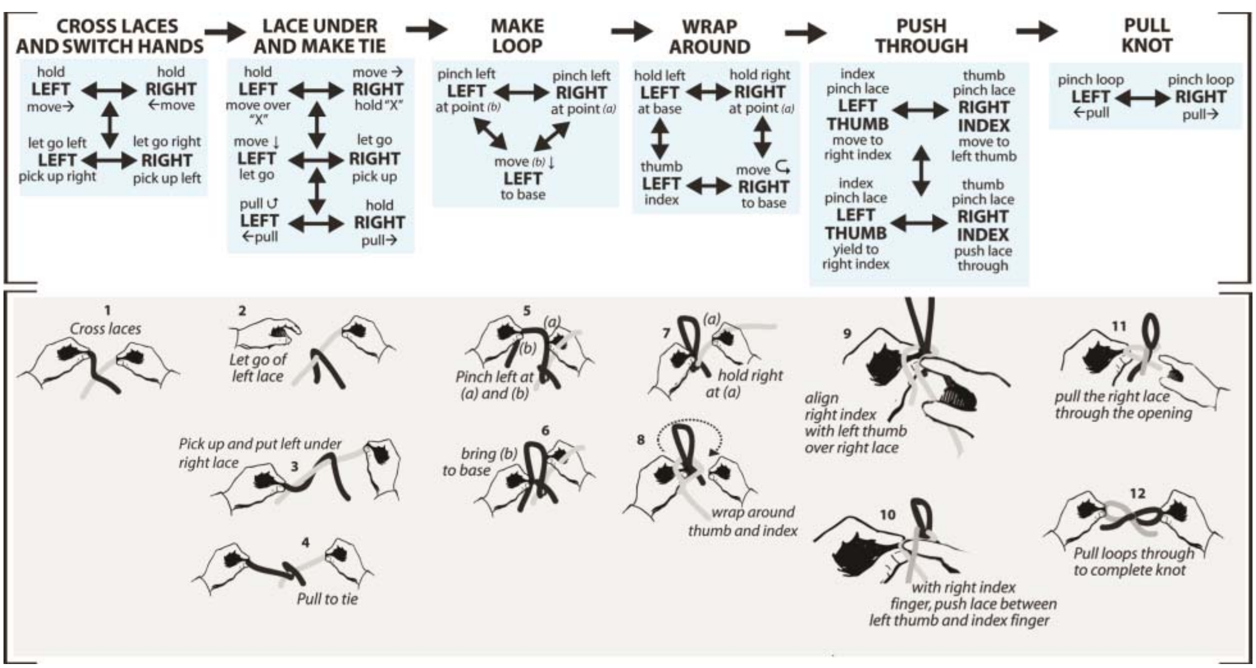


Figure 4.11 Task analysis for tying a bowknot (shoe tie).
Note. Diagrams on top panel consist of skill diagrams describing each component part of the task of tying a bowknot. Skill structures operate at the level of compounded sensorimotor systems. Diagram on the bottom panel indicate the nature of the specific movements involved in each step.

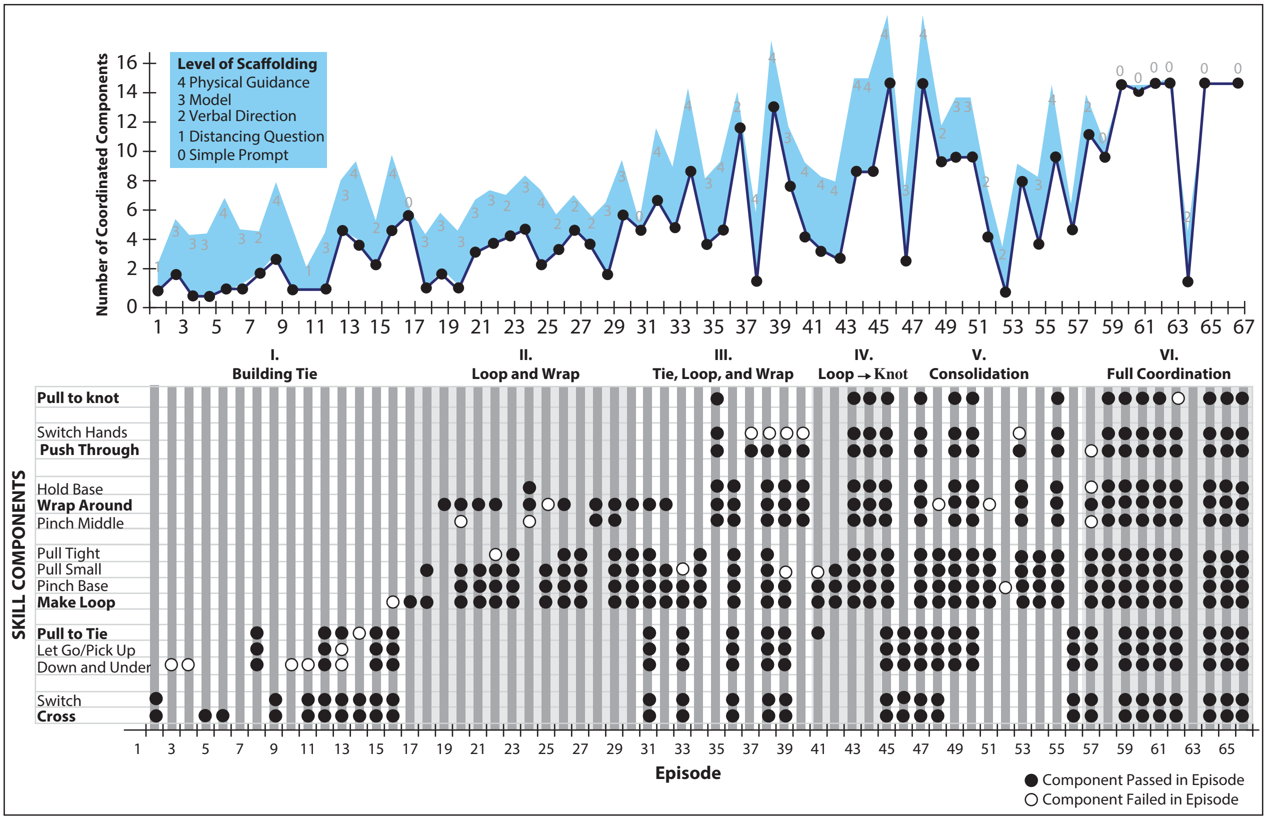


Figure 4.12 Developmental changes in the structure of teaching and learning to tie shoes.
Note. Top panel indicates (a) microdevelopmental changes in the number of task components coordinated by the child and (b) the level of scaffolding provided by the teacher in each conversational turn. The bottom panel identifies the specific task components attempted (failed) and completed (passed) on each.

level of the boy's actions increase over the course of the exchanges, the level of complexity rises and falls, sometimes showing dramatic fluctuations from one segment or exchange to the other. The organization of this trajectory is illuminated by an examination of the actual content of the child's actions over the course of his learning. Inspection of the bottom panel of Figure 4.12 indicates that the boy's skill developed in a series of six cascading phases. These phases are characterized by a cascading pattern of forward and backward movement in which the child gains initial mastery of different subskills before moving forward to coordinate the subskills into successively higher-order structures. Specifically, as indicated in Figure 4.12, first, the dyad worked together to develop skill in the initial act of *building a tie*. Having gained initial mastery over the tie, the dyad then moved to build skills for *making the loop* and executing the *wrap around*. During the third phase, the dyad worked to bring together these two subskills into a higher-order structure (*tie-loop-wrap-push through*). In the fourth phase, the dyad worked on mastering the skill to construct the final knot (*loop-wrap-push through-pull to tie*), before working to consolidate unstable during the fifth phase (*tie-loop-wrap-push through-pull to tie*). During the final phase, the dyad practiced the entire sequence to mastery.

The top panel of Figure 4.12 shows the pattern of social scaffolding that occurs between the teacher and learner in relation to the level of the child's developing skill. The teacher alternated among five of the nine levels of scaffolded support (see Table 4.1) over the course of teaching and learning (i.e., prompts, distancing, verbal direction, modeling, and hand-over-hand physical guidance). Throughout the course of teaching and learning, the child's actions were supported by a relatively high level of scaffolding. In most episodes, the teacher was actively involved in explaining, modeling, or providing physical guidance to direct the child's learning. Exceptions to this rule occurred during some, but not all, transitions between one subskill and a shift of focus toward building a new one, and when the child gained full mastery of the entire skill.

Social scaffolding was not the only form of scaffolding to occur throughout the teaching and learning process. Both *task-scaffolding* and *ecological scaffolding* (see Table 4.1) were operative. One example of ecological scaffolding concerns the origins of the learning sequence identified in Figure 4.12. Although the organization of the sequence of learning was neither fixed nor linear over the sessions, neither was it arbitrary. At many points in the process, the organization of the particular learning activity was constrained by the *ecology of the task itself*. For example, although some steps in the sequence must be executed in real time before others (e.g., *making a loop* must precede *wrapping a lace* around the loop), the order of acquisition of other subskills was free to vary. For example, once the child had completed the act of *making the initial tie*, a choice point emerged. The dyad could either move forward to the next step (*making a loop*) or return to the beginning, remake the tie and then move on. However, completing the subskill of *making the tie* occurs at a distinctive juncture. The sight of the completed tie invites or "affords" (Gibson, 1977) a transition to the next step.

Similar processes occur throughout the learning sequence. After the subskill of *wrapping a lace around the loop* was initially acquired, the child's attempt to *hold the lace in place* (around the loop) was unstable and difficult to sustain. However, the next subskill in the sequence (*push through*) requires stability in holding the loop in place. As a result, to move on and learn the *push through*, the ecology of the task all but requires the learner to move backward in order to move forward: the boy must *reloop the lace*, work on *holding the lace* stably in place, and then focus on the *push through*. This requirement "naturally" creates conditions in which *making the loop* and *wrap around* receive more practice than other steps. In this way, the *process of development itself* emerges as a product of the intercoupling of teacher, learner, task, and object. The task structure determines how the learning proceeds.

COCREATING THE DEVELOPMENTAL PROCESS: NEGOTIATING MEDIATIONAL MEANS

It is easy to think of learning to tie shoes as merely a sensorimotor skill. Shoe tying involves physically manipulating laces in order to tie them into a knot. It is also tempting to think that a child can learn to tie shoes simply by imitating the act modeled by others. However, learning to tie a knot is a complex process that requires the use of sign activity to mediate and direct sensorimotor movements. We have already seen that the task of learning to tie shoes is richly structured by the task itself. However, it is also deeply organized by the language that is used to build symbolic representations by partners to regulate their sensorimotor actions. Simultaneously, in moment-by-moment action, sensorimotor action and its effects on the world modify the very representations that we use to direct action. The richness of the coactive processes through which everyday action emerges is easy to miss, especially in research in which the variables of interest are aggregated measures collapsed across context.

An analysis of the changing structure of dyadic action can illuminate the richly coactive nature of the processes by which individual skills develop. Figure 4.13 tracks changes in the joint structure of action during the early phases of learning. When teaching and learning to lace shoes, both the teacher and the child typically operate at (at least) two developmental levels simultaneously, namely the representational and the sensorimotor levels. At the representational level, the child and adult use language to represent and direct meanings and relations; the *sensorimotor* level indicates the use of structures of sensorimotor action to move and tie laces. In Figure 4.13, representational structures are depicted in the upper portion of the dyadic skill diagrams; sensorimotor structures are indicated in the lower portion of the diagram and are displayed against a gray background. The complexity of the teacher's and the learner's actions tend to fluctuate among three levels of skill development. All sensorimotor actions operate at the level of sensorimotor systems (Sm3, see Figure 4.2). Representational actions tend to fluctuate between single representations (e.g., "that's your left hand"; Rp1) and representational mappings (e.g., "put your left hand *over* your right hand," Rp2).

Figure 4.13 identifies the process of teaching and learning how to put one lace under the other in order to complete the initial tie (Steps 2 and 3 in Figure 4.11). Inspection of these changes reveals three important points: First, it is possible to identity precisely the joint structure of the representational and sensorimotor actions involved in the development of shoe tying. Second, the use of *mediational means* (sign activity) employed by the teacher and the learner are crucial components of the process of learning to tie shoes. Third, mediational means themselves arise through the coactive interplay among teacher, task, object, and learner. Through the dynamic modification of mediational means, not only do structures of thinking

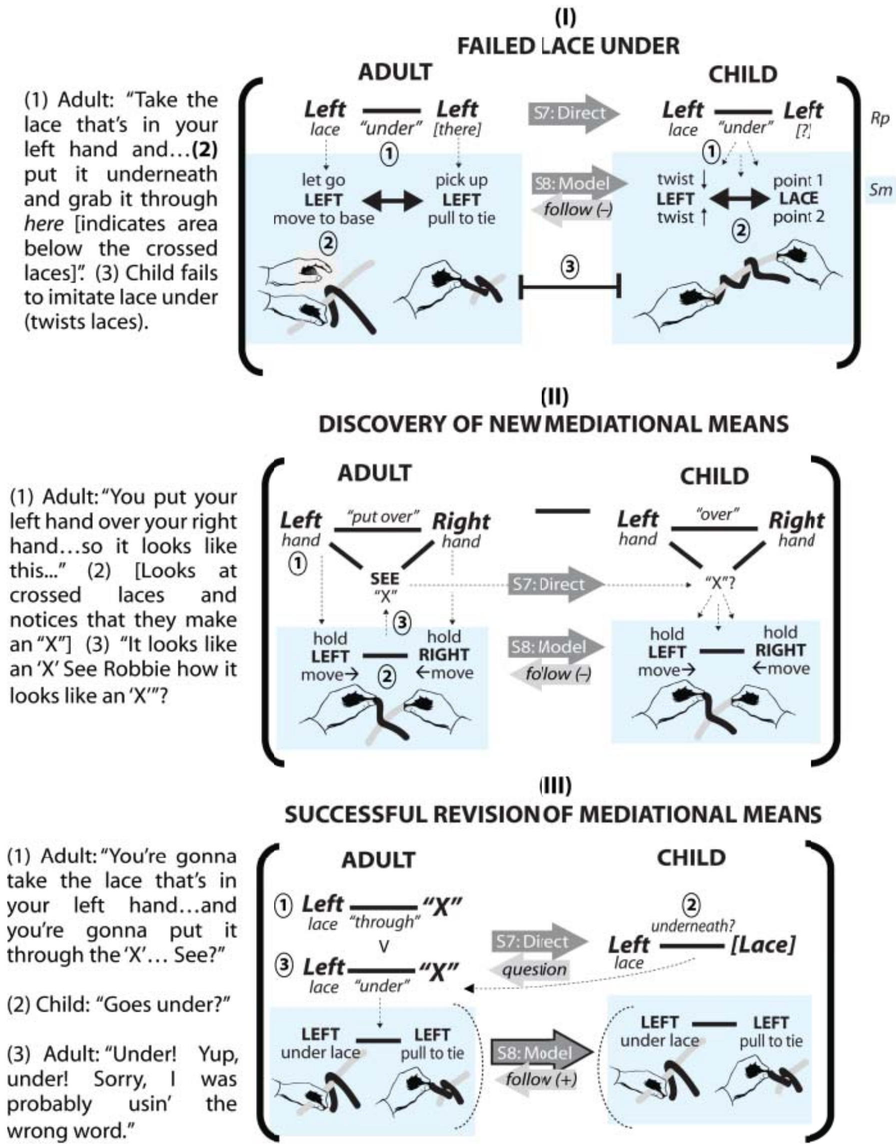


Figure 4.13 The coconstruction of mediational means (shoe-tying).

Note. Figure shows a series of dyadic action diagrams that specifies the evolving structure of joint action that occurs between the adult and child over the course of teaching the "lace under." The structure of the adult's action is indicated on the left portion of each diagram; the structure of the child's actions is indicated on the right. Unshaded structures indicate activity at the representational (Rp) level of functioning; shaded diagrams indicated the structure of sensorimotor action (Sm). Dotted arrows indicate the sequence of action and control over time.

and action develop over time, *the process of learning and development itself emerges and develops over time*.

As the teaching and learning process began, the child had already mastered the simple skill of crossing the laces. Building on this skill, Panel (I) in Figure 4.13 shows the structure of the child's first failed attempt to complete the initial tie (Steps 2 and 3 in Figure 4.11). Using a high level of scaffolding (Sc8), the teacher modeled the act of bringing one lace under the other. At the level of representational mappings, the teacher directed the child to "take the lace that's in your left hand and . . . put it *underneath* and grab it through *here* [indicating the area below the crossed laces]." However, despite the teacher's modeling, the child was unable to grasp the referential meaning of the term *underneath*. Instead of putting one lace *under* the other, the boy twisted one lace around the other, thus failing to complete the tie. The disparity between the teacher's modeling and the child's failed attempt is indicated at Point 3 in Panel (I) of Figure 4.13.

Panel (II) of Figure 4.13 illustrates the importance of *task scaffolding* in the coactive revision of the mediational means that the teacher uses to teach the task. Given the child's failure, the teacher untied her shoe and began to model the sequence of shoe tying from the beginning. As indicated in Panel (II), through the process of *task scaffolding*, the teacher discovers a new strategy for teaching the child how to put one lace under the other. At Point (1), the teacher modeled (Scaffolding Level 8) the act of crossing the laces. In so doing, she offered the directive (Sc7), "You put your left hand over your right hand . . . so it looks like *this*." At Point (2), the teacher paused and looked at her own crossed laces. *Noticing that her own crossed laces took the shape of an "X,"* she said, "It looks like an 'X.' The teacher then began to use the concept of "X" to mediate her instruction. As indicated at Point (3), the teacher directed the child by saying, "See Robbie how it looks like an 'X'? At this point, the child crossed his own laces. The idea of invoking the "X" to teach the child to put one lace under the other was not something that was planned beforehand. Instead, *it emerged as discovery* based on the teacher's *own actions in the task itself*—namely that of crossing her laces. Thus, the mediational means emerged coactively through the process of *task scaffolding*.

As indicated in Panel (III) of Figure 4.13, the teacher continued to use the notion of the *X* as an alternative to the concept of *underneath* to mediate her instruction. At Point (1) of Panel (III), the teacher said, "You're gonna take the lace that's in your left hand . . . and you're gonna put it *through the 'X'* . . . See?" Again, however, the child failed to comprehend meaning behind the teacher's use of the phrase *through the 'X.'* Confused, the child twice failed the lace under component of the task. As indicated at Point (2), on his third attempt, the boy moved his lace as if to experiment with where to put it, and asked, "goes under?" Apologizing, at Point (3) the teacher said, "Under! Yup, under! Sorry, I was probably usin' the wrong word." Having differentiated between *through the X* and *under the lace,* the child was able to put one lace under the crossed laces.

Over the course of these three episodes, the teacher discovered and refined the mediational means she used to represent the spatial relation to complete the *lace under*. The change in mediational means is indicated in Figure 4.14. After the teacher discovered that crossing the laces created an "X," her use of mediational means shifted from "*underneath/here*" → "*through the X*." After the

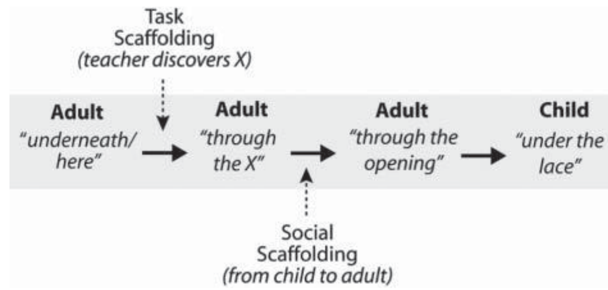


Figure 4.14 Development of mediational means.

child expressed confusion about the concept of "through," the teacher differentiated between the concepts of *under* and *through*. In specific, she invoked *under* with reference to *laces* (i.e., "Put the left *lace under* the right *lace*") and *through* with reference to the concept of an *opening* (i.e., "Put the left lace *through* the *opening*"). The novel use of the term *opening* identifies the area under the crossed "X" as the target of action.

The language invoked to mediate instruction and task completion are integral parts of the developmental processes. As such, it follows that central aspects of the process of development—the mediational means—emerged coactively over the course of teaching and learning. Thus, not only do the structures of development emerge over time, the process of change itself emerges and develops over time. As a result, it becomes difficult to separate the *structures* of development (i.e., skilled action) from the change process that organize development (i.e., coactive scaffolding; differentiation and integration). Structures of psychological activity and the processes by which those structures develop operate as flip sides of the same process.

CONCLUSIONS

We live in a complex world. It is composed of complex and dynamically emergent systems that exhibit both striking order and dramatic variability. It is the job of developmental scientists to understand the origins of such order and variation. As scientists, our work is necessarily informed by our conceptions of what it means to be a science. Science is committed to some form of *determinism*, the belief that events are both orderly and caused. Science is also committed to grounding assertions in empirical evidence, and, within the constraints of inescapable conceptual frameworks, to following where the data lead. As developmental scientists, we find ourselves at a juncture that should engender theoretical reflection. It we take the concepts of coactive emergence seriously, developmental science must address the conflict between an orderly determined world on the one hand and limited powers of prediction on the other. Predicting the course of human action is similar to predicting the weather. Over long periods, we are able to predict gross changes in human behavior. Just as we know that summer will eventually arrive after spring, we know that the capacity for symbol use will arise in some form after 2 years of sensorimotor-affective experience. In contrast, in the short term, just as we know that dark clouds will continue to move in our direction if they are near us rather than if they are far away, it is easier to predict what people will do in the coming minutes or hours than in the coming years. From the perspective of classic Cartesian-Split-Mechanistic science, such a state might seem discouraging. For the neopositivists of Cartesian science a central goal was to what will happen next and the ability to predict what comes next falls short of this goal.

Although scientists still committed to the traditional neopositivist values of prediction and control may lament this state of affairs, from an alternative view, our inability to predict what comes next may actually call for celebration. Our limited powers of prediction may not be a failure of our science, but instead may signal the inherent dynamism of the developmental process itself. If this is so, then we are served best by following the results of our inquiries where they seem to be leading us. In this case, they seem to suggest the importance of understanding the dynamics of coactive emergence. The concept of coactive emergence provides a framework for understanding what we have been trying to understand for so long—how novel and more powerful structures arise from existing and less powerful structures. Embracing the concept of coactive emergence suggests a new way of thinking about developmental science. Rather than seeking answers to the problem of origins by seeking to identify the assumed fixedness of *is*, it might be better to shift our mind-set toward the *dynamics of possibility*—understanding how novel forms emerge as systems self-organize under shifting developmental circumstances.

Trading a mind-set of prediction for a mind-set of possibility has important implications for our science. If order is an emergent product, it is possible we can understand the origins of order by identifying the circumstances under which coactions among systems occur. However, if order is an emergent product, it is also possible that variations in system functioning will create conditions under which something different will emerge. Novel developmental circumstances may foster the coactive production of novel and unanticipated forms. This principle applies to both individual development as well as the process of evolution. For the past century, evolutionary theory has relied on the explanatory staples of mutation, natural selection, and recombinant genetics to understand the process of evolutionary change. For years, we have lived with the difficulty of understanding how these quasi-random evolutionary processes—even over the course of millions of years—could bring about the stunning order of complex living systems. Modern epigenetic systems theory provides a framework for understanding how novel evolutionary forms can arise coactively, even in the absence of changes in the genome (Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume). According to Gottlieb (2002), the epigenesis of novel forms of *individual* behavior is key to understanding this process. When such novel gene-environment coactions recur across generations, new genome-epigenome-environment relations create novel possibilities for new developmental forms, even in the absence of changes in the genome. Such possibilities arise because of the untapped potential already existing within the genome for coactions with the epigenome and novel environmental circumstances. Novel genome-epigenome-environment relations can exploit this novel potential, leading to novel forms in the absence of genetic mutation.

However, to develop the promise of dynamic, relational, and epigenetic systems approaches to development, it will be necessary to continue to attend to several important conceptual and methodological issues. The first concerns the need for both precision and scope on the elaboration of developmental theory. Precision comes in the form of local theoretical models of local psychological and developmental processes (e.g., cognitive, affective, perceptual development). The testing of local models has been the primary mode developmental science for over a half-century. Equally important, however, is the elaboration of broader models of psychological development akin to those formulated by Piaget, Vygotsky, Erikson, and others. The continued elaboration of such models serves important functions in psychological science. They remind us that all observation is embedded in pretheoretical assumptions and beliefs that organize more local theory and research. They allow us to address broader questions at the level of individual person in addition to local questions at the subpersonal level of isolated psychological functions. Further, the synthesis of local research into general of psychological development provides a framework for understanding how different categories of psychological processes function in relation to each other. This not only provides a way to understand how local research fits into a larger framework, it also helps researchers become aware of how diverse psychological processes have implications for understanding a researcher's local research area, which is essential for the effectiveness of developmental analysis.

A second class of theoretical concerns involves issues related to the concept of development. As the weaknesses of general stage models of development have been revealed, many researchers have focused on the analysis of *age-related* rather than *structure-functional* changes in psychological processes (see Overton, Chapter 2, and Witherington, Chapter 3, this *Handbook*, this volume, for extended discussions of structure-function change). Although psychological development does not proceed as a linear, stage-like progression of structural changes, human behavior is nonetheless *structured*. As we have demonstrated repeatedly in this chapter, development involves dynamic transformations in the structure-function of behavior. Not all age-related changes are *developmental* changes. The concept of development is a directional one; it implies progressive movement toward one or another actual or idealized developmental outcome. Developmental movements are those that involve increasing differentiation and hierarchic integration of component parts over time. The skill scale described earlier provides a common measure for assessing changes in differentiation and integration of psychological structures as they develop within particular contexts and domains. Although the common scale is broadly applicable to assessing development in any given psychological domain, development assumes different shapes both within and between domains, contexts, people, and cultural groups. Again, development exhibits both order and dynamic variability.

Finally, although the focus of developmental science is on the nature of individuals, most psychological research focuses primarily on establishing relations at the level of the group or population. However, it is often unclear how relations established at the level of the group relate to the development of individuals. Over the past decades, evidence has accumulated that demonstrates the difficulty of drawing inferences about individual behavior from research conducted on groups (e.g., Molenaar & Nesselroade, Chapter 17, this *Handbook,* this volume; Nesselroade & Molenaar, 2010). Evidence suggests that more often than not, population insights represent only a small subset of individuals at best; at worst, they are statistical artifacts representing no one (Estes, 1956; Rose et al., 2013; von Eye, 2009; von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume). In developmental science, to create stable measures of behavior, researchers often base assessments of individuals on aggregate estimates of individual behavior by collapsing across multiple contexts. Although such data is helpful in differentiating groups of children who are more and less likely to produce target behaviors over time, they ignore the role of context in the production of target behavior at the level of individuals. It is not possible to understand the structures and processes of individual development simply by focusing on changes in group averages over time. To understand how novel structures emerge in development, it will be necessary to design research (see Molenaaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2010; Ram & Grimm, Chapter 20, this *Handbook*, this volume; von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume) assessing how individual behavior emerges coactively in real time within the person ←→ environment system.

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CHAPTER 5

Biology, Development, and Human Systems

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Biology has genetic, epigenetic, developmental, ecological, and evolutionary components. In addition to the scientific fields contributing to biology the philosophy of science also frames the field. As is the case with all the sciences, progress in biology depends on advances in theory building, empirical research, and modeling. Development, as one of the central processes of biology, has been the focus of both empirical and theoretical attention for centuries. Research techniques and methods used in biology to study development have evolved dramatically over the past several decades, generating a wealth of detailed empirical data. Metatheoretical frameworks, theories, and modeling have likewise advanced, calling into question established interpretations and assumptions about development, including the relation between genotype and phenotype, the nature and extent of heredity, the links between development and evolution, and the biological bases of behavior and cognition (e.g., see R. M. Lerner & Benson, 2013a). This chapter reviews the history and current status of biology's view of development and discusses the broader implications of this view for a psychobiological systems view of human development.

DEVELOPMENTAL THEORY IN THE HISTORY OF BIOLOGY

Development is the fundamental phenomenon of biology. It is also one of biology's most challenging problems.

The writing of this chapter was supported in part by NSF grant BCS 1057898 awarded to R.L. We thank Richard Lerner, Willis Overton, and James Tabery for their constructive comments.

What greater mystery could there be than the growth of something as complex as a human, made up of thousands of billions of cells organized into multiple organs, glands, muscles, and other body parts, from a relatively simple and formless tiny egg? How can it be that a single fertilized cell is able to give rise to an embryo and then, through many cycles of cell growth and division, an adult? The history of biology's evolving view of the remarkable process of development can be traced to debates begun more than 2,500 years ago between those who believed that all an organism's features are present prior to development at conception (*preformationism*) and those who believed that an organism's features do not preexist but rather come into existence progressively over the course of development (*epigenesis*). For example, according to the Hippocratic school of ancient Greece, each fertilized egg was thought to contain all the organized structures of the adult organism, but in miniature form. Development simply involved growth of this preformed homunculus. From this perspective, development did not involve an increase in overall complexity during the course of the individual's lifetime, as all the parts and organs were present and in their proper form from the outset. Based on his observations of animal embryonic development, Aristotle (384–322 BC) questioned this preformationist framework, noting in his text *The Generation of Animals* that in their earliest stages eggs appeared formless and only gradually did embryonic structure take shape. He argued that adult parts were not present at the beginning of development, but rather appeared sequentially as development proceeds. From this view, individual development included differentiation as well as growth.

However, the Aristotelian view of development, which eventually came to be known as *epigenesis*—a term coined by C. H. Waddington (see van Speybroeck, 2002)—faced the considerable problem of explaining how form emerges from formlessness. How, for example, do chicken eggs become chickens and frog eggs become frogs if both frog and chicken eggs are seemingly formless from the start? To deal with this thorny issue, Aristotle proposed that organisms have souls that internally direct the epigenesis process toward proper adult form (Maienschein, 2012).

Aristotle's general conception of development remained in play well into the 17th century. As a result of the increasing availability of microscopes, heated debate arose in the late 17th century regarding the plausibility of preformation versus epigenesis views of embryological development (Moore, 1993). The refutation of a strict homuncular view of preformationism was given a substantial boost in the middle of the 18th century with the careful observations of embryonic development by Caspar Friedrich Wolff (1733–1794), who was able to document that different organ systems differentiate and take form consecutively over the course of prenatal development. He emphasized that when organs first become observable, they do not appear in their final form. For example, the intestine of the chick embryo starts as a flat sheet and then becomes a tube. Wolff's findings were confirmed and extended decades later by Karl Ernst von Baer (1792–1876), whose detailed descriptions of the embryological sequences of fish, birds, and mammals in his 1828 monograph *On the Development of Animals, with Observations and Rejections* provided an initial map of the process of differentiation, further documenting and providing support for the epigenesis view that development proceeds from the general to the more specific. Von Baer stressed that development in vertebrate species could be universally characterized as progressing from the homogeneous to the heterogeneous. Further, in keeping with Aristotle's original insight, he provided compelling evidence that every step in development is only possible through the conditions preceding it.

Scientists of the 17th and 18th centuries (including von Baer) who advocated the epigenesis view of development continued to espouse the existence of a life force (akin to the Aristotlean soul) that directed the course of development. As a result, the epigenesis view remained linked to *vitalism*, a doctrine that held that living organisms contained an immaterial and immeasurable life-force responsible for form, growth, and animation. In contrast, the hypothesis of preformationism managed to avoid the issue of vitalism; if structure was present from the very beginning, then there was no problem of how to derive form from a formless state (Moore, 1993). As empirical evidence from improving technologies advanced, there was a concerted effort among embryologists in the 19th century to show how the alleged functions of vital forces could be explained in terms of physical processes consistent with a materialist philosophy.

By the second half of the 19th century, experimental embryologists and other biologists interested in development and heredity were attempting to find some middle ground between epigenesis and preformationism perspectives (Maienschein, 2012). One popular solution, exemplified by Weismann's *germ-plasm theory* (Weismann, 1893; see also de Vries, 1889), involved proposing that the individual characters of adults were specified by material particles present in germinal cells, rather than existing in miniature form at the start of development. This idea was originally proposed by Charles Bonnett (1720–1793), an 18th-century preformationist who in his 1762 book *Considerations on Organized Bodies* had argued that what was preformed was not the organs and other body parts in miniature, but rather organic particles or "germs" corresponding to and determining their growth. Although these material units of heredity eventually acquired a variety of different names at the hands of different biologists (e.g., Darwin's *gemmules*, Galton's *strips*," Weismann's *determinants*, de Vries's *pangenes*), it was generally agreed that these particles were somehow responsible for the phenotypic traits of the individual organism, representing a kind of material preformationism.

Moreover, in Weismann's germ-plasm theory it was assumed that these internal determinants were protected from any effects arising from the experience of the organism during its own lifetime. Weismann (1893) believed this was necessarily the case because the separation of the germ cells from all other cells of the body (what he called the *somatic line*) occurred so early in the course of the individual's development that what happened to somatic cells over the individual's ontogeny had no opportunity to effect the make-up of the germ cells. As a result, only changes in the *germ line* (contained in the sperm and egg) could contribute to heredity and ultimately to evolution. From this view, the fertilized egg contained all the necessary information for the development of the organism and this information was insulated from any environmental influences occurring during the individual's own lifetime.

Weismann's narrow conception of development and heredity had an enormous impact on the direction of theoretical biology for many decades. As the philosopher Griesemer (2002) has pointed out, Weismann's views provided the basic causal structure used to articulate ideas about genotype and phenotype, heredity and development, and evolution and selection for most of the 20th century. For psychology, Weismann's views provided a foundation for distinguishing between inherited and acquired behaviors (Johnston, 1995). In particular, his germ-plasm theory supported a distinction between those behaviors that are intrinsic to the organism (and assumed to be the result of *natural selection*) and those behaviors that were the result of the effects of experience (presumably through some form of learning). This distinction assumed that some behavioral patterns could be prespecified in the germ plasm, independent of environmental factors and already determined at conception. This assumption would influence thinking about both brain and behavioral development for much of the 20th century.

The material preformationist view of Wesimann was bolstered by the work of Gregor Mendel, whose research on the laws of inheritance in garden peas (resurrected some four decades after its initial publication in 1865) suggested to him that heredity came packaged in discrete units that were combinable in predictable ways. Mendel proposed that each of these discrete units or factors was associated with a particular phenotypic trait or character, a one-to-one correspondence between heredity factors and the structure or properties of the organism. Further, he proposed that each character was represented in the fertilized egg by two factors, one derived from the father and the other from the mother. These internal factors were thought of as self-contained packets of inheritance, passed on from generation to generation. Mendel's research thus provided a basis for making a conceptual dichotomy between the characters and qualities of individual organisms (later called the *phenotype*) and the factors or "units" of heredity that passed from parent to offspring in reproduction (later called the *genotype*).

During these early years of the 20th century a number of biologists worked to solidify the view that heredity and the resulting stability and variability of phenotypic traits observed across generations involved the passing on of discrete internal factors or "determinants" situated somewhere in the structure of fertilized cells. These hypothetical internal factors were termed *genes* by the Danish botanist Wilhelm Johannsen in 1909 (see Johannsen, 1911), and during the early decades of the past century it was still not clear whether these genes were fictitious or real (Keller, 2000), but to a large extent the material basis of genes did not matter. Genes were simply "units of heredity" used as intervening variables to explain Mendelian patterns of heredity of offspring phenotypes based on parental phenotypes (Griffiths & Stotz, 2006).

The celebrated discovery of the double helix by Watson and Crick (1953) solidified the material basis of genes as deoxyribonucleic acid. The pairing of the two strands of the double helix of DNA was thought to be the instructions for phenotypic development and the exclusive process for replicating the essential units of inheritance. As a result, development came to be increasingly characterized across the biological sciences as the process by which genotypic specification is translated into the phenotypes of individuals, including their anatomy, physiology, and behavior (Dobzhansky, 1937; Mayr, 1942, 1982). Influences above the level of the gene were thought to play a relatively minor role in developmental outcome. Stotz (2006) provides a succinct overview of this widespread perspective:

> For the largest part of the past century we came to see genes as a material unit with structural stability and identity, with functional specificity by means of their template capacities that encode information, and with intergenerational memory; we came to see genes as the designator of life and the site of agency and even mentality (in containing a plan or a program for and asserting control over developmental processes). (p. 914)

The mysterious and elusive vital force advanced by proponents of epigenesis in the 18th and early 19th century was thus gradually replaced by an equally mysterious and elusive *genetic program* believed to guide the process of development. This gene-centered perspective had at its core an underlying false premise that went unquestioned by many psychologists and biologists over the course of the 20th century: that the bodily forms, physiological processes, and behavioral patterns of organisms could be specified *in advance* of the organism's development. Indeed, the notion of a preformed program that resides in the genes and is directly responsible for an individual's phenotypic characteristics came to dominate much of 20th-century biology's concern with both developmental and evolutionary processes (Keller, 2000; Lickliter & Honeycutt, 2009; Oyama, 1985; Robert, 2004).

EVOLUTIONARY THEORY AND GENOCENTRISM

During the 19th century, the study of heredity and development were considered one science. Almost all theories of heredity of the time (including Darwin's) assumed that to understand heredity one must also understand development. In other words, explaining why traits or characteristics are similar between parent and offspring requires one to understand how those characteristics develop over individual ontogeny (Amundson, 2005). In this view, inheritance (heredity and development together) was about the reproduction of similarity across generations (Gerson, 2007). Further, since heredity was involved in evolution, it was thought that evolution was to be understood in terms of changes in developmental processes.

The widespread acceptance of Weismann's germ-plasm perspective on the nature of heredity and development and the rediscovery of Mendel's research suggesting that the inheritance of some traits or characteristics could be predicted with reference to internal factors transmitted in reproduction contributed to developmental issues becoming increasingly divorced from concerns with heredity and evolution in the early decades of the 20th century. If genes contained the necessary information for phenotypic traits, and if circumstances during individual development could not directly influence the traits or characteristics of offspring, then any role or influence of development in heredity and evolution had to be minimal. According to the evolutionary biologist John Maynard Smith (1982), "one consequence of Weismann's concept of the separation of the germ line and soma was to make it possible to understand genetics and hence evolution, without understanding development" (p. 6).

The architect of the chromosomal theory of heredity, Thomas Hunt Morgan (Morgan, 1917; Morgan, Sturtevant, Muller, & Bridges, 1915), contributed to this growing separation of heredity and development by drawing a sharp distinction between transmission genetics and developmental genetics. Morgan viewed *transmission genetics* as critical to evolutionary concerns, because it dealt with the hereditary transmission of (at the time, still hypothetical) genes, whereas *developmental genetics* (including embryology) focused on how genes were expressed during development and had little to say about evolution. This perceived separation of heredity and evolution from development was eventually solidified by the *Modern Synthesis* of evolutionary biology, crafted by animal and plant geneticists in the 1930s and 1940s (Mayr & Provine, 1980). This new framework, a synthesis of neo-Darwinian, Weismannian, and Mendelian concepts, promoted a narrow definition of evolution as "a change in the genetic composition of populations" (Dobzhansky, 1937). Following a line of thinking most clearly articulated by R. A. Fisher (1930), a species or a population became a collection of discrete Mendelian genes existing in different frequencies (so called *gene pools*) that were the objects of evolutionary change. Evolution was thus assumed to be changes in genes, rather than changes in developmental processes.

Watson and Crick's discovery of the structure and function of DNA in 1953 served to reaffirm the genocentric position of the Modern Synthesis—if genes are DNA, and copying errors for DNA to RNA to protein are the source of genetic variation, then evolution must indeed be "changes in gene frequencies in populations." A succinct overview of these basic tenets of the Modern Synthesis was provided by David Futuyma (1986) in his influential textbook: *Evolutionary Biology*:

> The major tenets of the evolutionary synthesis, then, were that populations contain genetic variation that arises by random (i.e. not adaptively directed) mutation and recombination; that populations evolve by changes in gene frequency brought about by random genetic drift, gene flow, and especially natural selection; that most adaptive genetic variants have individually slight phenotypic effects so that phenotypic change are gradual; that diversification comes about by speciation, which normally entail the gradual evolution of reproductive isolation among populations; and that these processes, continued for sufficiently long, give rise to changes of such great magnitude as to warrant the designation of higher taxonomic level (genera, families, and so forth). (p. 12)

Note that in this widely accepted view of evolution, it was assumed that the process of development as well as the environment in which the organism develops have little to do with the changes in gene frequencies thought to drive evolution. The special privileges assigned to genetic factors effectively divorced heredity (as genetic transmission) from development, and developmental influences from evolutionary processes. These divisions fostered the view that developmental analyses could add little or no explanatory value to evolutionary theory. Development was increasingly viewed as merely the reading out of genetic programs that were assumed to be the products of natural selection, and the rules governing the evolution of populations were assumed to be distinct from those governing individual development. As a result, the Modern Synthesis focused on population genetics, an approach that concentrated on the traits or characteristics of adults in populations and virtually ignored questions about how these characteristics were actually realized during the course of development. This strategy essentially "black boxed" the process of development, thereby peripheralizing developmental and behavioral scientists from the concerns of evolutionary biology. Attempts to explain evolution in terms of developmental processes were widely considered "an error of misplaced reductionism" (Maynard Smith, 1985).

PSYCHOLOGY AND NATIVISM

The internally driven and decidedly predetermined view of development commonplace in 20th-century biology was also widely embraced in psychology. In the first half of the century, several generations of psychologists relied on the notion of internally driven *maturation* as a causal explanation for physical growth, behavioral development, and cognitive skills (e.g., Bayley, 1951; Gesell, 1929; Witty & Lehman, 1933). Genes were thought to prescribe not only bodily structures and physical appearance, but also the fundamental form of human cognitive processes. Arnold Gesell's (1945) conception of human development, in which early behavior expands through "the innate processes of growth called maturation" is a well-known example of this theoretical framework.

The legacy of the maturational framework continues to play out across the psychological sciences (see Bateson, Chapter 6 and Overton, Chapter 2, this *Handbook*, this volume, for extended critiques of the concept "maturation"). For example, the assumption that aspects of development involve a programmed unfolding of genetic information, relatively independent of environmental factors, is still evident in contemporary developmental psychology, as the following quotes drawn from several developmental psychology textbooks makes clear:

- To those who emphasize *nature*, development is largely a process of maturation, the biological unfolding of the individual according to a plan contained in the genes (the hereditary material passed from parents to child at conception). Just as seeds turn into mature plants through predictable process, humans "unfold" within the womb (assuming that they receive the necessary nourishment from their environment). (Sigelman & Rider, 2012, p. 7)
- To grasp the meaning of development, we must understand two important processes that underlie developmental change: maturation and learning. Maturation refers to the biological unfolding of the individual according to a species-typical biological inheritance and an individual person's biological inheritance. (Shaffer & Kipp, 2010, pp. 2–3)
- *Nature* refers to traits, abilities, and capacities that are inherited from one's parents. It encompasses any factor that is produced by the predetermined unfolding of genetic information—a process known as maturation. (Feldman, 2012, p. 11)
- The term nature refers to the biological forces that govern development. To a certain extent our development is preprogrammed our genes—traits inherited from our parents and ancestors. In childhood this program unfolds.... Nature provides the genetic program. (Cook & Cook, 2005, p. 5)
- Whatever the source of the egg and sperm, and wherever they meet, their merger is a momentous event: The resulting 23 pairs of chromosomes define a child's heredity—what he or she will do naturally. (Kail, 2012, pp. 42–43)

Although textbook authors must often gloss over more nuanced theoretical points for their relatively naive readers, these passages clearly demonstrate a commitment to the notion of predetermined aspects of human development and also promote the standard version of the nature (internal, biological, and hereditary factors) versus nurture (experiential and environmental factors) dichotomy, one in which the two are treated as separate sources of developmental information. As is reviewed in more detail later, the widespread use of this distinction in the 20th century made it possible to split heredity from development and developmental analysis from evolutionary analysis, as well as legitimize attempts to partition phenotypic characteristics into those that are genetically determined and those that are produced by environment.

Despite persuasive efforts within the psychological and developmental sciences to successfully integrate conceptions of nature and nurture over the last several decades (e.g., Gottlieb, 1997; R. M. Lerner, 1978, 1991, 2006; Moore, 2002; Overton, 1973, 2004, Chapter 2, this *Handbook*, this volume; Oyama, 1985; Richardson, 1998; Sameroff, 2010; Stiles, 2008), developmental psychology has not yet successfully come to terms with various versions of the nature-nurture debate (Goldhaber, 2012; Lewkowicz, 2011; Spencer et al., 2009). Within the domains of perceptual and cognitive development, this struggle has often centered on the issue of to what extent humans are innately—see Bateson, Chapter 6, and Overton, Chapter 2, this *Handbook*, this volume, for the problematic nature of the term *innate*; also Mameli & Bateson (2011)—prepared to interpret and act on the world and to what extent they rely on learning and experience (see Blumberg, 2005, and Samuels, 2002, for contrasting views). "Nativistic" perspectives on perception and cognition typically rely (often implicitly) on the argument of the poverty of the stimulus: The developing organism displays too much knowledge, or too much skill for experience or learning to be an adequate explanation. Thus, nativists propose that there is a core set of innate—here the term *innate* meaning "biologically determined" rather than its strict definition "present at birth"—concepts that provide the foundation for later learning (e.g., Carey & Markman, 1999; Landau, 2009; Spelke & Kinzler, 2007). These core concepts are thought to be present in early infancy in the absence of obvious experience and are thus presumed to be biologically prespecified. For example, Spelke and Newport (1998) have argued for the differential roles of biology and experience, suggesting that a solution to the nature-nurture debate is the "thesis that human knowledge is rooted partly in biology and partly in experience and . . . that successful explanations of the development of knowledge will come from attempts to tease these influences apart" (p. 323).

In this chapter, we show how current biological research does not support these types of divisions or dichotomies. A major goal of this chapter is to make the case that if there is any lesson to be learned by developmental scientists from advances in the biological sciences, it is that "biology" and "experience" are completely fused and cannot be meaningfully separated or teased apart. In what follows, we outline and apply *developmental psychobiological systems* (DPS) to the enduring challenge of mapping out the relational causes of development, and we examine its relevance to the study of human development (see Overton, Chapter 2, this *Handbook*, this volume, for the close association between DPS and *relational developmental systems*).

Rather than viewing nature (genes or heredity) and nurture (environment or experience) as separate sources of information during development, DPS recasts nature and nurture in terms of product and process (Figure 5.1). The structure (anatomy, skills, habits, preferences) of an individual at any given time represents one's nature, and nurture is the process that organizes, maintains, and transforms one's nature (Oyama, 1985, 2002). From this view, organisms inherit *resources* for development, not trait or characteristics or specifications for traits or characteristics (Johnston, 2009; Overton, 2010, Chapter 2, this *Handbook*, this volume). DPS thus emphasizes that the pattern of internal and external factors involved in development and their temporal and spatial relations cannot be specified or predetermined in a genetic program (Griffiths & Tabery, 2013). Simply put, development is an historical process, not a programmed one. At whatever stage of the life cycle we identify a particular characteristic or capacity, a history of development already lies behind it. This hard won insight took most of the last century to achieve.

DEVELOPMENTAL PSYCHOBIOLOGICAL SYSTEMS

Before reviewing the central tenets of DPS, it is important to point out that DPS is a *meta*theoretical position or orientation (Godfrey-Smith, 2001). All scientific endeavors reflect some kind of metatheoretical assumptions about the relevant subject matter and how to study it (see Overton, 2006, 2013, Chapter 2, this *Handbook*, this volume) and DPS provides what we believe are productive assumptions for the scientific study of development in ways

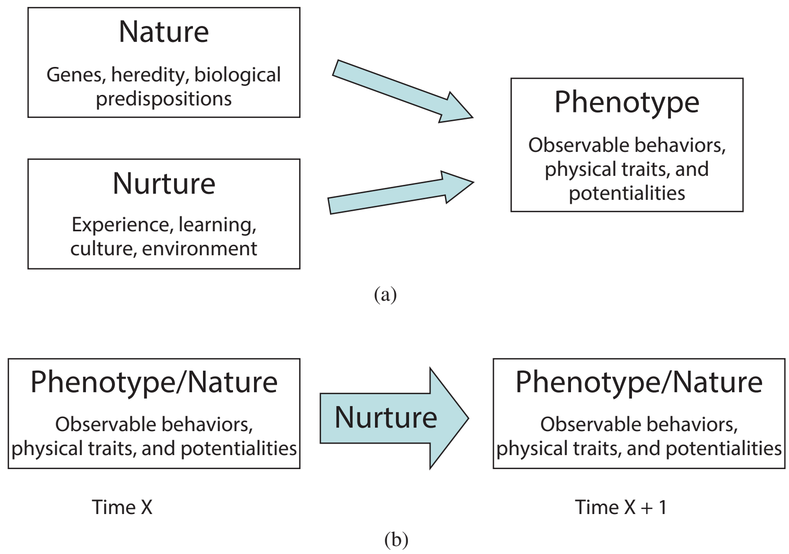

Figure 5.1 Contrasting views of nature—nurture relations. (a): Traditional conceptions of nature and nurture promote the two as separate sources contributing to phenotypic outcomes. (b): The developmental psychobiological systems view proposes that nature is best viewed as the dynamic product of the process of nurture, broadly defined to include all relevant developmental resources.

that are biologically plausible and that avoid misleading oversimplifications. Moreover, with its emphasis on process, activity, change, emergence, and self-organization, DPS is a *relational* metatheory of development (R. M. Lerner, 2006; R. M. Lerner & Benson, 2013a; Overton, 2006, 2010, 2013). DPS is, in fact, what Overton (2013, Chapter 2, this *Handbook*, this volume) has termed a *midrange metatheory,* functioning between the ontological and epistemological assumptions of a relational worldview and the specific concepts of any particular theory.

The roots of DPS trace back more than 50 years ago to a group of psychobiologists (many associated with the American Museum of Natural History) concerned with the role of experience in the development of behavior across a range of vertebrates and invertebrates (e.g., Denenberg, 1964; Gottlieb, 1971; Kuo, 1967; Lehrman, 1953, 1970; Levine, 1957; Moltz, 1963; Rosenblatt, 1969; Schneirla, 1956, 1966; Tobach & Schneirla, 1968; Turkewitz, 1977; see also Aronson, Tobach, Lehrman, & Rosenblatt, 1970). This research tradition was primarily concerned with the development of species-typical behavior of animals in their natural habitats, with a particular interest in the behavioral and psychological adaptations distinctive to each species and how these adaptations were modified in response to changing internal and external conditions. Because most species-typical behaviors were presumed to be innately (i.e., "biologically") determined at this time (Lorenz, 1937, 1950), DPS largely coalesced as a reaction to the widespread notion of genetically determined "instinctive" behavior (Lehrman, 1953; Schneirla, 1956).

CONCEPTUAL AND EMPIRICAL OBJECTIONS TO NATIVISM

In the early 20th century it was generally accepted that humans and other animals possess a basic set of unlearned (presumably inherited) instincts at birth (although others might appear at later ages). William James promoted the importance of instincts in his influential *Principles of Psychology* (1890) and William McDougall (1909) famously identified 12 major human instincts, including curiosity, gregariousness, and self-assertion (his list would grow to 17 several decades later). Psychologists of this era were divided on the types and number of instincts, but few questioned their existence. Even students of animal learning viewed instinct as a powerful influence on behavior. Edward Thorndike (1918), for example, proposed that,

> Any man possesses at the very start of his life—that is at the moment when the ovum and spermatozoön which are to produce him are united—numerous well defined tendencies for future behavior. Between the situations in which he will meet and the responses he will make to them, preformed bonds exist. It is already determined by the constitution of these two germs, that under certain circumstances he will see and hear and feel and act in certain ways. (p. 2)

Like most other psychologists, Thorndike wanted to experimentally separate that which was learned from that which is original in the nature of animals, including humans "to get the association process free from the helping hand of instinct" (Thorndike, 1911, p. 30).

By the 1920s the instinct concept had become a source of heated debate in psychology (Bernard, 1921; Carmichael, 1925; Dunlap, 1919; Kantor, 1920; Tolman, 1923), where criticisms of the instinct concept centered on its vagueness and circularity and on its nondevelopmental stance that instincts were determined by heredity, whereas other behaviors were the result of learning (see Johnston, 2009). Adding fuel to this debate was Zing-Yang Kuo (1898–1970), who proposed that not only were there no instincts in the traditional sense, but that the very distinction between instinctual versus learned characteristics was fallacious and served to stifle developmental analysis (see Honeycutt, 2011). Kuo noted that the instinct concept provided a "finished psychology," in the sense that it assumed an explanation of the origins of behavior by simply giving it a label. Lehrman (1953) captured the core of this shortcoming more than 60 years ago:

> Any instinct theory which regards "instinct" as immanent, preformed, inherited or based on specific neural structures is bound to divert the investigation of behavior development from fundamental analysis and the study of developmental problems. Any such theory of "instinct" inevitably tends to short-circuit the scientist's investigation of intraorganic and organism-environment developmental relationships which underlie the development of "instinctive behavior." (p. 359)

Kuo (1930, 1938) supported his theoretical position by the results of his various lines of comparative research. For example, he challenged the "rat-killing" instinct in cats by raising kittens in a variety of different social environments. Some kittens were raised with or without an adult cat, and some kittens were raised with rodents (rats or mice). Every few days each kitten was given the opportunity to chase and kill an unfamiliar rodent. After 4 months of testing, more than 90% of those kittens raised with adult cats killed a rodent compared to less than half of those kittens raised in groups without adults. More strikingly, less than 10% of those kittens raised with rodents had killed a rodent by 4 months of age. Indeed, these rodent-raised kittens showed numerous attachment-related behaviors (e.g., separation anxiety) to their rodent cage mates. In addition, Kuo took those kittens that did not kill rats and exposed them to an adult cat that killed a rodent in their presence. This experience had a profound impact on kittens raised without adults (100% killed rodents) but had a much smaller effect on those raised with rodents (10% killed rodents). Clearly, the development of the so-called rat-killing instinct, far from being unlearned or built-in, depended on the early raising conditions and experiences of kittens. If one is to speak of a rat-killing instinct, then one must also speak of a rat-loving instinct as well, at which point the instinct concept itself becomes useless. As Kuo (1930) succinctly put it: "nothing is more natural than for the cat to 'love' the rat . . . and if one insists that the cat has an instinct to kill the rat, I must add that it has an instinct to love the rat, too" (p. 35).

Kuo's raising experiments underscored the *probabilistic* nature of behavioral development. Over the course of development, each individual encounters its own unique array of experiences, opportunities, and constraints, thereby making some behavioral outcomes more likely to be supported and maintained and others prevented or eliminated. The enormous range of the *possible* becomes the *actual* behavior we observe as a result of the organism's real-time active experience, its developmental history, and the nature and features of its developmental context. Artificial divisions and descriptive labels like nature and nurture (and related dichotomies such as instinct versus learning) fail to capture these underlying dynamics of individual development and in so doing hinder progress in understanding the ways and means of basic life processes (Keller, 2010).

The shortcomings identified by Kuo in regard to instinct are equally problematic for more modern nativist notions regarding the causes of behavior (i.e., maturation, biological predispositions, developmental programs), as these accounts of development presuppose the very phenomenon that is to be explained. Thelen and Smith (1994) have pointed out that most major theoretical systems associated with the study of human development have had a common teleological core that implicitly assumes an "end state" before the process of development even begins (see also Overton, 2010, Chapter 2, this *Handbook*, this volume). In this sense, nativism is a thoroughly nondevelopmental concept, and as previously noted, effectively serves to sidestep empirical developmental analysis. Echoing the earlier claims of Lehrman and Kuo, Stotz (2008) argues that

> The main problem with all allegedly explanatory categories and concepts of behavior, such as instinctive, learned, or genetically programmed, is that they block further investigations into real ontogenetic and evolutionary causes of a behavior just by their very nature of purporting to explain while really doing nothing but labeling it. (p. 365)

For example, claims that aspects of behavior or cognition are prespecified assume that such "primitives" are not subject to development. As a result, studies conducted to document innate (i.e., biologically determined) abilities or knowledge at best only provide information about *what* individuals can do and *when*. The *how* question is overlooked by invoking the presumed action of genetic programs, instructions, or predispositions. Similar problems arise by calling something environmentally determined or "due to learning." In either case, this kind of simple determinism glosses over the complex developmental dynamics involved in the generation of all an organism's characteristics. A DPS orientation encourages researchers to focus on *how* phenotypes actually develop, and emphasizes that any explanation of phenotypic development will involve a system of interrelated factors that become causally relevant by their coactions (see Bateson, Chapter 6, this *Handbook*, this volume, for a similar analysis from an ethological perspective).

A common misunderstanding used to challenge a DPS orientation is to conflate DPS's denial of preformationism (i.e., innate [i.e., biologically determined] preferences or "core" knowledge) with the extreme empiricist position that individuals begin life as "blank slates" (Pinker, 2002). Animal and human newborns are not blank slates; they display an array of biases, preferences, and proclivities following birth. However, like any other trait or characteristic of an organism, these biases and predispositions must develop (Harshaw & Lickliter, 2011; Moore, 2009; Spencer et al., 2009). To claim that predispositions are "biologically given" or "innate" is a thoroughly nondevelopmental point of view that says nothing about the developmental origins of these early behaviors.

The Roles of Experience

To move away from simple (internal or external) models of determinism requires a reformulation of what is meant by experience. Traditionally, the way in which experience was thought to affect the development of behavior was through various forms of learning (Johnston, 2009). However, as pointed out by a number of prominent developmental psychobiologists during the last half century (e.g., Gottlieb, 1976; Kuo, 1967, Lehrman, 1953, 1970; Schneirla, 1956), it is important to keep in mind that *experience* is not synonymous with *learning*, but rather refers much more broadly to function or activity (Overton, 2006, Chapter 2, this *Handbook*, this volume), and is construed very broadly to include the electrical activity of neurons and their processes, neurochemical and hormonal secretion, the use of muscles and sensory systems, and the behavior of the organism itself. Thus, the term *experience* is also not synonymous with *environment*, but rather refers to functional activity at the neural, physiological, and behavioral levels of analysis.

Importantly, experience may contribute to development in subtle and often nonobvious ways, as was elegantly demonstrated by Gottlieb's decades-long research project on the development of species identification in ducklings (reviewed in Gottlieb, 1997). Ducklings have to hear their own or broodmates' prenatal vocalizations to show species-specific responsiveness to their respective maternal call following hatching. Ducklings denied this normally occurring experience failed to show a preference for their species-specific maternal call. The finding that prenatal experience plays a formative role in the development of species-typical behavior provided empirical support for Gottlieb's notion of *probabilistic epigenesis* (1971, 1991, 2007), a core tenet of the DPS framework, which holds that because of the rich traffic of bidirectional influences within and between levels of analysis, individual development cannot have a predetermined trajectory.

Integrative Levels: Situated Relational Causality

For all multicellular organisms, there is a hierarchy of integrated levels, including genes—cells—tissues—organs—organ-systems—organism—populations. Another core tenet of the developmental psychobiological systems approach is that developmental causation is both "bottom up" and "top down" (see Overton, Chapter 2 and Witherington, Chapter 3, this *Handbook*, this volume). Genes and all other levels of the hierarchy are recognized as part of a complex system, in which the cytoplasm can influence the genes, extracellular hormones can influence the cell nucleus, external sensory stimulation can influence the genes, hormones can be influenced by the external environment, and so on (Gottlieb, 1997, 1998). From this framework, the influence that any component may have on other parts can extend to higher or lower levels, or remain at the same level. The relations between components are bidirectional or reciprocal (←→), whereby one component that affects another can be influenced by it in turn. Within this context it has generally been useful to differentiate all additive forms from these reciprocal relations by referring to the latter as *coactions* (Gottlieb, Wahlsten, & Lickliter, 2006). We continue this tradition here—except when *interaction* appears in a quote or is appropriately used—and will understand *coaction* as similar to other relational terms used to describe nonadditive influences. These include the concepts of *reciprocal determination* (Overton & Reese, 1973), *fusion*, (Greenberg, 2011; Partridge, 2011), *relational bidirectional* (←→) *causality* (R. M. Lerner, 2006), *relational causality* (Gottlieb & Halpern, 2002; Overton, 2006), and *circular causality* (Witherington, 2011).

An appreciation of the importance of integrative levels is not a new concept in biology (e.g., Novikoff, 1945; Russell, 1930; Schneirla, 1949, 1956; von Bertalanffy, 1933; Woodger, 1929; see also Greenberg & Tobach, 1984), but was not widely applied during most of the past century due to the prevalence of the gene-centric approach to development outlined earlier. This pattern has shifted in recent decades, due in large part to advances in molecular genetics, endocrinology, neuroscience, and developmental biology. As we review later, across biological and psychological domains there is a growing emphasis on the importance of genetic-environmental coactions, requiring complicated systems analyses to address the multiple part-whole dynamics underlying the process of development (Kohl, Crampin, Quinn, & Noble, 2010; Noble, 2010).

More than 50 years ago, the embryologist Paul Weiss (1959) provided a simple but useful diagram (Figure 5.2) of the hierarchy of reciprocal influences he thought to be involved in the process of development. His diagram represents a hierarchically organized system of increasing size, differentiation, and complexity, in which each component affects, and is affected by, all the other components at its own level as well as at lower and higher levels. Weiss's arrows of influence thus not only go upward from the gene, eventually reaching all the way to the external environment through the activities of the organism, but also return from the external environment through the various levels of the organism back to the genes. In this model, functional coactions occur both within levels and at the interfaces of the various levels of the hierarchy.

For example, the causal interconnections that have been found to underlie the expression of reproductive behavior in the ring dove (*Streptopelia capicola*) illustrate the rich network of internal and external factors involved in their courtship, nest-building, egg-laying, incubation, and parental care. Our knowledge of ring dove reproductive behavior, based in large part on studies by Lehrman (1964, 1965) and Michel (1986), recognizes the historical, contingent, and dynamic nature of phenotypic outcomes by demonstrating that: (a) hypothalamic, pituitary, and gonadal functions, essential for the range of reproductive

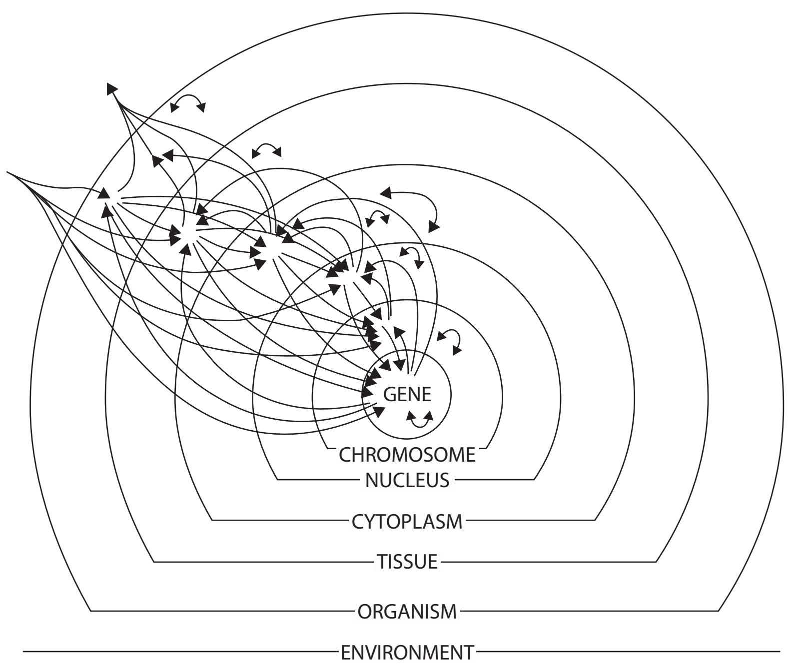

Figure 5.2 Embryologist Paul Weiss's representation of the hierarchy of reciprocal influences involved in development. Weiss's hierarchy spans from the lowest level of organization (gene) to the highest level (external environment). As such, the diagram represents a hierarchically organized system of increasing size, differentiation, and complexity, with feed-forward and feed-backward traffic within and across levels of organization.

Source: From "The Significance of Biology for Human Development: A Developmental Psychobiological Systems View" (p. 215), by G. Gottlieb, D. Wahlsten, and R. Lickliter, in *Theoretical Models of Human Development*, R. M. Lerner (Ed.), Volume 1 of the *Handbook of Child Psychology*, 6th ed., W. Damon and R. M. Lerner (Editors-in-Chief), 2006, Hoboken, NJ: Wiley.

behaviors seen in ring doves, are largely determined by the social and physical stimuli associated with the reproductive cycle (i.e., the long days of spring, the presence and activities of the mate); (b) changes in levels of circulating hormones influence the dove's sensitivity to specific social and physical stimuli (i.e., the presence of a nest, the activities of the newly hatched young); and (c) the dove's prior reproductive experience alters the pattern and regulation of behavior by its influence on the sensitivity of the dove's nervous system to specific hormones and to social and physical stimuli (see Michel & Moore, 1995, for further discussion).

Taken together, the coactional traffic between neural function, hormones, behavior, and environmental resources involved in the reproductive behavior of the ring dove highlights the difficult but critically important task of developmental analysis—filling in the bidirectional details among the specific internal and external factors contributing to the generation of any phenotypic trait or character. An understanding of the ring dove's reproductive behavior was not achieved by examining only neurological, endocrine, or physiological levels of analysis; it also required detailed information about the organism's physical and social milieu. In keeping with another basic tenet of the developmental psychobiological systems approach, the causes of reproductive behavior in the ring dove can be said to be distributed across several levels of organization. In any given aspect of the reproductive process, some factors might be more central and predominate more than others, but the variety of factors at play always operate in a context in which their effects are dependent on their relation with other factors. Understanding development thus requires, as suggested earlier, a relational concept of causality (Gottlieb & Halpern, 2002; Overton, 2006, Chapter 2, this *Handbook*, this volume).

The relational integrative framework illustrated in Weiss's diagram (Figure 5.2) is fundamental to developmental psychobiological systems (Gottlieb et al., 2006; Griffiths & Tabery, 2013; Hofer, 1981; Michel & Moore, 1995) and as we explore later, is now being successfully applied across multiple levels of inquiry across biology, including genetics, epigenetics, neuroscience, and evolutionary biology. The insight that the causes and control for development do not reside in any one factor or component, but rather reside in the nature and dynamics of the relations among factors *internal* and *external* to the organism has shifted thinking about development away from the internally based, prespecified framework prevalent for most of the past century and toward an appreciation of development as a *situated process* that is dependent on resources distributed across the organism-environment system. In other words, control of development is exerted by the regulatory dynamics of the gene-in-a-cell-in-an-organism-in-an-environment system (Oyama, 1985; Robert, 2004). Recognizing that development is a process that is fundamentally "situated" represents a major shift in thinking from the largely decontextualized, internally driven view of development that dominated the life sciences for most of the past century.

The contemporary developmental psychobiological systems framework (e.g., Ford & Lerner, 1992; Gottlieb, 1997; Griffiths & Gray, 1994; Griffiths & Tabery, 2013; Johnston, 2009; Lickliter & Berry, 1990; Michel, 2010; Moore, 2002; Overton, Chapter 2, this *Handbook*, this volume; Oyama, 1985; Oyama, Griffiths, & Gray, 2001) extends this core principle and emphasizes that because of the reciprocity of influences within and between levels of analysis within the organism-environment system, attempts to partition developmental outcomes into those attributable to the genes and those that are the result of the environment is simply not possible. Attempts to dichotomize developmental causality into "nature" and "nurture" effectively ignore the multiple levels of influence, resources, and coactions between genes and behavior (Gottlieb 2007; Johnston & Edwards, 2002; Meaney, 2010), thereby isolating developmental psychology and its concerns from developmental genetics, developmental biology, and developmental neuroscience (Gottlieb et al., 2006). A particular aim of developmental psychobiological systems approach has thus been to replace the simplistic metaphor of a genetic program with a more accurate account of genetic and nongenetic influences on development.

Situating Genes in the Developmental System

Schaffner (1998) outlined five concepts that DPS applies to the relations between genes, development, and behavior. These include: *parity,* the idea that genes are not privileged but rather are one part of an integrated developmental system; *nonpreformationsim*, the idea that we will not find the "information" for characteristics in genes, as all phenotypic characteristics are generated by the process of development; *holism*, the idea that genes have meaning only in the context of other genes and their cellular, extracellular, and extraorganismal environment; *indivisibility*, the idea that the separate effects of genes and environment on characteristics cannot be identified in any meaningful sense; and *unpredictability*, the idea that it is not possible to predict *a priori* an organism's characteristics, as they are emergent in the process of development. These five core concepts are consistent with a *relational* metatheory of development (Overton, 2006, 2013, Chapter 2, this *Handbook,* this volume), with its emphasis on process, activity, change, emergence, and self-organization.

An example from the study of anatomical development serves to illustrate this shift in emphasis. From the gene-centered view dominant over much of the past century, limb development was seen as a relatively straightforward process—genes were thought to provide the specific instructions for the growth and development of bone and muscle, thereby accounting for the observed stability of form and function within a species and across generations. Evidence from developmental biology indicates a more complicated and distributed explanation. In vertebrates the *active movement* of the embryo is required for the normal or species-typical development of bone, joints, muscles, tendons, and ligaments (Müller, 2003). For example, the fibular crest is a leg bone that connects the tibia to the fibula in most bird species. It allows the force of the iliofibularis muscle to pull directly from the femur bone to the tibia bone. This direct connection between the femur and tibia is important, as it allows the reduction in size of the femur bone seen in birds when compared to mammals. Developmental biologists have shown that when chicken embryos are prevented from moving within the egg during periods of their prenatal development, this bone fails to develop (Müller & Steicher, 1989).

Under the normal conditions of prenatal development the bird embryo is subjected to ongoing stimulation from a host of factors, including gravity, thermal gradients, amnion contraction, maternal stimulation, and also self-stimulation of its own muscles, joints, and sensory systems as it moves and positions itself in the egg (or in the case of the mammalian embryo, the uterus). For example, in the chick embryo the first muscle contractions are observable by the third day of incubation. The prenatal environment (and later the more complex postnatal environment) thus provides a range of stimulation and activity that turns out to be essential for normal anatomical, physiological, and behavioral development (see Gottlieb, 1997; Lickliter, 2005, for behavioral examples). In the example of skeletal development, the *use and exercise* of the chick embryo's leg turns out to influence gene expression, the activity of nerve cells and their processes, as well as the release of various neurochemical and endocrine secretions during prenatal development. All of these factors and their coactions are necessary resources for the normal development of the skeleton of the young bird, starting with the patterned deposition of cartilage-forming cells, the precursors of the bones (Streicher & Müller, 1992). Similar processes are undoubtedly at play in human fetal development.

The complex coactions between genes, gene products, self-stimulation, and external influences involved in avian skeletal development illustrates a basic feature of the process of development appreciated by most biologists and developmental scientists—what a gene does in the sense of what it provides development depends on the expression and activity of other genes, as well as nongenetic factors internal and external to the organism. In other words, genes are not exempt from influences at other levels of analysis and are, in fact, dependent on them for initiating and terminating a sequence of activity. The same contingency applies to the influence of any other factor or developmental resource (e.g., hormone level, neural activity, sensory experience, social coaction). The anthropologist Tim Ingold (2004) has noted that,

> If genes interact with anything, it is with other constituents of the cell, which interacts with other cells in the organism, which interacts with other organisms in the world. It is out of this multilayered process that the capacities of living beings emerge. In other words, these capacities are outcomes of the whole *developmental system* comprised by the presence of the organism, with its particular genetic and cellular composition, in its environment. (p. 217)

A common misunderstanding of the DPS approach is to conflate its "parity thesis" (the tenet that genes are not privileged sources of developmental information) with the notion that genes are relatively unimportant or play a limited role in the achievement of many phenotypic outcomes. The developmental biologist Scott Gilbert (2003), for example, has argued that because DPS places all developmental factors (e.g., genes, cells, environments) on the same informational level, it makes an error of not distinguishing between those factors that are instructive versus those that are merely permissive. Instructive information, he argues, is typically a function of genomes. To illustrate this point, Gilbert draws on the classic work of the experimental embryologist Hans Spemann (1869–1941), who transplanted the jaw-forming region of an early frog gastrula into the jaw-forming region of a salamander embryo (and vice versa). Following these experimental manipulations, the young salamanders developed frog-like jaws and the frogs developed salamander-like jaws. Gilbert argues that this remarkable morphological specificity is best explained by the genome of salamanders and frogs.

To single out genes as the source of species-specificity in this example is, however, misleading. Spemann transplanted jaw-forming *tissues*, not just genes. Moreover, the instructive power of jaw-forming tissue is itself contingent on a variety of other factors. What would be the outcome if the jaw-forming tissue was excised and transplanted at earlier or later points during embryogenesis? What if the jaw-forming region of a frog gastrula was transplanted to a different (non-jaw-forming) body region of the salamander embryos? The DPS framework emphasizes that the property of morphological specificity (as well as physiological or behavioral specificity) depends on a complex system of nested temporal and spatial factors distributed well beyond the genome. To make this claim does not mean that frog and salamander genes are unimportant; they are critical to the process of jaw formation. However, formation of these structures is a function of the process of development, not simply “information” provided by the genes. Given that development is always the result of a series of elaborate temporal and spatial coactions within and between levels that are inherently context dependent (e.g., Coen, 1999; Nijhout, 1990; Noble, 2006), DPS holds that it is not possible to meaningfully assign “instructive” control to any one variable of the developmental system.

In the next sections, we review and provide some examples supporting this developmental point of view using findings drawn from genetics, epigenetics, neuroscience, ecology, and evolutionary biology. Our overview is not intended to be thorough and is highly selective, as our examples have been screened through the authors’ own interests and with an eye to the interests and concerns of developmental scientists.

GENES, EPIGENETICS, AND DEVELOPMENT

Earlier we briefly traced the history of the gene concept in biology and noted how genes were assigned a privileged role in development throughout most of the past century. Genes were thought to direct the development of the organism and nongenetic environmental factors were deemed necessary for normal development, but only in the sense that they supported or in some way triggered the unfolding of genetic information. As a consequence, it was assumed that an understanding of the structure of the genome and the mechanisms of gene regulation were both fundamental to an understanding of development and also sufficient for this understanding (Nijhout, 1990). Moreover, genes were assumed to be the sole source of biological heredity. From this view of development, the instructions for building organisms were present in their genes and genes were also the exclusive means by which these instructions were transmitted from one generation to the next.

These traditional assumptions about genes have been seriously challenged by evidence drawn from molecular genetics, cell biology, and the rapidly growing field of epigenetics. Not to be confused with *epigenesis*, which refers to the causal coactions that bring about embryonic form, *epigenetics* is a term used by molecular and developmental biologists to refer to modifications of gene activity in the absence of any alteration to DNA sequence. More broadly, epigenetics is used to refer to developmental and hereditary influences arising from environmental effects (Ho, 2010; Meaney, 2010). The developmental biologist Conrad Waddington first described epigenetics more than 70 years ago as the branch of biology that studies the causal coactions of genes with their environment that bring the phenotype into being (Waddington, 1942; see also van Speybroeck, 2002). The genetic, molecular, and cellular details of phenotypic development were poorly understood at that point in time. Based in part on his experimental work with fruit flies, Waddington came to question the canonical view that there was a simple correspondence between genes and phenotypic characteristics and proposed that only an understanding of the coaction of genes with each other and with the internal and external environment of the organism could successfully account for phenotypic development. Waddington was advocating a new conceptual framework for the study of development and evolution, one that emphasized changes in what he termed *developmental systems*. From this view, the contribution of the genome always depends on the influence of the features of its surrounding contexts, beginning with the cytoplasmic environment provided by the mother’s egg at conception. Waddington’s efforts to integrate genetics, development, and evolution was well ahead of the prevailing consensus of his time and was motivated by what he viewed as the inability of population genetics to provide a workable model of the operation of genes in development and evolution (Hall, 2001).

Contemporary epigenetics includes the study of how patterns of gene expression are passed from one cell to its descendants, how gene expression changes during the differentiation of one cell type into another, and how environmental factors can modify how genes are expressed. Contrary to Weismann's influential doctrine of the "encapsulated" genome that dominated 20th-century biology, contemporary epigenetic research has provided abundant evidence demonstrating that genetic activity is regularly influenced by neural, behavioral, and environmental events, both in real time as well as across the course of development and across generations (see Charney, 2012; Gottlieb, 1998; Hallgrimson & Hall, 2011; Jablonka & Lamb, 2005; Jablonka & Raz, 2009; Keller, 2010; Meaney, 2010, for multiple examples). As a result of these findings, many biologists have moved away from the notion of genes as the primary or privileged cause of phenotypic characteristics to one of genes as cooperative players in a complex hierarchical web of regulation (e.g., Bateson, Chapter 6, this *Handbook,* this volume; Bateson & Gluckman, 2011; Gilbert & Epel, 2009).

For example, studies with fish, birds, and mammals have demonstrated that social stimulation can also lead to changes in brain and behavior through effects on the genome (Robinson, Fernald, & Clayton, 2008). Some of the first demonstrations of gene response to social stimuli came from studies of immediate early genes in songbirds (Clayton, 2000; Mello, Vicario, & Clayton, 1992). Immediate early genes (IEGs) are a class of genes that are rapidly expressed in response to particular forms of environmental stimulation (as opposed to genes that are expressed only when other genes induce them to contribute to protein production). For instance, in the male zebra finch, the singing of another male bird induces the expression of *egr-1* (also known as *zif-268)*, a transcription factor-encoding gene, in a region of the bird's auditory forebrain involved in hearing. Other types of social coactions have been found to effect the expression of *egr-1* in other regions of the songbird brain and can vary based on the immediate context of the experience. Expression of *egr-1* can be induced by brief social experiences (with effects seen within minutes) and can immediately enhance or suppress the transcription of other genes. Many other transcription factor-encoding genes in addition to *egr-1* have subsequently been shown to increase or decrease their expression in the male zebra finch auditory forebrain within 30 minutes of the onset of an unfamiliar male song (Replogle et al., 2008).

These types of findings have fostered a deeper appreciation across both biology and psychology of the responsiveness of gene activity to internal *and* external regulatory influences. As Nijhout (1990) pointed out some years ago,

> A single genotype can produce many different phenotypes, depending on the contingencies encountered during development. That is, the phenotype is the outcome of a complex series of developmental processes that are influenced by environmental factors as well as by genes. Different environments can have an effect on the outcome of development that is as profound as that produced by different genes. (p. 445)

Our understanding of how this is so has advanced significantly in recent years, due in large part to advances in genomics and epigenetics.

The Relational Gene

Traditional molecular genetics defined a gene as a protein coding sequence of DNA nucleotides. More specifically, a "gene" referred to a DNA sequence that is transcribed to produce a messenger RNA molecule that in turn is processed to produce a protein or a functional RNA. Advances in molecular genetics over the past several decades have called this definition into serious question and suggest it will have to be replaced with a different explanatory framework (see Keller, 2000). As we review later, we now know that genes may be coded in pieces that need to be combined, the same DNA sequence can result in different proteins due to alternative splicing, and gene regulation can span multiple genes.

Before a gene can be transcribed, a "reading frame" must be established to determine where transcription begins and ends. Some genes are known to overlap, so that depending on the state of the surrounding context, the same region of DNA can be read in different ways. For example, under one set of conditions a particular region might be used as a promoter (involved in initiating transcription), whereas under a different set of conditions that same region may be read as a coding region (part of the template used in protein synthesis, see Stotz, 2006). Thus, it is the surrounding context and system of RNA factors that in some sense brings a "gene" into being. Neumann-Held (1999) captured this dynamic quality of the genome, arguing that "there is no fundamental way by which the classical . . . gene concept could be applied to DNA segments. One focuses at the same bit of DNA, and different structures and functions can appear. One focuses on different levels of the expression process . . . and again different structures and functions appear" (p. 125).

Once a gene sequence is transcribed from DNA to mRNA, a complex series of events takes place before the mRNA exits the nucleus of the cell. The transcribed RNA contains numerous, noncoding nucleotide sequences (*introns*) that must be removed, leaving only coding sequences (*exons*), which are spliced together and used in protein synthesis. However, depending on the state of the surrounding conditions, RNA can be edited in alternative ways, bringing about different proteins. In one extraordinary case, an mRNA transcript of a single fruit fly gene can be spliced into over 38,000 different protein variants (Schmucker et al., 2000). It has been estimated that about 65% of human genes undergo alternative splicing (Leipzig, Pevsner, & Heber, 2004). To complicate matters even further, it has been found that two gene sequences are sometimes combined to create a single mRNA transcript that is used to build novel proteins, and in still other cases, exons from different mRNA transcripts can be combined in a single transcript (called *trans-splicing*; see Gerstein et al., 2007).

Even after the translation process, contextual factors continue to play an informative role in the construction of proteins. Once amino acids have been strung together, proteins must fold into a particular shape, and this shape determines its particular function. It used to be thought that proteins and their shape and function were coded by contiguous stretches of DNA arranged on the chromosome like beads on a string. The sequence of amino acids (specified by DNA) is certainly an important factor involved in protein folding, but numerous other factors have also been identified in determining protein shape. For example, study of the production of glucocorticoid receptor protein variants has revealed at least eight different versions of the glucocorticoid receptor *a* protein, each produced from the same gene and the same mRNA (Lu & Cidlowski, 2006). Importantly, this diversity is not associated with variation in nucleotide sequence, but rather is dependent on the cellular context within which the gene is activated. According to Meaney (2010),

> Both the form and the function of the protein product are defined by context. The function of the gene can only be fully understood in terms of the cellular environment in which it operates. And the cellular environment, of course, is dynamic, changing constantly as a result of signals from other cells, including those that derive from events occurring in the external environment. (p. 48)

Given the number of factors, events, and contingencies involved in synthesizing proteins, it no longer seems meaningful to say that genes code for protein synthesis. This has led some to redefine genes as *relational entities or processes that include DNA and a host of other factors involved in the production of proteins by cells* (see Gonzalez-Pardo & Alvarez, 2013; Neumann-Held, 1999; Stotz, 2006).

It should be clear from the discussion thus far that it is not possible to identify what DNA segments constitute a gene, let alone predict what proteins a particular gene might contribute to, without knowledge of the cell structure and the state of its surround. Whether a gene is transcribed, to what extent, and what kinds (and amounts) of proteins are produced are all contextually contingent, involving a host of other molecules besides DNA. As Stotz (2008) put it, "The factors that interactively regulate genomic expression are far from background conditions or supportive environment; rather, they are on a par with genetic information since they co-specify the linear sequence of the gene product together with the target DNA sequence" (p. 364).

Epigenetic Processes and Gene Regulation

Difficulties in demarcating the boundaries between gene and environment are exacerbated when we take into account how gene transcription is regulated and maintained by cellular processes over time. Genes are not self-expressive and the presence of a gene as part of an individual's genotype does not mean that it will necessarily be transcribed (Charney, 2012; Slavich & Cole, 2013). We now know that there are complex cellular processes that lie between the gene, its expression, and the functional outcome associated with the gene's product. These cellular processes, often referred to collectively as the *epigenome*, the complex biochemical regulatory system that silences or activate gene expression, began to be studied in the mid-1970s as researchers focused on how cells that have differentiated (for example, into liver cells or brain cells) remain differentiated over time and transmit their specialized state to daughter cells. In addition, effort was devoted to understanding the processes involved in X-chromosome inactivation (when one X chromosome is silenced in XX females) and gene imprinting (when genes are silenced based on parent of origin). Subsequent studies (see Martin & Zhang, 2007) detailing the processes by which genes could be expressed or not expressed led to the discovery of several cellular processes by which genetic expression could be regulated (see Figure 5.3).

To understand the regulatory mechanics of gene transcription, one must first appreciate how chromosomes

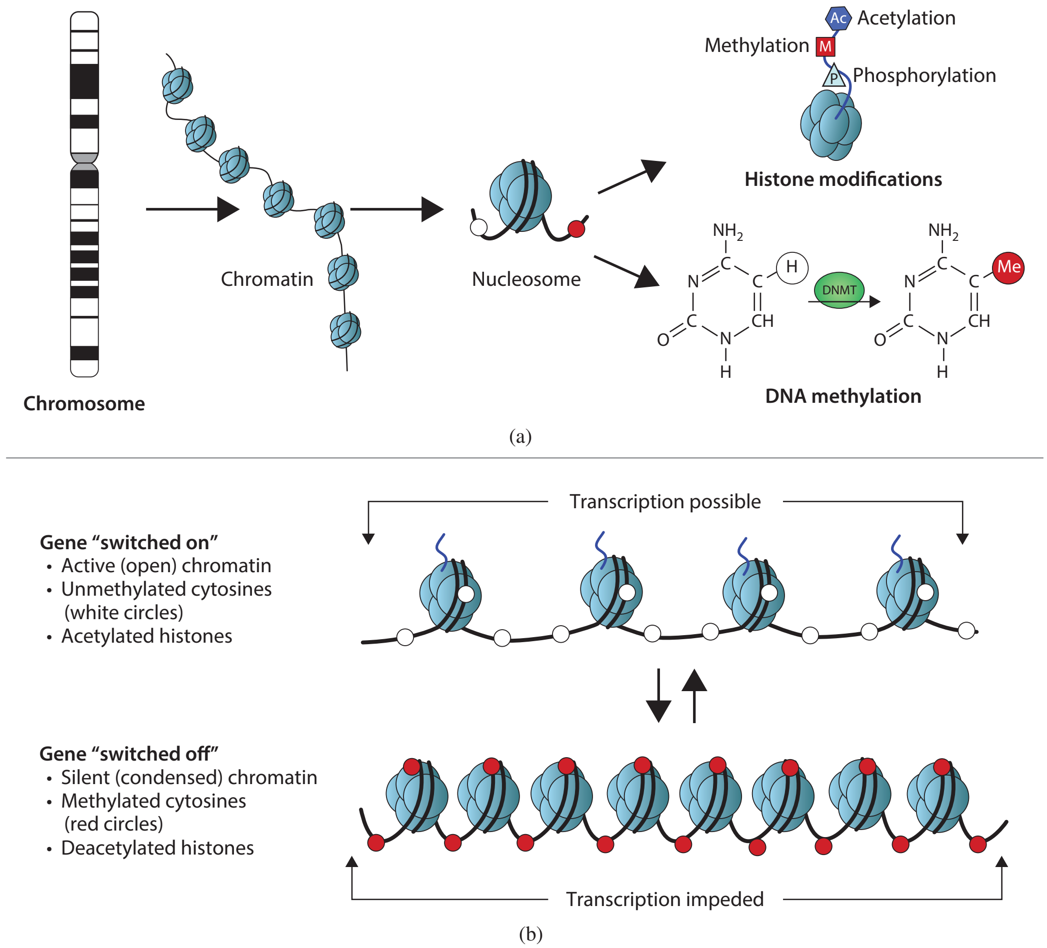

Figure 5.3 Schematic of epigenetic modifications that influence gene expression. A depiction of DNA methylation, histone modification, and their effects on gene activation. (a): Strands of DNA are wrapped around histone octamers, organized into chromatin. DNA methylationn provides a unique epigenetic signature that regulates chromatin organization and gene expression. (b): Genes are expressed when the chromatin is open (*active*) and are inactivated when the chromatin is condensed (*silent*).

Source: From *Basic Principles of Genetics*, by P. Luong, 2009. Retrieved from http://cnx.org/content/m26565/1.1/

are packaged within cell nuclei. In humans, the 23 pairs of nuclear chromosomes span approximately 2 meters of DNA (Sultan & Day, 2011). As a result, nuclear DNA does not float freely in the nucleus but is compacted and entwined around core histone proteins that are densely packed together in structures called *chromatin*. More specifically, negatively charged nuclear DNA is wrapped around (and attracted to) positively charged histone proteins in a series of beadlike structures (nucleosomes). For transcription factors to gain access to DNA to initiate gene transcription, chromatin must be chemically altered to loosen the connection between DNA and histone proteins. This alteration involves the addition or removal of molecules (e.g., acetyl or methyl groups) via enzymes on the histone proteins, thereby altering the overall charge (see Meaney, 2010). Depending on how this charge is altered, the connection between DNA and histone proteins can be loosened or strengthened, thereby making DNA regions more or less accessible for transcription (Figure 5.3).

Space limitations preclude a review of all of the known processes, so in what follows, we focus on *DNA methylation*, the most studied of the chromatin modification processes. Methylation takes place when a methyl group attaches to the nucleotide base cytosine. Methylated cytosine attracts methyl-binding proteins that act as a physical barrier to the gene. The presence of methylated cytosine does not influence the structure of a protein if the gene is transcribed, but it does influence the likelihood that a gene will be transcribed (Jablonka & Lamb, 2005). Methylation patterns (and other chromatin systems) are reproduced in daughter cells during the replication of DNA, and thus appear to play an important role in differentiation and cellular memory. Specific cell types acquire their precise and well-defined functions through the process of differentiation; this process is largely directed through the process of DNA methylation, resulting in the expression of some genes and the silencing of others, and leading to the formation of differentiated neurons, blood cells, liver cells, and so on, which are identical in terms of their DNA sequences but differ in their epigenetic profiles (Gudsnuk & Champagne, 2011).

Environmentally Induced Epigenetic Effects on Development

Epigenetic processes are known to be responsive to environmental input, and these responses can bring about significant morphological differences, even in genetically identical individuals. As a case in point, genetically identical bee larvae differentially fed relatively high amounts of royal jelly develop into the more complex and fertile queen bees rather than sterile and less sophisticated worker bees. Kucharski, Maleszka, Foret, and Maleszka (2008) provide evidence that royal jelly yields its effect by influencing methylation patterns. For example, they were able to create adult bees with queen characteristics in the absence of royal jelly by silencing an enzyme that methylates a single gene, *dynactin p62* in the newly hatched larvae.

Initially, it was thought that plasticity of epigenetic modifications was limited to very early embryological development; however, this assumption has been challenged by evidence indicating environmentally induced epigenetic variation across the life span (Champagne, 2010; Slavich & Cole, 2013). For example, Fraga and colleagues (2005) found that significant differences in DNA methylation and histone acetylation patterns among monozygotic human twin pairs take shape over the first several decades of life. Interestingly, twins who spent less time together during their lives or who had different medical histories showed the greatest differences in their methylation and histone profiles. Further, the older the twin pair, the more different they were when compared to younger twins. For example, a 50-year-old pair of twins had 4 times as many differently expressed genes as did a 3-year-old pair (Fraga et al., 2005). Research has shown that divergent methylation patterns between twin pairs can be found at birth, indicating the importance of prenatal factors to gene activation (Ollikainen et al., 2010).

Advances in neuroscience and psychobiology have shown that epigenetic modifications play important roles in learning, memory, and cognition (see Graff & Mansuy, 2008; Sultan & Day, 2011; Sweatt, 2010, for reviews). One of the first suggestions that epigenetic processes are involved in learning and memory came from a study examining histone acetylation in the insular cortex, a brain region involved in novel taste learning (Swank & Sweatt, 2001). Subsequent research has also addressed the importance of histone acetylation and DNA methylation in object recognition and spatial and contextual memory. For instance, experiments with rodents have shown that the formation and recall of contextual fear memories (the association between a specific environment and an aversive stimulus) can be improved or impaired by drugs that act on enzymes involved in the methylation of histones (Levenson & Sweatt, 2005).

In a groundbreaking series of studies with rodents, Meaney and colleagues (see Champagne, 2010; Meaney, 2010; Zhang & Meaney, 2010, for reviews) have provided detailed evidence that the social environment during early development can affect physiological and behavioral response to stress in adulthood. Meaney and colleagues found that low levels of maternal licking and grooming during early postnatal development results in rat pups that grow up to show enhanced fearfulness and an increased hypothalamic-pituitary-adrenal response to stressful events when compared to pups that receive high levels of maternal licking and grooming. These differences are maintained in part by different levels of glucocorticoid receptors in the hippocampus. Weaver and colleagues (Weaver, Diorio, Seckl, Szyf, & Meaney, 2004) went on to identify more than 900 genes in the hippocampus that appear to be regulated by levels of maternal care. Using microarrays to monitor changes in hippocampal gene expression, they found 253 transcripts that were upregulated and 50 transcripts that were downregulated in rat pups of high versus low LG mothers. Following both drug manipulations and cross-fostering, a related study found that these epigenetic changes emerged during the first week following birth and regulated expression of these genes over the course of the life span (Weaver, Cervoni, et al., 2004).

Evidence has also linked epigenetic processes to stressful events in the prenatal environment. For example, Mueller and Bale (2008) found that adult male rats born to mothers who had experienced gestational stress showed changes in the expression of corticotropin-releasing factor (CRF) and glucocorticoid receptor genes and increased HPA-axis responsivity. In particular, prenatal stress exposure resulted in significantly reduced methylation in the CRF gene in both the hypothalamus and amygdala of adults.

In humans, newborns of mothers who experienced depression during the third trimester of pregnancy showed increased methylation of the glucorticoid receptor gene when compared to infants born to symptom-free women. This increase in methylation was positively correlated with salivary cortisol levels in response to stress at 3 months following birth (Oberlander et al., 2008). Methylation of this same gene in adult clinical (depressive and bipolar) samples has also been positively correlated with amount and severity of childhood abuse (Perroud et al., 2011). A study also reported a relation between depression in pregnant women and methylation of the serotonin transporter gene promoter in their newborns (Devlin, Brain, Austin, & Oberlander, 2010), providing further evidence that human gene activity is not impervious to environmental influences, but rather is a regulated and reactive component in the cellular system that is itself a regulated and reactive component in the individual's larger developmental system.

The implications of epigenetic processes for biological and psychological development are as yet not fully known, but clearly are significant (Gonzalez-Pardo & Alvarez, 2013; Masterpasqua, 2009; van Ijzedoorn, Bakermans-Kranenburg, & Ebstein, 2011). Epigenetic processes are increasingly recognized as a key means by which early life events can have long-lasting effects on neurobiology and behavior (Roth, 2012), and emerging evidence suggests that epigenetic factors may underlie various forms of disease and psychopathology (e.g., Graff, Kim, Dobbin, & Tsai, 2011; Isles & Wilkinson, 2008; Stuffrein-Roberts, Joyce, & Kennedy, 2008). For example, Cole and colleagues (Cole et al., 2007) identified 209 genes that were differentially expressed in circulating leukocytes from individuals reporting high versus low levels of subjective social isolation (loneliness), including genes involved in immune activation, transcription control, and cell proliferation. Impaired transcription of glucocorticoid response genes and increased proinflammatory transcription control pathways were identified in socially isolated individuals, indicating genome-wide activity can be altered in response to perceived levels of social connection. There is also growing evidence that epigenetic processes have a role in several psychiatric disorders, including depression and schizophrenia. For example, reductions in the expression of *reelin* and GAD1 genes, known to be involved in synaptic function and memory, in the hippocampus and cortex of schizophrenic patients have been consistently reported in postmortem studies (Costa et al., 2002; Grayson, Chen, Dong, Kundakovic, & Guidotti, 2009).

Transgenerational Epigenetic Inheritance

Epigenetic changes are known to be at play across the life span (see Slavich & Cole, 2013; Sweatt, 2010) and growing evidence also indicates that changes in response to an environmental event in one generation may in some cases be transferred to subsequent generations (Harper, 2005, 2010; Jablonka & Lamb, 2005). Most of the known transgenerational effects are associated with altered diet, toxin exposure, or temperature changes, although there have been reports of some transgenerational effects stemming from altered sensory conditions and behavioral patterns. In most cases the specific process responsible for the trangenerational effect remains unknown, but in some cases, the effects have been attributed to altered methylation patterns.

One of the first demonstrations of transgenerational epigenetic inheritance came from the study of coat color variations associated with the A^{vy} allele in *Agouti* mice (Morgan, Sutherland, Martin, & Whitelaw, 1999; Waterland & Jirtle, 2003). The expression of this allele typically results in a yellow coat color and a strong tendency toward obesity and diabetes in this strain of mice. However, when *Agouti* females are fed a diet high in folic acid and vitamin B12 (both of which are high in methyl donors) before and during pregnancy, their methyl-rich diet effectively silences the *Agouti* allele in their developing embryos. As a result, females fed on the altered diet give birth to mostly thin, brown furred pups, whereas control mice not fed the altered diet give birth to pups that are mostly fat and yellow furred (and as adults have higher susceptibility to obesity, diabetes, and cancer). The methyl supplements that the mouse embryo received from the mother during prenatal development modified the embryo's epigenome, effectively preventing the *Agouti* gene from being expressed. In contrast, embryos whose mothers received no methyl supplementation showed no such silencing effects. Importantly, these results were observed in genetically identical mice.

There are numerous additional findings documenting transgenerational developmental effects of diet. For example, Zamenhoff and colleagues (reviewed in Zamenhoff & van Marthens, 1978) found that prenatal exposure to protein-deficient diets in rats is associated with stunted growth patterns of offspring, even when the offspring are themselves raised on standard diets. Zambrano et al. (2005) have shown that such transgenerational effects of protein restriction on growth in rats vary according to sex and the timing of the dietary restriction (during pregnancy and/or lactation). Although the specific processes remain unclear, these observations clearly indicate that what happens in one generation can have lasting, systematic consequences on offspring in subsequent generations.

Research has also begun to address possible transgenerational effects of altered diets in humans. A study by Pembrey et al. (2006), using the Avon Longitudinal Study of Parents and Children, explored the effects of food supply on offspring and grandchild mortality risk ratios. They found that the paternal grandfather's food supply (based on estimates from local harvest and food price records) was linked to the mortality risk ratios of grandsons, whereas the paternal grandmother's food supply was linked with granddaughters' mortality risk ratios. Importantly, these transgenerational effects were only seen when low food supply exposure occurred before the prepubertal periods of both grandparents, or during the fetal development of the grandmother. Such findings suggest that the environment can induce epigenetic changes in the sex chromosomes, which are then passed on to offspring (and in turn, their offspring). In other words, sex chromosomes can apparently be marked across generations according to the parent of origin, suggesting a process for the intergenerational transmission of modifications of gene expression via the gametes. The understanding of the ways and means of epigenetic variation and inheritance is still in its infancy and additional longitudinal analyses and research are needed to confirm *germline dependent* epigenetic inheritance in humans. Applying a multigenerational perspective will undoubtedly add to an understanding of the processes by which the consequences of adverse experiences do not remain limited to the individual experiencing the adversity, but may also be transmitted to their nonexposed children, grandchildren, and beyond (see Harper, 2005).

A dramatic example of how toxin exposure can lead to trangenerational effects has been documented by Anway, Cupp, Uzumcu, and Skinner (2005), who exposed pregnant female rats to the pesticide vinclozolin (widely used on vineyard grapes and known to be an androgen antagonist) during the period of gestation when their embryos were undergoing gonadal differentiation. Male offspring of these mothers showed decreased spermatogenic capacity and decreased male fertility. These effects were found to persist across four generations, with no further vinclozolin exposure. These changes were not associated with any changes in DNA sequence, but rather were associated with DNA methylation at specific genes involved in spermatogenesis. Further research found that in each generation males whose ancestor had been exposed to the toxin showed an increase in cancer, prostate and kidney disease. When tested in a partner preferences paradigm, females that were three generations removed from the one-time toxin exposure discriminated and preferred males that did not have a history of toxin exposure; males did not exhibit such a preference when tested with exposed females (Crews et al., 2007). Modification of DNA methylation by toxin exposure thus altered mate choice not only in the exposed generation, but also in several generations removed from the one time exposure.

Taken together, these various results from both animal and human studies support the notion that the scope of what constitutes inheritance across generations includes factors above the level of genes and these factors are certainly not complete at the moment of fertilization. All organisms depend on the transgenerational presence of a large number of highly specific and essential developmental resources, including temperature, photoperiod, particular types and amounts of foods, and parental care. In other words, organisms inherit *resources* for development, not traits or characteristics. This insight is foundational to a fully realized psychobiological systems view of development. What is inherited across generations is a structured developmental system that includes components internal (e.g., genes, cytoplasm, cells) and external (e.g., diet, light cycles, conspecifics) to the organism. DPS recognizes that the recurrence from generation to generation of the specific resources and coactions that make up an organism's physical, biological, and social environments are as causally informative to the development and transmission of phenotypic characters as are genes contained within this system. A central concern of DPS is thus the identification of the developmental resources that allow for the repeated assembly of phenotypic characteristics, both within and across generations (see Caporeal, 2003; J. Lerner et al., 2012; Overton, 2010, Chapter 2, this *Handbook,* this volume, for further discussions of system resources).

The relational and dynamic nature of the genome, coupled with a growing appreciation of the pervasiveness of epigenetic regulation of gene expression throughout the life span, clearly has significant implications for psychology (Gonzalez-Pardo & Alvarez, 2013), developmental science (Gottlieb, 1998; Meaney, 2010), and in particular, the assumptions, methods, and goals of quantitative behavioral genetics (Charney, 2012).

Implications for the Methods and Assumptions of Quantitative Behavioral Genetics

Quantitative behavioral genetics has long been organized around a concern with determining how much differences in heredity (i.e., genes) and differences in environment relate to differences in behavior (e.g., Plomin, 1990). Research in quantitative behavioral genetics has involved two basic assumptions: first, with a combination of genetic and behavioral methods, the contribution of genetic and environmental factors to behavioral characteristics can be intelligibly partitioned; second, it is possible to identify specific genes that determine phenotypic characteristics, including psychological disorders (e.g., Plomin, Owen, & McGuffin, 1994). Starting with a conceptual and statistical framework provided by Francis Galton in the last decades of the 19th century (Galton, 1874), quantitative behavior geneticists have employed a range of research designs, including animal breeding studies and kinship studies, in their attempts to quantify the relative contributions of genotypic and environmental differences to the total phenotypic variation of a particular characteristic in a particular population.

This emphasis on partitioning the causal determinants involved in development has a long and storied history over the course of the past century (see Keller, 2010; Moore, 2013, for recent overviews) and continues to be evident in contemporary behavioral genetics (e.g., Plomin, DeFries, Knopik, & Neiderhiser, 2013), despite the growing body of evidence reviewed above demonstrating the fundamentally fused interdependence of genes and environment. This emphasis on partitioning has directed the focus, methods, and assumptions of the field, many of which have been called into question by advances across the biological sciences.

Animal Breeding Studies

One of the earliest and most widely employed methods to estimate the relative contributions of heredity and environment to phenotypic characteristics involved breeding studies with animals. The logic of animal breeding studies is seemingly straightforward: If a given characteristic can be selectively bred for across generations, then that characteristic must be determined by genetic factors. This assumption has been widely applied in livestock breeding programs since the 19th century, where a wide range of phenotypic characteristics associated with appearance, efficiency, and productivity are "artificially selected" through selective breeding across generations. This assumption has also been evident in scientific concerns with behavioral characteristics, including perceptual and cognitive skills. For example, beginning in the 1920s the psychologist Robert Tryon engineered two strains of rats that diverged in their ability to solve various mazes (reviewed in Tryon, 1940). He selectively bred together rats that showed the fewest errors in solving complex mazes, while also interbreeding rats that showed the most errors, to create strains of "maze bright" and "maze dull" rats. In the following decades numerous researchers created similar strains of rats and mice using selective breeding for various maze-solving measures (see Wahlsten, 1972). Because the environments between strains were kept relatively constant across generations (and between strains) in these designs, the differences in performance in the maze by different strains were attributed to heredity. More generally, this approach assumed that differences between animals of the same inbred strain are caused by environmental factors and differences between animals of different strains are caused by genetic factors (Belknap et al., 1998). This assumption can be valid only if the effects of genes and environment are strictly additive (Gottlieb et al., 2006).

The strictly genetic basis of strain differences was eventually challenged as a growing number of studies demonstrated the context dependent nature of observed strain differences. For example, Cooper and Zubek (1958) bred for bright and dull rats as Tyron had done decades earlier, and once the strain difference was established over many generations, they transferred some of the offspring from the "bright" and "dull" lines to either an enriched or impoverished raising environment. When these transferred rats were later tested for their maze-solving abilities, they found no differences between the two strains when both were raised in the impoverished or in the enriched condition. Similar elimination of strain differences following environmental alterations were subsequently reported by Hood and Cairns (1989), who bred mice raised in social isolation following weaning for low or high frequency of attacking intruders. Once the strain difference in aggressive behavior was established over multiple generations, they raised some offspring in social groups (rather than in isolation) following weaning and found that the observed strain differences in aggressive behavior disappeared. Hood (2005) went on to show that these strain differences could be eliminated by social raising even after 39 generations of selective breeding for aggressive behavior.

Because each highly inbred strain is genetically different from other strains, and because each member of a specific strain has nearly identical genes, it is possible to test samples of different strains across a range of different environmental conditions and establish a graphical *norm of reaction* (NoR, see Sarkar, 1998). Such graphs are intended to represent the phenotype of organisms of a particular genotype as a function of their environment. More formally, the norm of reaction is defined as the set of ontogenetic trajectories produced by a genotype in response to naturally occurring or experimentally imposed environmental variation (Schlichting & Pigliucci, 1998). Establishing a norm of reaction is not usually possible for organisms that have not been highly inbred, limiting its broad applicability, but in some cases a NoR can be determined as an average across genetically different individuals if random assignment to condition is employed (Gottlieb et al., 2006).

Although NoRs can be used to help identify environmental and strain-related effects on the development of phenotypic characteristics, we argue that it is doubtful that such studies can successfully identify strictly or solely genetic effects. This is the case because inbred strains differ not only in their genotypes but also in their behavioral, physiological, and anatomical phenotypes, and as Gottlieb (2003, p. 339) cautioned, "much of what passes for gene-environment interaction is actually organism-environment interaction." In keeping with this insight, we argue that what is actually measured in NoR studies is how different phenotypes (strains) respond to different environmental manipulations. Phenotypes should not be treated as a proxy for underlying genotypes, because phenotypes themselves can play a causal role in observed strain differences.

Researchers engaged in this type of work are well aware of how some phenotypic factors (for example, maternal behaviors) can contribute to strain related differences and they typically take measures (for example, cross-fostering) to control for such possible confounds. However, such postnatal manipulations do not control for potential prenatal factors contributing to observed strain differences. For example, egg yolk factors have been found to contribute to phenotypic differences between broiler and layer chicken strains (Ho, Reed, & Burggren, 2011). When the yolk environments between these two strains were switched so that broiler chicken embryos developed in layer chicken yolk environments (and vice-versa), the manipulated embryos showed significant differences in body mass, heart rate, and general rates of development when compared to controls.

In rodents, pregnant females from different strains can differ in body size, litter size, gestation period, amount of food intake, activity levels, and/or hormone levels, all of which could potentially contribute to strain-related differences in physical and behavioral development. To illustrate this point, consider the work of McLaren and Michie (1958), who conducted a study on anatomical development in mice using an embryo transfer procedure they helped pioneer. They were interested in explaining why some strains of mice tend to have mainly five lumbar vertebrae (C3H/Bi) versus six lumbar vertebrae (C57BL/How). When they implanted fertilized eggs between females of these two strains, they found the number of lumbar vertebrae in female offspring tended to match the foster mother's strain rather than the genetic mother's strain, indicating a uterine effect on number of lumbar vertebrae. This remarkable study was among the first to suggest that a strain-specific phenotype (in this case, the uterine environment) contributes to the realization of strain-specific characteristics.

In related research, Cowley, Pomp, Atchley, Eisen, and Hawkins-Brown (1989) transferred mouse embryos between a smaller sized strain (SWR) and larger strain (C3H). To eliminate postnatal effects, all transferred embryos were raised after birth by isogeneic C6BF1 females. They found that SWR mice gestated in C3H females showed significantly heavier body weights (and had longer tails) than untransferred SWR embryos. Similar effects on body weight were found by transferring embryos between different strains of deer mice (Roth & Klein, 1986). Francis, Szegda, Campbell, Martin, and Insel (2003) reported an additional prenatal effect on *behavior* in mice strains using embryo transfer procedures. They transferred mice of the B6 strain (C57BL/6J) into foster dams of a different strain (BALB). They found that B6 mice that developed in BALB uteri and were raised by BALB dams behaved liked BALB mice in a variety of behavioral measures of exploration (open-field tests), anxiety-related behaviors (plus-maze performance), and water maze behaviors. However, the effect could not be attributed to only prenatal factors alone, as neither B6 mice embryos that only developed prenatally in BALB mice and were then raised by B6 dams nor B6 mouse pups that were only raised by BALB dams after birth showed the BALB pattern of behavior. In the latter group, the B6 pups (raised by BALB dams after birth) were transferred to B6 dams for gestation, so they did not receive a prenatal manipulation. As the authors suggest, these results indicate that some of the observable phenotypic differences between mouse strains must be attributed to aspects of both prenatal *and* early postnatal environments.

Taken together, the findings on prenatal and postnatal maternal effects on strain differences call into question whether animal breeding studies can actually tease apart genetic contributions to development, particularly in light of the complex epigenetic processes known to be at play during early development. As Gottlieb (1991) noted, the norm of reaction is “essentially non-predictive because . . . each new environment is expected to have a different influence on developmental outcomes that cannot be stated in advance of actual empirical investigation” (p. 5). This is not to say that such studies lack value. Comparing the development of different strains across a range of prenatal and postnatal environments can help identify and define the complex network of factors involved in behavioral and morphological development. However, if the goal of such research is to identify phenotypic effects associated with genotypes independent of nongenetic factors, this strategy is bound to fail.

Kinship Studies

The primary method of quantitative behavioral genetics has been some form of the kinship study, the goal of which is to determine whether individual differences in characteristics are associated with degrees of relatedness. The simplest form of these studies compares how offspring resemble other biological relatives of varying degrees (parents, siblings, cousins, half-siblings). The logic of this type of study is relatively straightforward: If a characteristic is caused by hereditary factors, then we should see a greater concentration of the trait or characteristic among members of the same family, proportional to their degree of genetic relatedness (Joseph, 2010). However, shared environmental factors often confound these studies, so to better estimate genetic influences behavior geneticists typically employ the adoption method, in which behavioral measures of adopted individuals are compared to measures obtained from their biological and adoptive parents. Genetic effects are inferred when adopted people are more similar to their biological than to their adoptive relatives. Even more commonly, behavior geneticists rely on twin studies in which correlations (or concordance rates) between monozygotic and fraternal twins are compared. Genetic influences on traits or characteristics are then inferred when monozygotic (MZ) twins are more similar than are dizygotic (DZ) twins.

Francis Galton pioneered the examination of the relative roles of nature and nurture in the late 19th century by the use of human twin studies. Using surveys he provided parents, he found that twins who were similar at birth (i.e., by nature) tended to remain similar despite changing circumstances, whereas twins dissimilar by nature tended to remain dissimilar despite similar environments (Burbridge, 2001). Based on the results of his surveys, Galton concluded that nature was far more important than nurture in the development of human characteristics. Galton’s research and his conclusions were fundamentally flawed in hindsight (he did not distinguish between monozygotic and dizygotic twins, nor did he consider any role of prenatal factors), but the notion that the study of twins could serve as a valid method to distinguish between the effects of heredity and environment gained strength in the early decades of the 20th century and continues to stand as the primary means by which genetic influences on human characteristics are inferred by behavior geneticists (e.g., Bouchard, 2004; Lang, Livesley, & Vemon, 2006; Plomin, 1990).

However, like family studies more generally, adoption and twin studies are challenged by a number of confounding variables and questionable assumptions (see Joseph, 2006; Moore, 2013). For example, adoption studies deviate from a random-effects design as a result of selective placement of children into types of homes that tend to fall within a restricted range of intelligence levels, education, and other sociocultural variables (Richardson & Norgate, 2006). In studies of twins reared apart, not only are their environments not entirely dissimilar (i.e., they grow up in similar times and locations), the twins are often aware of one another and have had long-lasting relationships (Charney, 2008).

More problematic are the underlying assumptions that provide the foundation for comparisons across individuals. For example, the assumption that the adoption method can effectively separate heredity and environment presumes that the prenatal environment has no role in individual differences and that the uterine environment is essentially the same across all women (Gottlieb et al., 2006). This is certainly not the case. The state of the mother’s health, diet, stress level, and teratogenic exposure are widely known to have a major effect on the neural and physiological development of her fetus (Bateson & Gluckman, 2011). Thus, monozygotic twins separated at birth and reared in different households could both show low IQ because of prenatal alcohol exposure or prenatal malnutrition. Moreover, monozygotic twins who share a chorion and placenta are known to be more similar on various physical and psychological measures than are monozygotic twins that do not share chorions and placenta (Phelps, Davis, & Schartz, 1997; Prescott, Johnson, & McArdle, 1999), suggesting that some identical twins may be more similar than other twin sets as a result of shared prenatal environments.

Further, in most twin studies it is assumed that the postnatal environments of monozygotic twins are equivalent to the postnatal environments encountered by fraternal twins (the "equal environments assumption," EEA). Rutter (2006) noted that to infer that genetic factors explain MZ versus DZ twin differences, "one has to assume that all the contrast between MZ and DZ pairs can be wholly attributable to genes because the environmental variation within MZ pairs should be much the same as within DZ pairs" (p. 41). Surprisingly little research has been conducted to validate this foundational assumption, and what little support there is could just as easily be used to argue against the notion of the EEA (Beckworth & Morris, 2008; Joseph, 1998, 2006; Richardson & Norgate, 2005). Research has shown that in childhood identical twins are more commonly dressed alike, share the same playmates, more often share bedrooms, and are treated more similarly by others (Scarr, 1968). In adolescence, identical twins spend more time together and have more friends in common than fraternal twins, and when these social variables were included in a multivariate analysis, apparent genetic effects were significantly reduced or eliminated (Horwitz, Videon, Schmitz, & Davis, 2003). The paucity of reliable supporting evidence and known violations to the EEA led Joseph (2010) to conclude that there is "little reason to accept that the twin method has measured anything other than the more similar treatment, greater environmental similarity, and closer psychological association experienced by MZ versus same sex DZ pairs" (p. 581).

Given the range of problems and confounds associated with kinship studies, we argue that it is difficult to interpret their results. Although relatives frequently have characteristics in patterns that would be predicted by genetic theories, these patterns also match predictions made by theories of nongenetic causation as well. In fact, all of the patterns of correlations used to support a genetic argument (that characteristics run in families, that monozygotic twins are more similar than dizygotic twins, that monozygotic twins separated at birth are similar) can be explained just as readily from an environmentalist perspective. Of course, the environmentalist position, like the genetic point of view, fails to appreciate the fundamental interpenetration of genes and environment elegantly demonstrated by findings from contemporary epigenetic research.

Heritability Estimates

Since its inception, the goal of behavioral genetics has been to measure the extent to which variation in a phenotype in a population can be accounted for by genetic variations (Gottlieb, 1995; Gottlieb et al., 2006). These "heritability" estimates are constructed on the basis of *additive models* that assume genetic and environmental effects on any given phenotype are separate and statistically independent. Researchers working in this tradition generate heritability estimates ranging from 0% to 100%, and assume that as the percentage increases towards 100%, the importance of genetic influences on the characteristic in question correspondingly increases. In humans, the most common method for heritability studies is to compare the similarity of identical twins with the similarity of fraternal twins. The roots of the heritability statistic date back to the efforts of the geneticists Ronald Fisher and Sewall Wright, who in the early decades of the 20th century sought to make biometric models of continuous variation in characteristics in populations congruent with Mendelian genetic principles (see Feldman, 1992; Griffiths & Tabery, 2007). Fisher assumed that continuous traits in a population were influenced by a large number of segregating genes, each with miniscule but additive effects. When summed, Fisher showed that these genetic contributions could bring about a normal distribution of that phenotype in the population. In 1918, Fisher introduced the analysis of variance (ANOVA) to statistically separate the phenotypic variability of a population into genotypic and environmental components, and their interaction.

According to an ANOVA, the total amount of phenotypic variability in population for a given trait or characteristic (V_P) can attributed to the additive contributions of genetic variation in that characteristic (V_G), environmental variation (V_E), and their interaction ($V_{G\times E}$), which results in the following equation:

$$V_P = V_G + V_E + V_{G\times E}$$

However, V_G can be subdivided into variation attributable to the additive effects ("breeding value") of genes (V_A), which are thought to be responsible for the relations between parents and offspring, as well as dominance effects (V_D), and interactive (epistatic) genetic effects (V_I) resulting in the following equation:

$$V_P = (V_A + V_D + V_I) + V_E + V_{G\times E}$$

Broad-sense *heritability* (H^2) refers to the proportion of total variance of a characteristic in a population attributed to all genetic components (V_G/V_P). Most quantitative behavioral geneticists are interested in narrow-sense *heritability* (h^2), which refers to the total proportion of variance in a characteristic in a population statistically attributed to additive genetic variance ($V_A + V_P$). This estimate is thought to be useful in predicting offspring outcomes or how well a trait or characteristic might respond to selective pressure in certain environments (Feldman, 1992; Wade, 1992).

The statistical problems with calculating heritability have been discussed at length elsewhere (see Bailey, 1997; Charney, 2012; Lewontin, 1974; Vreeke, 2000; Wahlsten, 1994; see also Bateson, Chapter 6, this *Handbook*, this volume), but suffice it to say that in calculating narrow heritability, quantitative behavioral geneticists make an unwarranted assumption: they assume a completely additive model, so the values of V_D, V_I, and $V_{G \times E}$ are treated as nonexistent and set at zero (Stoltenberg & Hirsch, 1998). As we have reviewed earlier, this assumption is no longer biologically plausible and calls into question any meaningful interpretation of h^2. Further, the epigenetic research we reviewed earlier challenges the statistical assumption that variation in characteristics can be fully explained by two sources of influence (genetic and nongenetic) and their coaction (see Charney, 2012; Molenaar, Boomsma, & Dolan, 1993; Moore, 2013; Wahlsten, 1994, for further discussion). Given that we now know that much of what genes do is to react to signals from the internal and external environment, the idea of dividing developmental influences into genetic and environmental factors no longer seems biologically possible (Gottlieb, 2003).

Molenaar et al. (1993) emphasize that there exists a third (nonlinear, epigenetic) source of phenotypic variation (historically called "developmental noise") in biometric models independent of genetic and environmental factors. Molenaar et al. (1993) review a wealth of evidence for this third factor, beginning with Sewall Wright's (an originator of the heritability statistic) analysis of fur coloration in guinea pigs over 90 years ago. Wright (1920) found that this third source of variability accounted for 91% of the total variation observed. Molenaar (2007) has argued that the existence of this epigenetic factor challenges some fundamental assumptions of modern quantitative genetic analyses. In traditional biometric analyses it is assumed that the structure of variation at the population level is equivalent to the structure of variation at the individual level. To make this claim requires that one assume that that (a) all individuals (or units) in a population (or ensemble) are homogenous (i.e., obey the same dynamic processes), and (b) that the process under investigation is stationary (not time-dependent). Molenaar (2007; Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume) points out that neither of these assumptions is tenable in the study of developing individuals. Obviously, the latter assumption is violated when studying psychological processes (like learning or development) that vary across time. Moreover, the existence of nonlinear, epigenetic sources of variation challenges the homogeneity assumption. For example, in a study of EEG responses in dizygotic twin pairs in a visual discrimination task, Molenaar found substantial heterogeneity (subject-specificity) in EEG responses over time (Molenaar, Smit, Boomsma, & Nesselroade, 2012).

Besides its statistical assumptions, there are additional issues with the meaning and usefulness of heritability. Most notably, high heritability of a characteristic does not indicate that genetic factors are more important than environmental factors in the development of a characteristic. Likewise, low heritability of a characteristic does not indicate that genetic factors are less important (see Moore, 2013). A simple thought experiment serves to illustrate this point. Imagine a heritability analysis was conducted on Cooper and Zubek's (1958) maze bright and dull rats raised in only the standard laboratory environment. Because genetic background would reliably predict maze-solving scores and because there was no measured environmental variation, heritability would be very high. Now imagine we calculate the heritability of maze-solving skills in only the enriched condition. Because genetic background would not predict differences in maze solving, heritability would be zero. This example not only illustrates that heritability does not speak to the causes of characteristics, it also shows that the values (high, moderate, or low) of heritability depend on and are limited to the populations studied and the contexts in which they are calculated. In other words, any heritability estimate is specific and limited to a particular population at a particular time. Further, for most complex characteristics we can assume that there are additional environmental factors at play that are not measured (or controlled for) in standard heritability estimates. As Moore (2008) put it,

> Generalizing the results of a heritability study from a population of research participants to a much broader population requires confidence that the variation in developmental environments experienced by the broader population is no different than the variation in developmental environments experienced

> by the research participants. But, because we typically do not know which factors play important roles in the development of a particular characteristic, it is not possible to know if the variation in those factors is the same across the broader population as it was in the original population of research participants. (p. 338)

To make matters even more challenging, in human populations we cannot experimentally control either environments or levels of genetic variation, thereby rendering the interpretation of heritability estimates even more suspect.

Although heritability estimates can be useful in making some types of predictions (*does* like beget like) under constant conditions, it is important to emphasize that the statistic does not inform us about the causes or the relative importance of the various causes of characteristics (*how* like begets like). Some quantitative behavior geneticists endorse this point. Turkheimer (2011, p. 236), for example, proposes that behavioral genetics has "failed to offer much in the way of etiological insight into complex behaviors." To address this situation, some quantitative behavioral geneticists (e.g., Plomin, 2013; Plomin, Haworth, & Davis, 2009; but see Turkheimer, 2012) have proposed that advances in molecular genetic technologies will finally allow researchers to correlate specific genetic markers with specific phenotypes, thereby establishing the "missing link" between quantitative and molecular genetics.

Molecular Genetics and Behavior

In the past several decades there has been a rapid rise in studies aimed at correlating genetic variants with population trait or characteristic variation, due in large part to advances in technology that are becoming both more powerful and less expensive. The most common genetic variants tested are polymorphic regions of a gene, including differences in single nucleotide bases at specific loci. Millions of these *single nucleotide polymorphisms* (SNPs) have been identified. SNPs can be found in the coding or regulatory region of genes, making it possible to associate characteristics with actual functional genetic variants. However, in many cases SNPs serve as indirect markers that identify a nearby functional genetic variant that may contribute to a characteristic (Gray, Campbell, & Spurr, 2000). Researchers have turned to using genome-wide association studies (GWAS), in which hundreds of thousands of SNPs are examined from many thousands of participants. Wahlsten (2012, p. 479) claims that "the power of the method is so great that, if there is a genetic variant in a population with a noteworthy influence on some psychological or neural function, GWAS can find it."

Despite the power of these new technologies, there is growing concern that these studies may fail to deliver on the promise of finally linking quantitative behavioral and molecular genetics. For example, when associations between SNPs and characteristics are found, the effect size tends to be extremely low. As one case in point, one SNP thought to be involved in height accounted for only 0.3% of variation in height (Weedon et al., 2007). Even when combined with other studies that looked at a total of 40 SNPs, the combined effect explained about 5% of height variance (Visscher, 2008). These small effects were surprising given that height is consistently one of the most highly heritable characteristics by conventional methods of analysis. Because similar small effects have been documented across a range of other phenotypes with high heritability, there has been a growing interest in explaining this so-called missing heritability problem (Joseph, 2012; Maher, 2008; Manolio et al., 2009; Plomin, 2013).

Perhaps more problematic, however, is the failure to replicate reported findings. For instance, Caspi et al. (2003) reported evidence for an association between depression and two alleles ("short" versus "long") located on the serotonin transporter (5-HTT) gene. They found that symptoms of depression were greater for individuals possessing the short allele, but only for those persons dealing with many major life (e.g., financial, relational, and health) stressors. No genetic association was found for people experiencing fewer life stressors. Following its publication, this study was met with much acclaim in both the scientific community and popular press, as it seemed to link a functional genetic variant with a common psychological profile, as well as show how genes can interact with life experience. However, in the ensuing years, the association between the short allele and depression reported by Caspi and colleagues has been called into question (see Zammit & Owen, 2006). In some studies, researchers found no association between these alleles and depression, others found gender-specific effects, and some studies reported finding effects in the opposite direction (i.e., greater depression associated with the long allele). These discrepancies led Zammit and Owen (2006, p. 201) to caution that "although heralding much promise, the extent to which this fascinating area of research will enhance our understanding of psychiatric disease remains to be seen." A meta-analysis of 14 studies by Risch et al. (2009) found no evidence of a relation between the presence of short and long alleles and depression (but see Karg, Burmeister, Shedden, &

Sen, 2011, for an opposing view and meta-analysis). Further, genome-wide association studies have to this point failed to find any reliable genetic association with depression (Ripke et al., 2012; Wray et al., 2012).

Similar failures to replicate have been found in the hunt for genetic associations with other psychological characteristics and disorders. For example, Chabri and colleagues (2012) attempted to replicate associations of 12 SNPs with measures of general intelligence using three independent data sets totaling nearly 10,000 individuals. Only one SNP (*SSADH* rs2760118) in one of the three data sets achieved marginal significance, and even this weak association was suspect given that the alleles of this SNP were found to have different associations with intelligence in one of the other data sets (i.e., the genotype associated with higher intelligence in the former was found to be associated with lower intelligence in the latter, though in both cases they were not statistically significant). Failures to replicate have also been found for various SNPs and memory (Need et al., 2008), personality (see Munafo & Flint, 2011, for review), and Parkinson's disease (Evangelou et al., 2010) to name a few (see Wahlsten, 2012, for additional examples).

How are we to make sense of these failures to find an association between psychological characteristics and gene variants? Some molecular biologists seem to be of the opinion that genetic associations exist, but are still too rare to detect or that the methodologies available are not suited to deal with gene-gene interactions that may be responsible for the small reported relations (e.g., Haig, 2011; Zuk, Hechter, Sunyaev, & Lander, 2012). On the other hand, it could be that the search for genetic associations of complex characteristics is simply bound to fail. Joseph (2012), for example, argues that "the issue researchers are grappling with is not missing heritability but missing *genes*, and there is good reason to believe that these 'missing' genes are actually 'nonexistent' genes" (p. 80, emphasis in the original). In other words, there simply are no genes independently responsible for depression, schizophrenia, intelligence, or temperament/personality.

One interesting suggestion to the "missing heritability" problem is to include epigenetic and environmental inheritance systems into the analysis (Danchin et al., 2011; Furrow, Christiansen, & Feldman, 2011). From the DPS perspective, this approach rightly recasts heritability as a developmental issue that requires developmental analysis. This approach can potentially enhance our understanding of the distribution of phenotypes in a population, as well as provide insight into how this population might respond to selective pressures. However, incorporating environmental and epigenetic inheritance systems into heritability statistics will necessarily remain limited, in that they remain correlational attempts to account for variation in populations. As such, they cannot inform us about the identity of the relevant factors or processes by which genes and nongenetic factors actually influence the development of characteristics in individuals. Lehrman (1970) and Lewontin (1974) have each provided a particularly lucid account of the distinction between analysis of variation (as used in behavior genetics) and the analysis of causes (as used in developmental science).

Given the limitations of gene association studies, we suggest more effort be placed on studying gene expression and its consequences in developing organisms. Indirect measures of gene transcription (via measures of RNA) using microarrays and other techniques have successfully linked gene activity with specific characteristics, as seen in Weaver et al.'s (2004) research on the long-term effects of maternal behavior in rodents discussed earlier. Modern techniques also allow for more direct manipulations of genes (e.g., selectively mutating, inserting, silencing, or deleting genes) to assess genetic contributions to development. Many human psychological phenomena cannot be studied in this way, but given the similarities between humans and other animals, much can be gleaned by understanding the basic neurobiology of brain development and function in model organisms whose genomes we can directly manipulate (Wahlsten, 2012).

For example, Lim, Wang, Olazábal, Terwilliger, and Young (2004) transferred a vasopressin receptor gene (*V1aR*) found in the affiliative and monogamous prairie vole (*Microtus ochrogaster*) into a specific region (ventral pallidum) of the ventral forebrain of juvenile male meadow voles (*Microtus montanus*), which typically display asocial and promiscuous sexual behavior. Following the gene transfer, normally asocial male meadow voles showed increased vasopressin receptors in this brain region and increased pair-bonding behaviors similar to those seen in prairie voles. In this case, a single gene yielded a powerful influence on functionally important and complex social behaviors.

Findings such as these, however, should not be used to promote a new form of genetic determinism. As the authors of the study astutely point out, "a single gene does not act alone in the control of complex social behavior; it must ultimately be placed within preexisting biological pathways that then interact with socioecological factors, developmental pathways, and stochastic events in the lives of organisms" (Lim et al., 2004, p. 757). In other words, it is important to identify candidate genes that can strongly impact how particular behaviors develop, but this is only the first step in understanding *how* such genes actually contribute to development. Kaplan (2006) has summarized this key insight as follows:

> Every trait of an organism is the result of the interaction of various genes and environments during the developmental process. In order to be successful, organismal development always requires the presence and coordinated actions of various kinds of resources (genetic, epigenetic, and environmental, to name a few), so it makes no sense to ask if a particular trait is genetic or environmental in origin. Understanding how a trait develops is not a matter of finding out whether a particular gene or a particular environment causes the trait; rather it is a matter of understanding how the various resources available in the production of the trait interact over time. (p. 50)

Because of the variability of relevant resources across different environments and because only a portion of the genome is expressed in any individual (due to its specific developmental context and experience), what is actually realized during the course of individual development represents only one of many possibilities. As we pointed out earlier, this insight is a core tenet of the developmental psychobiological systems perspective—because of the multiplicity of levels, factors, and coactions involved and because of its history-dependent and situated nature, neither physical nor behavioral development can have a predetermined trajectory (Gottlieb, 2007). Contrary to the assumptions of classical quantitative behavior genetics, DPS emphasizes that to understand the presence, maintenance, or transformation of any phenotypic trait, it is necessary to study its development in the individual. Given that all phenotypes, including behavior and cognition, have a specific developmental history that explains their emergence, a developmental mode of analysis is required to fully explain their structure and function.

Atchley and Newman (1989) highlighted several types of resources—genetic, maternal, and environmental—that impact the stability and variability of developmental outcomes. Their model for integrating genetics with developmental analysis recognizes that multiple factors, including contingencies in mating (which create the developing organism's genome) and contingencies of the maternal environment (cytoplasmic and uterine in the case of mammals) in which the individual develops mediates variability and stability in developmental outcome. As a result, understanding the developmental pathways of morphological, physiological, and behavioral phenotypes requires knowing the dynamic and contingent processes of internal and external factors operating over the course of individual ontogeny.

Application of this insight is increasingly apparent in the neurosciences, where advances across several levels of analysis, including genetics and epigenetics, are changing our understanding of the relations between experience, brain, behavior, and human development. These advances are making clear that attempts to reduce psychological phenomena to neuroanatomical, neurochemical, neurophysiological, or genetic factors misrepresents the key role of other levels of influence involved in the dynamics of brain development, as well as behavioral and cognitive development (Cicchetti & Curtis, 2006; Dalton & Bergenn, 2007; Greenberg, 2011; Overton, 2004; Tucker, 2007).

EXPERIENCE, EPIGENETICS, AND NERVOUS SYSTEM DEVELOPMENT

The human brain is a massively complex system with a hierarchy of tightly integrated levels of organization, from synapses and cells to neural circuits and brain regions. It contains at least a million billion synapses and thousands of miles of neural wiring, forming a dense web of cellular connections that has yet to be completely mapped (Sporns, 2011). In keeping with the dominant view of development in play during most of the past century, brain structure and function was long viewed as the product of a genetically predetermined maturational process (see Hamburger, 1957; Thompson et al., 2001). Until a few decades ago, many scientists assumed that the brain was somehow hard wired and that neuronal connections were predesignated to perform fixed functions. Moreover, the relation between brain and development was viewed as unidirectional—the structural maturation of the brain was thought to be the primary cause of both behavioral and cognitive development. For example, Lenneberg (1967) argued that neural systems that are involved in higher cognitive functions, including language, develop as a result of a maturational blueprint, and that specific brain regions are genetically "prespecified" for specific cognitive functions. More generally, the Nobel Prize winner Roger Sperry (1971) proposed that "one could now see how it could be entirely possible for behavioral nerve circuits of extreme intricacy and precision to be inherited and organized prefunctionally solely by the mechanisms of embryonic growth and differentiation" (p. 32). The behavior geneticist Ronald Wilson (1983) boldly claimed that "the brain is the ultimate structure underwriting human behavioral development" and its "precise wiring is coded in the DNA" (p. 313). Some have claimed that human brains contain hundreds or even thousands of separate, genetically determined neural circuits (modules) that are specialized to respond to specific objects or events (e.g., faces, language, potential mates; see Samuels, 1998, 2002).

These bottom-up views of brain development ignore the fact that neural factors, like genetic factors, are always part of the individual's integrated developmental system. A wealth of evidence emerging from the neurosciences over the last several decades has established that a unidirectional framework is simply not up to the challenge of understanding the complex links between genes, brain, behavior, and the physical, biological, and social environments in which individual development occurs (see Dalton & Bergenn, 2007; Mareschal, Johnson, Sirois, Spratling, & Thomas, 2007; Marshall, Chapter 7, this *Handbook*, this volume; Stiles, 2008). Although it is not possible to adequately review this research effort in a few pages, here we briefly discuss findings from selected studies that collectively serve to illustrate the multifaceted, activity-based nature of brain development, a process guided and constrained by the rich bidirectional traffic among genetic, epigenetic, and environmental factors.

Prenatal and Postnatal Experiential Influences on Brain Structure and Function

In his classic text, *The Organization of Behavior*, Donald Hebb (1949) famously proposed that an organism's experience—its actions/activity—could alter brain structure and function. His idea of how learning and memory could arise from changing coactions among neural connections was among the first proposals that provided a feasible way in which learning and memory might be explained at the neural level. Further, Hebb's proposal suggested that *plasticity* is a fundamental property of neural systems (see Cicchetti & Curtis, 2006; Nelson, 1999, for further discussion). Given the technological constraints of his day, Hebb and his colleagues were only able to provide indirect empirical support for this notion (e.g., Hebb, 1949). The role of individual experience on regulation of neuronal activity and development was more directly supported by subsequent research concerned with the possible implications of environmental enrichment for brain structure and function. In the 1960s, Rosenzweig, Krech, Bennett, and Diamond (1962; Rosenzweig, Love, & Bennett, 1968; see Renner & Rosenzweig, 1987, for a review) were able to demonstrate effects of environmental enrichment on rodent brain anatomy and chemistry. Greenough and colleagues (e.g., Greenough & Chang, 1988; Markham & Greenough, 2004) extended this groundbreaking work, showing that variations in both the type and timing of environmental conditions can affect patterns of synaptic connectivity in the developing rodent brain. Hubel and Wiesel's (1967) classic work on the development of ocular dominance columns in cats likewise demonstrated the importance of both type and timing of experience on the development of cortical organization. We now know that there are many ways in which neuronal functioning (including neurogenesis, synaptogenesis, myelination, axonal sprouting, and vascular changes) can change in response to specific experiences. According to Zatorre, Fields, and Johansen-Berg (2012), "the brain is the source of behavior, but in turn it is modified by the behavior it produces. This dynamic loop between brain structure and brain function is at the root of the neural basis of cognition, learning and plasticity" (p. 528).

The degree to which experience can play an inductive role in brain organization has been elegantly demonstrated in the work of Mriganka Sur and colleagues, who have explored the effects of experimentally rewiring young ferret brains (see Newton & Sur, 2004; Sur, Angelucci, & Sharma, 1999, for reviews). Typically, the medial geniculate nucleus (MGN) of the ferret's thalamus receives auditory input from the superior colliculus and projects to the auditory cortex. However, when the input connections to the MGN are experimentally severed in young ferrets, retinal projections innervate the MGN, as well as the lateral geniculate nucleus (LGN, an area normally innervated by retinal projections). As a result, the response properties of the MGN in rewired animals resemble those of the LGN. Likewise, the rewired primary auditory cortex functionally and structurally resembles the primary visual cortex. These data indicating that both auditory and visual neurons can change their physical characteristics and assume functions of the visual cortex and vice versa clearly challenge any notion that brain structure and function can be exclusively driven by intrinsic maturational factors.

Effects of prenatal experience on brain structure have been reported by Rao et al. (2013), who demonstrated that activation of a light-response pathway in the retina of the mouse fetus must occur during gestation to produce normal eye development. Under the typical conditions of development, photons of light penetrate the uterine wall and activate the protein melanopsin in the fetus, which is critical for initiating and directing the development of blood vessels and retinal neurons in the eye. When activated, this light-sensitive pathway holds local expression of vascular endothelial growth factor (VEGFA) in check, suppressing the number of blood vessels that form in the retina. These blood vessels are critical for the high metabolic demands (including large amounts of oxygen) of retinal neurons. Dark raising mouse dams during the later stages of pregnancy fostered a large expansion in blood vessel growth in their embryos, resulting in abnormal retinal development in their pups. It appears that prenatal light exposure is critical for preparing the eye for vision, both by regulating retinal neuron number and initiating the pattern of ocular blood vessels.

Similar effects of prenatal experience—keeping in mind that experience refers to the actions/activity of the organism—have also been reported for functional outcomes. For example, during the later stages of prenatal development the avian embryo is oriented in the egg such that its left eye is occluded by the body and yolk sac, whereas the right eye is exposed to diffuse light passing through the egg shell when the female is intermittently off the nest during the incubation period. This differential prenatal visual stimulation resulting from the embryo's invariant postural orientation in the egg has been shown to facilitate the development of the left hemisphere of the brain in advance of the right hemisphere. Further, this light-induced developmental advantage for the left hemisphere has been shown to influence the direction of hemispheric specialization for a variety of postnatal behaviors, including visual discrimination, spatial orientation, feeding behavior, and various visual and motor asymmetries (reviewed in Rogers, 1995). Altering the normal pattern of light stimulation available during prenatal development can modify this typical pattern of brain and behavioral development (Deng & Rogers, 2002). For example, a left spatial turning bias is seen in the large majority of quail chicks following hatching (> 85%; Casey & Lickliter, 1998). This species-typical turning bias can be reversed by occluding the right eye and stimulating the left eye with light prior to hatching. Further, the induction of such lateralization can be prevented by incubating eggs in darkness or by providing the same level of light stimulation to both eyes in the period prior to hatching (Casey & Lickliter, 1998). These findings suggest an equipotentiality for hemispheric specialization and indicate that late prenatal experience can have a significant influence on the stability and variability of functional lateralization.

Evidence also indicates that the activity of experience can contribute to structural and functional specialization in neural development following birth. For example, in rats differences in postnatal maternal stimulation is known to bring about differences in brain development and behavioral differences between male and female pups (see Moore, 2006). Rat dams typically engage in high levels of perineal or anogenital licking (AGL) of their pups in the first several weeks postpartum. Under normal conditions, males receive significantly more anogenital licking than do their female siblings during this period, due in large part to the chemical composition of their urine. Increased levels of anogenital licking of males has been shown to influence the retention of cells in the spinal nucleus of the bulbocavernosus (SNBC), which innervates the bulbocavernosis muscle involved in penile erections. At birth, both male and female pups have equivalent numbers of cells in the SNBC, but over time females lose most of these cells. In contrast, males retain these cells as a consequence of receiving higher levels of anogenital licking. Not surprisingly, males that receive little anogenital lickling following birth display numerous problems copulating as adults (Moore, 2006). Further, when female pups are injected with testosterone, they are licked as much as males, and as adults these females show many of the male behaviors involved in sexual reproduction. These results indicate that species-typical afferent input (AGL) can contribute to the sexual dissimilarity of nervous system morphology observed between males and females. Further, these results suggest that variation in maternal behavior can produce individual differences in neural processes among males that can affect their subsequent reproductive success.

The development of neuroimaging technologies (see de Haan, Chapter 18, this *Handbook*, this volume), particularly functional magnetic resonance imaging (fMRI) and diffusion tensor imaging (DTI), has provided researchers new and powerful tools for exploring the roles of experience on human brain structure/function relations. This body of research has confirmed and extended earlier findings based on histological studies and have provided an evergrowing information source about the relations among activity, experience, brain growth, and development. Although not without its critics, functional neuroimaging techniques are altering our understanding of brain-behavior relations and advancing our ability to observe developmental processes across relatively short time scales. As a case in point, using neuroimaging methods, Draganski and colleagues (2004) found that when adults learn to juggle over a 3-month-period, the repeated training leads to increased gray matter concentration in occipito-parietal regions of the brain involved in visual-motor coordination, reaching, and grasping. Further, these changes were apparent after as little as 7 days of training. Similarly, practice of a complex whole-body balancing task has been found to increase gray matter in frontal and parietal cortex after just two training sessions and changes in white matter regions after 6 weeks of training (Taubert et al., 2010). Hu et al. (2011) reported that children who received extensive training on an abacus (a traditional hand-operated calculator used for thousands of years in China) showed greater myelination in parts of the corpus callosum as well as other fiber tracts involved in motor and visuospatial function when compared to children who had not experienced regular use of an abacus. These types of findings, along with a wealth of supporting evidence available from similar neuroimaging studies (see May, 2011) highlight the remarkable capability of the brain for structural alteration in response to changes in activity and more broadly, environmental changes.

Luu and Tucker (1996) cogently commented some years ago that "to understand neuropsychological development is to confront the fact that the brain is mutable, such that is structural organization reflects the history of the organism" (p. 297). Just like the genome, the developing brain is an active and actively responsive system, and just as the notion of genetic programming of protein synthesis was found to be wanting, the notion of genetic programming of brain development likewise falls far short of explaining neural structure and function (Kolb & Gibb, 2011; Nelson, 1999; Stiles, 2008).

Situating Gene Activity in Brain Development

As early as the 1970s, research had revealed a greater variety of RNA molecules in the cortex of rats raised in complex as compared to simple or impoverished environments, suggesting that experience could affect the ways in which genes are expressed (Grouse, Schrier, Bennett, Rosenzweig, & Nelson, 1978). Since these initial discoveries, developmental neuroscience has been steadily advancing our understanding of the processes whereby early experience and environmental factors can influence neural and gene activity to result in the interindividual stability *and* variability of neural structure and function (e.g., Graff et al., 2011; Roth & Sweatt, 2011; Stiles, 2011; Sultan & Day, 2011). We now know that the structure and function of neural systems depends on dynamic historical processes that involve highly complex spatial and temporal patterns of coaction across genetic, neural, and environmental factors, and that epigenetic processes play a fundamental role in this process, with multiple feed-forward and feedback pathways (Cedar & Bergman, 2009).

An example of this distributed causality comes from work on gene expression during sleep/wake cycles in rats (Cirelli & Tononi, 2000). This research focused on the links between behavior, neuronal activity, and gene expression over short time scales. Using mRNA differential display and cDNA microarray technologies to screen for changes in gene expression in the cerebral cortex, Cirelli and Tononi were able to show changes in gene expression across behavioral states. They found that sleep and waking differ not only in behavior, metabolism, and neuronal activity, but also in the expression of distinct categories of genes, including those associated with glucose transport, neuronal plasticity, and protein folding. Cirelli, Pompieano, and Tononi (1996) also found that gene expression was influenced by the hormone norepinephrine from brain stem neurons that fire at very low levels during sleep and at high levels during waking. In this case, arousal level is tied to genetic expression by a specific hormone (norepinephrine) emanating from the activity of a specific neural structure (locus coeruleus), whose activity waxes and wanes in relation to the psychological state of the organism.

Epigenetic processes provide a means of dynamic gene regulation, allowing the nervous system to make both short-term and long-lasting changes at the level of neural circuitry and neurotransmission as a result of experience. Given that epigenetic processes pervade all aspects of development, it should not be surprising that these processes are involved in brain structure and function across the life span; current evidence indicates that epigenetic regulation of gene expression plays an important role in the development of the nervous system, synaptic plasticity, learning and memory, and the maintenance and survival of neurons (see Graff et al., 2011, for a review). As Hebb speculated more than a half-century ago, long-lasting changes in synaptic plasticity are one of the key processes underlying learning and memory, and a growing body of evidence indicates that histone modification and chromatin remodeling are regularly involved in the synaptic changes associated with various forms of learning and memory consolidation (Sultan & Day, 2011).

These types of findings suggest that the characteristics of epigenetic processes in the nervous system are similar to the processes involved in the differentiation of embryonic stem cells, in that they allow cells to respond and adapt to their environment, and keep a cellular memory of previous activity. In other words, the same processes that provide genomes with different identities or profiles during cellular differentiation are likely involved in generating different neural profiles of individuals in response to their life experiences (Szyf & Bick, 2013).

The advances in the neurosciences briefly reviewed earlier demonstrate the complex interplay of gene expression, cellular and hormonal activity, the physical environment, as well as the nature and patterns of social interaction, on the course of plasticity and learning across the life span. These findings emphasize the historical and situated nature of brain development and highlight the importance of research efforts focused on a fuller understanding of the particulars of experience and its varied contributions to neural and behavioral development. We have long known that experience has its effects on behavior by changing neural circuitry, including creating new synaptic connections and strengthening, weakening, or eliminating existing ones. We now know that these effects or implemented through changes in the expression of genes within the nuclei of nerve cells. These processes are proving to be far more complex and distributed than suggested by outdated notions of "genetic programs" or "biological maturation." It seems important to emphasize that the brain is *embodied and situated*; it develops and functions within a body that is itself situated in a physical and social environment (Mareschal et al., 2007; Marshall, Chapter 7, this *Handbook*, this volume; Overton, 2004, Chapter 2, this *Handbook*, this volume; Thelen & Smith, 1994). As a result, Greenberg (2011) notes that "it is the probabilistic, epigenetic, and self-organizing principles of development within a dynamic ecological context that shape the processes of differentiation and integration that characterizes a given individual's genetic, neurological, and behavioral attributes, rather than the other way around" (p. 182).

Greenberg's developmental insight also holds for our understanding of evolutionary processes. The relations between individual development, ecology, and evolutionary change have been the subject of renewed interest over the past several decades in several areas of biology, and as we discuss in what follows, has significant implications for developmental science.

INTEGRATING DEVELOPMENT AND EVOLUTION

Broadly speaking, three general concerns of biology over the past several centuries have been heredity, development, and evolution. Earlier we discussed how the perceived relation among these three concerns were initially forged in the 19th century and changed dramatically during the early decades of the 20th century, eventually giving rise to the Modern Synthesis of evolutionary biology (see Amundson, 2005; Bowler, 1989). In this section we review how the Modern Synthesis came to be applied to the psychological and behavioral sciences and explore the shortcomings of this application in light of advances in developmental and evolutionary theory. These advances are fueling new ways of thinking regarding the links between heredity, development, and evolution and leading to calls for a new "extended synthesis" in some quarters of evolutionary biology and beyond (e.g., Gissis & Jablonka, 2011; Jablonka & Lamb, 2005; Pigliucci & Müller, 2010). This extended synthesis has the developing phenotype rather than the genes as its primary focus, with a particular concern with identifying aspects of development that can lead to flexibility and adjustment when the environment or the genome changes (see West-Eberhard, 2003). As we explore later, this shift in emphasis affords a new way to conceptualize the role of behavioral development in evolutionary change and thus offers a potential avenue to synthesize psychology and biology in new and important ways.

The Modern Synthesis and the Behavioral Sciences

Proponents of the Modern Synthesis largely focused on the evolution of physical characteristics. Behavioral characteristics were thought to evolve in a manner similar to physical characteristics, but little empirical attention was devoted to this issue in mainstream evolutionary biology (but see Roe & Simpson, 1958) during the first half of the last century, in large part because behavior was not thought to contribute to evolutionary change (Bateson, 1988). However, in the 1960s and 1970s, the genocentric principles promoted by the Modern Synthesis began to be extended to the study of behavior, particularly in the field of sociobiology (Dawkins, 1976; Wilson, 1975, 1978).

Sociobiology

Sociobiology proposed that all animals, including humans, behave in ways that maximize their chances of transmitting their genes (directly or indirectly via kinship relations) to the next generation. With this in mind, sociobiologists argued that many social behaviors of animals, including humans (e.g., altruism, incest avoidance, mate preferences, parental investment, territorial aggression), could be best understood as genetically determined adaptations generated by the process of natural selection. As a result of this emphasis, sociobiology focused on the purported adaptive value of behavior (resulting from "ultimate" causes) and was not concerned with the "proximate" causes involved in the development of behavior (Griffiths, 2008; Lickliter & Berry, 1990). This "ultimate" perspective had at its core an underlying premise that went unquestioned by most researchers of this period, namely that the behavioral dispositions of organisms could be specified in advance of the organism's development. This postulate is at the heart of the genocentric view of development that dominated biological thought over the last century and that still remains prominent in some quarters of biology and psychology. Adult behaviors are seen to be the result of genetic programs, with little concern for the intervening resources, factors, or relations that construct the adult from the zygote.

Evolutionary Psychology

In the 1980s, many of these core assumptions of sociobiology were combined with aspects of cognitive science to forge a new field called Evolutionary Psychology (EP; Barkow, Cosmides, & Tooby, 1992; Cosmides & Tooby, 1987; Tooby & Cosmides, 1990; see also Buss, 1995). The original formulations of EP focused on human social and nonsocial behaviors (including perception and cognition) and set out to modify and extend the explanatory basis of sociobiology. Rather than focusing directly on behavioral adaptations, EP focuses on the "evolved cognitive mechanisms" thought to generate behavior. In particular, promoters of EP propose that modern human minds are composed of a large set of domain-specific cognitive modules that evolved by means of natural selection as adaptations to solve specific, recurring problems encountered in our ancestral environments. These modules are thought to guide and constrain a wide range of human perceptual and cognitive skills, including detecting cheaters, perceiving faces, learning language, guiding mate preferences and parenting strategies, among many others (Samuels, 1998; Sperber, 2001). Because all humans are thought to have the same set of modules, their totality represents human nature. To identify these modules and their origins, EP argues that we must consider the problems faced by our earliest hunter-gatherer ancestors during the emergence of *Homo sapiens* hundreds of thousands of years ago because, it is claimed, there has not been enough time for selection to modify the innate (i.e., biologically determined), modular nature of the human mind, despite significant changes in our living conditions over the past 10,000 to 15,000 years. Harris (2009) provides a succinct example of this view: "The mind we inherited from our ancestors was tested against alternative versions and won out against the competition because it was more successful in dealing with the challenges of hunter-gatherer life" (p. 30). In its strongest form, the EP viewpoint assumes that many human perceptual and cognitive processes, as well as some overall executive function, are preformed and triggered by species-typical experience (Pinker, 2002). Development is thus seen as the unfolding of programs or specifications that are already in place, imported into the life-cycle by means of the genome.

This framework has allowed most contemporary evolutionary psychologists (e.g., Buss, 1995; Tooby & Cosmides, 1990) to sidestep the accumulating evidence for the role of developmental processes involving specific mutually influential relations between individuals and contexts that occur at specific times (in ontogeny and history) and within specific places (see Elder, Shanahan, & Jennings, Chapter 2, this *Handbook*, Volume 4), in the realization of all phenotypic traits or characteristics by emphasizing that they are concerned with phylogenetic rather than ontogenetic causality. Proponents of EP argue that they focus on the "ultimate" causation of human behavior and its function or adaptive value, with the aim of understanding how human behavior was designed or shaped by natural selection over the course of evolution. This emphasis has resulted in minimal interest in developmental issues in most of the EP literature (but see Bjorklund, 2006; Bjorklund & Pellegrini, 2002; Frankenhuis, Panchanathan, & Barrett, 2013; Ploeger, van der Maas, & Raijmakers, 2008). The DPS perspective argues that sidestepping development is not justifiable because *development and evolution are two elements of one process* (Ioannidis, 2008; Lickliter & Berry, 1990; Lickliter & Honeycutt, 2003). EP's attempts to divide phenotypic causality into "proximate" and "ultimate" components misconstrues the fundamental link between development and evolution, in large part by assuming that processes that occur within the lifetimes of organisms following conception (diet, behavior, learning, social coactions) can have little if any influence on evolutionary change (see R. M. Lerner & Benson, 2013b; Walsh, 2013, for additional discussion). It has become increasingly clear that this is not the case (Gissis & Jablonka, 2011).

The problems associated with the underlying assumptions of EP (and sociobiology) can be traced in large part to the narrow genes-eye view of development and evolution promoted by the Modern Synthesis of evolutionary biology (Honeycutt & Lickliter, 2007; Lickliter & Honeycutt, 2003). The metatheoretical assumptions of the Modern Synthesis effectively split the internal world from the external world, and in placing priority on the former, promoted a predetermined and nondevelopmental explanation of physical and behavioral characteristics (Overton, 2006; Oyama, 1985; Richardson, 2013). As a result, with few exceptions, evolutionary psychologists have effectively ignored the findings that have emerged from genomics, molecular and cellular biology, and epigenetics and their implications for our understanding of heredity and evolution. In response to the charge of genetic determinism from many developmental scientists, evolutionary psychologists counter that they offer a detailed interactionist framework, as psychological adaptations require environmental input for their proper development and proximate activation (see Confer et al., 2010). In this form of interactionism, genes continue to be characterized as playing the primary or determinative role in the form and function of phenotypic characteristics and nongenetic or environmental factors are delegated to playing a necessary, but clearly supportive role. This perspective promotes a decidedly lopsided view of gene-environment relations and overlooks a wealth of converging evidence from the life sciences indicating the fundamental role of factors above the level of the genes to the origins, emergence, and maintenance of phenotypic outcomes across generations (e.g., see R. M. Lerner & Benson, 2013b).

The Developmental Challenge to the Modern Synthesis

The regulative and generative aspects of development revealed over the past several decades and reviewed in earlier sections of this chapter indicates that the natural selection of random genetic mutations (the cornerstone of the Modern Synthesis framework) simply cannot be sufficient to account for evolutionary change. A growing acknowledgment of this insight has fostered a renewed interest in development within evolutionary biology (as opposed to evolutionary psychology) and increasing recognition that changes in evolution reflect changes in developmental processes (e.g., Arthur, 2002; Gilbert, Opitz, & Raff, 1996; Gottlieb, 1992). This focus on the complexities of the dynamics of development is bringing together genetics, molecular, cellular, and developmental biology, neuroscience, ecology, and evolutionary biology to forge a more comprehensive explanation of the ways and means of the stability and variability of phenotypic characteristics (e.g., Gilbert & Epel, 2009; Hallgrimson & Hall, 2011; Lickliter & Harshaw, 2010; Müller & Newman, 2003; Richardson, 2013). As the philosopher Robert (2008) points out, taking a developmental point of view involves understanding that there is more to development than differential gene expression, that development is not a genes-*plus*-environment phenomenon, and that the causal analysis of development is required to understand evolution.

The developmental challenge to the Modern Synthesis has deep historical roots and involves contributions from numerous scientific disciplines (Gottlieb, 1992; Laubichler & Maienschein, 2007; Robert, 2004; West-Eberhard, 2003). As noted as far back as 1871 by Darwin's critic, St. George Mivart, phenotypic change must come about *before* natural selection is possible. In other words, variation must exist in a population before selection among the variants can occur. Mivart's insight that natural selection can only change the frequency or range of phenotypic variations already present in a population led Mivart to relegate natural selection a more minor role in evolution than Darwin had proposed and to argue that other factors must be at play that were capable of generating the variations upon which selection can then act. Mivart (1871) thought that these factors must somehow be based on the united action of internal and external forces that modified individual development, but he was necessarily vague as to how this might work, as Mivart and his contemporaries of 19th-century biology knew relatively little about details of development or the internal and external forces at play in evolutionary change. Nevertheless, Mivart's insight that the origins of new forms or characteristics must come about through changes in the process of development was a shift in thinking about the process of evolution, one that has received serious attention within the biological sciences in recent decades (e.g., Carroll, 2005; Gerhart & Kirschner, 1997; Gottlieb, 1992; West-Eberhard, 2003). This developmental challenge to the Modern Synthesis view of evolution has been coming from many disciplines, including developmental biology, ecology, animal behavior, and developmental science, and has suggested several processes of evolutionary change beyond simply changes in gene frequencies.

For example, following the thread of an idea proposed by Etienne Geoffroy Saint-Hilaire more than 100 years earlier, the embryologist Gavin de Beer (1940) argued that evolutionary change in the phenotype can only come about by changes in development. However, for de Beer and the few other theorists working on the relation between development and evolution during the first half of the last century (e.g., Garstang, 1922; Goldschmidt, 1940; Russell, 1930) alterations in development that were proposed to initiate evolutionary changes were thought to result from genetic modifications resulting from random mutation, drift, or recombination. Epigenetic processes were not seriously considered in discussions of evolutionary change (even by those focusing on the importance of development) because it was generally supposed that nongenetic factors could not be reliably replicated across generations and therefore could not provide for the heritable variation upon which natural selection could act.

This view has undergone considerable revision of late, due in large part to discoveries in molecular and cellular biology indicating that a variety of developmental resources beyond the genes reliably reoccur across generations. As discussed earlier, we now know that parents can transfer to offspring a variety of nongenetic factors that can directly influence phenotypic outcomes, including methylation patterns, chromatin marking systems, cytoplasmic chemical gradients, and a range of sensory stimulation necessary for normal development (reviewed in Harper, 2005; Jablonka & Lamb, 2005; Lickliter, 2005; Mameli, 2004). In mammals, where the embryo develops within the body of the female, these epigenetic factors can include noncytoplasmic maternal effects, including uterine effects (vom Saal & Dhar, 1992).

At conception, the human zygote inherits not just its genes, but also a structured cell, located inside a structured environment (the uterus), inside a female who is situated in a structured (and historically construed) physical and social environment. Changes in any of these factors could have potentially important implications for development as well as the course of evolutionary events. We propose that understanding how these various hierarchical levels change and how these changes are maintained and transformed across generations is central to a complete evolutionary analysis (see Figure 5.4). This is not a new perspective. Writing nearly 75 years ago, Waddington (1941) pointed out that,

> A theory of evolution requires, as a fundamental part of it, some theory of development. Evolution is concerned with changes in animals, and it is impossible profitably to discuss changes in a system unless one has some picture of what the system is like. Since every aspect of an animal is a product of development, or rather is a temporary phase of a continuous process of development, a model of the nature of animal organization can only be given in developmental terms. (p. 108)

In this light, the contemporary developmental psychobiological systems perspective recognizes the need to understand how combinations of genetic, hormonal, neural, physiological, behavioral, and social processes function synergistically as a system from which characteristics develop and are maintained within and across generations. A growing body of evidence indicates that a persistent change in any of the networks of coactions involved in the development of an organism can lead to anatomical, physiological, or behavioral modifications in that individual and in many cases in their offspring and grand-offspring as well (see Harper, 2005, 2010; Jablonka & Lamb, 2005, for examples). As a result, definitions of inheritance that

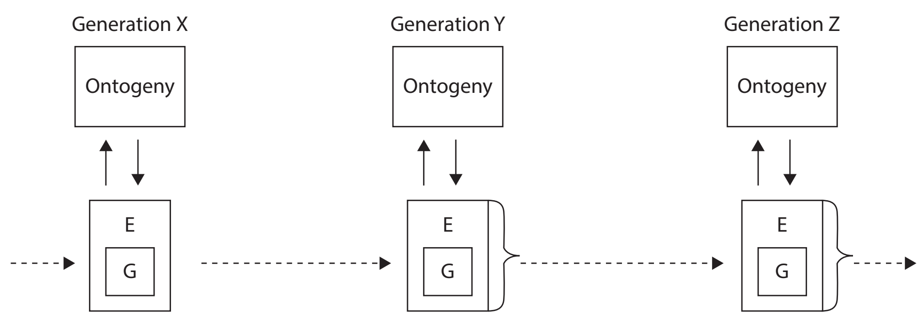

Figure 5.4 Probabilistic epigenetic model of development and heredity. The box containing genetic factors (G) is embedded within environmental factors (E) to represent the developmental system and illustrates that the effects of G and E are interdependent and causally contingent. The dashed arrows running between generations indicate that it is the developmental system that is "transmitted" across generations. The double arrows running between the ontogeny boxes and the developmental system boxes indicate that information going into ontogeny is itself a product of ontogenetic processes, which makes prespecification of outcomes impossible and allows events that occur during one generation to affect the developmental system made available to subsequent generations.

Source: From "Rethinking Epigenesis and Evolution in Light of Developmental Science" (pp. 30–47), by R. Lickliter and H. Honeycutt, in *The Oxford Handbook of Developmental Behavioral Neuroscience*, M. Blumberg, J. Freeman, and S. Robinson (Eds.), 2009, New York, NY: Oxford University Press.

do not include all components of the developmental system that are replicated in each generation and which play a role in the production or maintenance of the life cycle of the organism are bound to be less than complete (Figure 5.4; see also Gray, 1992; Mameli, 2005). Moreover, because some resources become available later in life (e.g., antibodies and bacteria in breast milk), inheritance is not complete at the moment of fertilization. In addition to genes, individuals inherit cell assemblies, an embryonic and fetal stimulative environment, and parents, peers, and the places they inhabit (Lickliter, 2005; Oyama et al., 2001; West & King, 1987). As emphasized throughout this chapter, gene-environment relations occur at all of these levels of the developmental system. At present, there is no overarching theory that adequately addresses the breadth of heredity processes at play in individual development and evolution. We believe such a theory is attainable, but has yet to receive the conceptual and empirical attention it deserves.

As we explore next, one of the most radical implications of a developmental point of view for evolutionary theory is the notion that *genetic changes often follow rather than initiate evolutionary change* (Gottlieb, 1992; Ho, 2010; Johnston & Gottlieb, 1990; West-Eberhard, 2003). From this view, environmentally induced change in an organism's behavior can provide an important process for how phenotypic plasticity might drive both genetic change as well as evolutionary change.

Behavior, Development, and Evolution

Over the past several decades a number of biologists and psychobiologists have proposed that behavior can potentially play a key role in evolutionary change (e.g., Bateson, 1988; Chapter 6, this *Handbook*, this volume; Gottlieb, 2002; Ho, 1998; Johnston & Gottlieb, 1990; Plotkin, 1988; Wcislo, 1989). Although the importance of behavior as an agent of evolutionary change is not a new idea (Baldwin, 1896; C. Lloyd Morgan, 1896), it has yet to be fully incorporated into evolutionary theory. Exploring the various roles of behavior in evolutionary change affords developmental scientists (and psychologists more generally) the opportunity to play an important role in shaping a new extended evolutionary synthesis.

The work of Gottlieb (1987, 1992, 2002) provided an innovative conceptual framework for understanding how changes in behavior could contribute to the evolutionary process. In Gottlieb's view of evolution, enduring transgenerational phenotypic change can occur at the behavioral, anatomical, and physiological levels before it occurs at the genetic level. His theoretically oriented perspective proposes that changes in development that result in a novel behavioral shift that recurs across generations can facilitate new organism-environment relations. These new relations, which can include "invasion" of novel environments, can bring out latent possibilities for morphological or physiological change. Eventually, a change in gene frequencies may also occur as a result of geographically or behaviorally isolated breeding populations. Thus, changes in behavior can be the first step in creating new phenotypic variants on which natural selection can act (Gottlieb, 2002).

In this view of evolutionary change, genetic change is often a secondary or tertiary consequence of enduring transgenerational behavioral changes brought about by alterations of normal or species-typical development. These developmental modifications often put individuals in new relations with their local environments, subjecting them to new selection pressures and increasing the likelihood of eventual change in the genetic composition of the population. This perspective introduces a plurality of possible pathways to evolutionary change, complementing genetic factors such as mutation, recombination, and drift.

In a seminal paper exploring the nature of the links between development and evolution, Johnston and Gottlieb (1990) provided an illustrative example of how new phenotypes may arise due to an enduring change in behavior before changes in gene frequencies. They describe a scenario in which a population of rodents whose normal diet consists of soft vegetation encounters a new food source of relatively hard but highly nutritious seeds. As the animals learn to sample and eventually increase the representation of seeds in their diet, a number of developmental effects of their new diet become evident, including possible changes in body size and composition, fecundity, age of sexual maturation, and indirect changes in morphology. For example, as the diet changes from soft vegetation to harder seed items, the mechanical stresses exerted on growing jaw tissues during development will change. Given that patterns of bone growth are known to be determined, in part, by forces exerted on the growing bone (Frost, 1973), the skeletal anatomy of the jaw will likely be different in the animals that experience hard versus soft diets early in life. Such changes in diet have, in fact, been shown to affect the jaw and skull of rats (Bouvier & Hylander, 1984).

In this example, behavioral change in members of a population (a preference for a new diet of hard seeds) leads to specific anatomical changes (modification of the jaw and teeth). Such changes can endure across generations, and as long as the new diet remains available, may eventually lead to changes in gene frequency as a result of long-term behavioral or geographic isolation among variants within the population. Following this line of thinking, West-Eberhard (2003) has provided a wealth of evidence suggesting that genes are probably more often followers than leaders in evolutionary change. From this view, the basis of phenotypic evolution cannot be reduced to population genetic events, but rather must include organisms' physical properties, self-organizing capacities, and responsive potential to external influences. Of particular importance in this concern is the recognition that variations in morphology, physiology, and/or behavior arising from modifications to the developmental process can place organisms in different ecological or functional relationships with their environments. If these phenotypic variations provide even slight advantages in survival and reproduction, then competitors without the novel phenotype will eventually decrease in frequency in the population, thereby contributing to evolutionary change.

Drawing on decades of work by developmental psychobiologists (see Michel & Moore, 1995), it seems clear that the conditions that best favor the expression of modified or novel phenotypes are species-atypical alterations in environmental conditions and contingencies that occur early in ontogeny (e.g., Blumberg, 2009; Gottlieb, 1971; Kuo, 1967; Levine, 1956). Shifts in behavior brought about by alterations to the developmental system can arise at any stage of the life cycle, but are generally more likely to occur earlier in individual development. This important point was highlighted by several evolutionary theorists during the last century (e.g., de Beer, 1940; Garstang, 1922; Goldschmidt, 1940; Waddington, 1975), who despite their different backgrounds and perspectives realized the significance of embryonic and neonatal periods of development for the generation of phenotypic novelties. These early periods of development are a time of rapid morphological, physiological, and behavioral change, and modifications to an individual's developmental system during this time can initiate a host of physical and behavioral changes, and in some cases (given the availability of appropriate developmental conditions) persist across subsequent generations. Developmental science has much to contribute in this area, particularly to exploring how previous developmental outcomes and current experiences in specific contexts combine to influence these processes.

For example, the observed behavioral changes reported in enriched rearing and early handling experiments (i.e., enhanced exploratory behavior, increased problem-solving abilities, resistance to stress) are types of behaviors that could support the seeking out and utilization of new habitats, leading to a host of other potential phenotypic novelties and setting the stage for possible evolutionary change. Gottlieb (1997) pointed out that animals that have had considerable variation in social and physical experiences early in life are more likely to seek out variation later in life, showing greater levels of exploratory behavior and novelty seeking than animals having more limited early experience. This sort of behavioral plasticity, the willingness to approach and explore novel objects, places, or situations, can increase the likelihood of particular individuals utilizing or migrating to new habitats, where they could encounter different types of functional demands. Although many changes in functional demands would be transient, others could be long lasting and persist across generations, revealing latent morphological or physiological variability not expressed in the original environment. How these processes work and the underlying biology involved remains poorly understood and developmental science can provide a developmental and ecological perspective to the ways and means of such transgenerational processes and their effects. It is important to emphasize that a developmental evolutionary approach involves unpacking developmental dynamics across numerous levels of analysis (genetic, epigenetic, behavioral, social, ecological) and time-scales (ontogenetic and transgenerational).

A related task for developmental science is to provide more detailed empirical evidence for the role of behavior as a leading edge in the evolutionary process. Changes in behavior brought about by changes in prenatal and postnatal rearing environments have been well documented in comparative psychology (e.g., Champagne, 2010; Kuo, 1967; Lickliter, 2005; Michel & Moore, 1995) but how such changes are significant to evolutionary issues has received relatively little empirical or conceptual attention. For example, differences in physical measures (e.g., body weight, endocrine responses) and behavioral measures (e.g., fearfulness) between groups of rats whose mothers or grandmothers were handled or not handled as pups have been reported for decades (e.g., Denenberg & Rosenberg, 1967). Despite the importance of these findings to both developmental and evolutionary concerns, the transgenerational effects of early rearing conditions on both physiological and behavioral responsiveness (including curiosity, novelty seeking, and emotional regulation) are only beginning to receive research attention and remain poorly understood. An experimental focus on how changes in experience can lead to genetic, morphological, or physiological alterations will help identify the specific biological and psychological processes potentially involved in the behavioral initiation of evolutionary change. This approach will necessarily be grounded in a view of behavior as both the *product* of development and as a component of the *process* by which development takes place (Stotz, 2008), and will require a multidimensional, process-oriented methodology that includes a variety of levels of analysis beyond the behavioral, including the environmental regulation of gene expression and cellular function and the effects of sensory stimulation on neural and hormonal responsiveness.

This multidimensional perspective on development and evolution provided by DPS highlights a persistent challenge for developmental theory—making sense of the relation among the various time scales over which change occurs. These time scales include *real time*, the immediate experiences and encounters of the individual with the extant physical, biological, and social environments, *developmental time*, the continuing influence of prior experiences and encounters on the individual's ongoing coaction with varied environments, and *evolutionary time*, the transgenerational effects of the individual's experiences and activities during ontogeny (Johnston & Lickliter, 2009). Improving our knowledge of the dynamics of developmental processes across these multiple time scales will undoubtedly contribute to a deeper understanding of the ways and means of both development and evolution.

SUMMARY AND CONCLUSIONS

Biology has been undergoing a significant shift in how to characterize the process of development over the past several decades. As in any science, the models and frameworks that form the foundation of our current knowledge have to be reevaluated and updated as new evidence is revealed. Just as the concepts of instinct and maturation, applied by generations of psychologists, have been shown to be simplistic and even misleading, several of the core concepts widely applied in biology during the last century to address the process of phenotypic development have likewise proven to be in need of revision. In particular, assumptions regarding the role of genes in development, heredity, and evolution (namely, instructions for building organisms resides in their genes, genes are the exclusive means by which these instructions are faithfully transmitted from one generation to the next, and there is no meaningful feedback from the environment or the experience of the organism to the genes) have been seriously challenged by demonstrations of the epigenetic regulation of gene expression and cellular function, in some cases across generations, as well as the varied effects of sensory stimulation and social coaction on genetic, neural, and hormonal responsiveness.

Consistent with the developmental psychobiological systems perspective outlined in this chapter, a major conclusion to be drawn from these advances in contemporary biology is that causation in biological systems runs in both directions: "bottom up" from the molecular level (including genes), and "top down" from all other levels, including cellular, tissue, organ, organism, and external physical, ecological, and social environments (Keller, 2010; Kohl et al., 2010; Noble, 2006, 2010; Richardson, 2013; Witherington, 2011, Chapter 3, this *Handbook*, this volume). These levels of organization reciprocally influence each other, and both the course of development and the impact of a change in development are thus contingent upon the state of the surrounding system. In other words, what happens at one level in a system (genetic transcription, neural activity, or behavior) depends on what is happening at other levels of the system (cellular environment, sensory environment, and so on). Further, all characteristics are jointly determined by internal and external developmental resources; *these are not competing alternatives*. So-called biological influences do not operate independently of (and cannot be meaningfully separated from) experiential influences. To argue otherwise both oversimplifies development and hinders further developmental analysis.

This growing appreciation of the complexities of developmental dynamics across biology has prompted some to call for a new evolutionary synthesis in the life sciences (e.g., Jablonka & Lamb, 2005; Keller, 2010; Pigliucci & Muller, 2010). Given that (a) biological form and function (from the genetic to the neural and anatomical levels) are routinely influenced by behavior, (b) that heredity includes specific features of physical and social environments, and (c) that behavioral changes can initiate and drive evolutionary change, it seems evident that the psychological sciences must have a key role in any such reformulation.

Much work lies ahead in creating a unified theory of heredity, development, and evolution. A comprehensive understanding of these phenomena and their relations across levels of biological complexity, from genes to cells to organs to organisms, has challenged generations of biologists and psychologists and is far from realized. That being said, it is certainly the case that genetics, neuroscience, and evolutionary biology have all undergone significant changes in recent years by the inclusion of a developmental point of view. The complexity of the bidirectional traffic across hierarchical levels inherent in the process of development being revealed through this inclusion highlights the dynamic fusion of biology and ecology and sets the course for future efforts aimed at a deeper understanding both developmental and evolutionary change. This task will require both description and experimentation, with the goal of explaining how each generation sets up the necessary developmental conditions and resources for the next and how specific changes in developmental conditions lead to specific changes in behavior, anatomy, physiology, as well as gene expression.

We began this chapter by asking what greater mystery there could be than how to explain the origins of form, function, and transformation within and across lifecycles. The complexity of this mystery is proving to be far greater than anyone anticipated. It may be the case that the number of variables, transactions, and contingencies involved from fertilized egg to functional adult may put a full understanding of the phenomenon of development beyond our comprehension. On the other hand, we have learned important lessons over the past century about how (and how not) to frame questions about development to address this complexity more accurately and profitably. The developmental psychobiological systems approach we have outlined in this chapter reflects these insights and provides a particularly useful and effective framework to address the scientific pursuit of human development.

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CHAPTER 6

Ethology and Human Development

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Human development presents many wonders, but one of the most remarkable is how a fully functional individual grows from a microscopic embryo. The processes that are involved have often seemed beyond understanding and, even now, much remains to be discovered. Nevertheless, the factual certainties have been known for a long time. The *robust* constancies of development are profound and real. Nobody will confuse a human with a rhesus monkey. At the same time, the *plasticity* of each individual is as remarkable as his or her robustness. Humans possess great capacity for change, a capacity that, as in other species, emerges very early in development. It does not follow, though, that two distinct processes can be cleanly separated, one leading to invariant outcomes and the other generating differences between individuals due to culture, education, and differences in experience. If this were true, it might be sensible to ask the question how much of behavior pattern is innate and how much is learned or more generally, how much is genetic and how much is due to the environment. This dichotomy, which was popular in the early days of ethology (e.g. Tinbergen, 1951) is neither true nor helpful and confuses folk psychology with real science.

In this chapter I review the profound changes that have taken place in how biologists think about behavioral development. I write as somebody with a degree in zoology and originally trained as an ethologist. It is difficult nowadays to define ethology. It was regarded as the biological study of naturally occurring patterns of behavior that are adaptive and typical of the species. Ethologists were strongly influenced by Darwinian thinking. In doing so, they have been contrasted with psychologists whose primary drive was to find universals and understand cognition and the human mind. A mistaken view held about ethologists has been that their work was solely conducted in the field. Many have been first and foremost experimentalists. Nevertheless much emphasis has been laid on simply watching the behavior of animals including children. Advice was given to the budding ethologist to produce an *ethogram* of all the behavior patterns of the subject under investigation. The assumption was that all members of the same species would behave in the same way. The assumption was clearly wrong because members of the same species, the same sex, and the same age sometimes differ dramatically from each other. Ethology, like psychology, broadened out, and made strong contacts with a great many different fields from the neurosciences to the developmental sciences, psychiatry, and anthropology.

Changes in my own interests also reflect the broadening character of ethology. As a boy I was a keen naturalist and wanted to study birds in the field. My first scientific paper, written when I was an undergraduate, was on the breeding biology and behavior of a rare Arctic bird, the Ivory Gull (P. Bateson & Plowright, 1959). However, my doctoral work was on behavioral imprinting, by which young birds form a strong attachment to the first conspicuous object they encounter. This research under Hinde was experimental and based in a laboratory (P. Bateson, 1966); it led to a lifelong interest in behavioral development and its underlying processes. On a 2-year postdoctoral position in California, I worked with the eminent neurosurgeon and neuropsychologist Karl Pribram. Subsequently, a substantial part of my research was with neuroscientists (e.g., P. Bateson & Horn, 1994; Horn, Rose, & Bateson, 1973). Later my developmental interest led me to work with epigeneticists who explained developmental phenomena in terms of the differential regulation of gene expression and, in particular, by epigenetic processes that lead to changes in gene expression without a change in nucleotide sequence. Despite or even because of these interests, I am strongly committed to reversing the reductionist trend and bringing the focus of developmental science back to the level of the whole organism (e.g. P. Bateson, 2005). This chapter surveys some of the contributions that ethology in its various guises, has made to an understanding of how humans develop and evolve and how these contributions are being integrated with modern studies of human development.

SETTING THE SCENE

The nature/nurture dichotomy is not merely a feature of popular science and folk biology and folk psychology. Many eminent biologists have accepted an *either/or* account of development. For example in his book *Sociobiology*, Wilson (1975) tacitly accepted this position. In a large collection of reviews of the book published in the journal *Animal Behaviour* in 1976, Wilson was attacked because he had not considered the interplay between the developing organism and its environment. In response to these criticisms he wrote that, in his view, development was a black box or module that could be decoupled when the relations between genes and the characteristics of the adult organism were considered (Wilson, 1976). The use of the nature/nurture distinction often involved a confusion of categories, since nurture was seen as a developmental process and nature was often viewed as the genetic origin of that process. For some, however, nature was viewed as the adult expression of a developmental process (P. Bateson & Gluckman, 2011). For others, though, nature was reserved for those features that developed robustly, unaffected by the vagaries of the environment, and nurture was used for those features that were plastic, greatly influenced by the conditions in which the individual developed.

The nature-nurture distinction runs through persistent arguments about the origins of human faculties. The 17th-century philosopher John Locke believed that all reason and knowledge was derived from experience. Charles Darwin's cousin, Francis Galton, expressed a strongly contrasting view about the development of human mental faculties, believing that education and environment produce only a small effect on the human mind and that most human qualities are inherited. The debate continues to the present day (see Downes & Machery, 2013). It extends across the full range of human faculties, styles of thinking, and behavior. The universalists claim that these faculties are shared by and intrinsic to all human beings. The relativists argue that all the cognitive characteristics of humans emerge from the culture in which they are embedded (see Lloyd, 2007). Reducing the problems of origin to either this or that is deeply unsatisfactory. Equally unhelpful, I argue, is the conflation of origins with developmental processes. Many others have taken the same view. In particular Gottlieb (1997), Johnston (Johnston & Edwards, 2002), Lickliter (Lickliter & Honeycutt, 2010, Chapter 5, this *Handbook*, this volume) and Oyama (1985) have argued strongly for a systems approach to development (see also the essays in the book edited by Oyama, Griffiths, & Gray, 2001). Developmental systems theory was also introduced to psychology by Ford and Lerner (1992) and later enlarged as relational developmental systems by Overton (2006) and later by Lerner and Overton (2008; Overton, 2013, Chapter 2, this *Handbook*, this volume; Overton & Lerner, 2012; Witherington, Chapter 3, this *Handbook*, this volume). Before focusing on how the robust features of development are integrated, I consider how ethological thinking has changed since the rise of ethology in Western Europe during the mid-20th century.

CHANGES IN THE ETHOLOGICAL APPROACH TO DEVELOPMENT

The notion of instinct became a focus of intense interest among the founders of modern ethology (Burkhardt, 2005), particularly Lorenz and Tinbergen. Lorenz had been struck by how behavior patterns that had looked so appropriate in the natural worlds to which the animals had been adapted looked odd when performed spontaneously outside of their normal context. A few days after hatching a hand-raised duckling touches with its bill a pimple above its tail and then wipes its bill over its down. Yet this pimple, which becomes an oil-producing gland in the adult, is not yet functional and the duckling would normally be made waterproof by the oily feathers of its brooding mother. Observations such as this led Lorenz to conclude that behavior patterns that were well-adapted by evolution to the biological needs of the animal are qualitatively distinct from behavior acquired through learning (Lorenz, 1965).

The classical ethologists emphasized how complex and coordinated behavior patterns develop without practice. Birds, for example, can usually fly without prior experience of flying. In one classic experiment, young pigeons were raised in narrow boxes that physically prevented them from moving their wings after hatching. They were then released at the age at which pigeons normally start to fly. Despite having had no prior opportunities to move their wings, the pigeons were immediately able to fly when released, doing so almost as well as the pigeons that had not been constrained (Grohmann, 1939). In a similar way, European garden warblers that have been hand-raised in cages nevertheless become restless and attempted to fly south in the autumn—the time when they would normally migrate southward. The warblers continue to be restless in their cages for about a couple of months, the time taken to fly from Europe to their wintering grounds in Africa. The following spring, they attempt to fly north again. This migratory response occurs despite the fact that the birds have been raised in social isolation, with no opportunities to learn when to fly, where to fly, or for how long (Gwinner, 1996).

Stable Features of Development

Lorenz, who had had his academic training in comparative anatomy, believed that behavioral activities could be regarded like any physical structure or organ of the body. They have, he argued, a regularity and consistency that relates to the biological needs of the animal, and they differ markedly from one species to the next. Indeed, the developmental progression from a single cell to an integrated body of billions of cells, combining to produce coherent behavior, is astonishingly orderly. Just as animals grow kidneys with a specialized biological function, adapted to the conditions in which they live, so they perform elaborate and adaptive behavior patterns without any previous opportunities for learning or practice. Particular behavior patterns are, Lorenz argued, like body organs in serving particular biological functions; their structure was likely to have been adapted to its present use by Darwinian evolution and depends on the ecology of the animal; and they develop in a highly coordinated and systematic way.

Certain aspects of human behavioral development recur in everybody's life despite the shifting sands of cultural change and the unique contingencies of any one person's previous history. Humans are remarkably similar to each other in many aspects of their behavior—at least, when compared with members of other species. With few exceptions, humans pass the same developmental milestones as they grow up. Most children have started to walk by about 18 months after birth, have started to talk by around 2 years and go on to reach sexual maturity before their late teens. Individual differences among humans seem small when any human is compared with any chimpanzee.

Human facial expressions have characteristics that are widely distributed in people of many different cultures. The emotions of disgust, fear, anger, and pleasure are read off the face with ease in any part of the world (Darwin, 1872; Eibl-Eibesfeldt, 1970; Ekman, 2009). An enormous archive of photographic records of human expressions in different cultures at different stages of economic development has been collected. The similarities in, for example, the appearance of the smile or the raised eyebrows are striking. The cross-cultural agreement in the interpretation of complex facial expressions is also remarkable. People from very different backgrounds agree about which emotions are being expressed. They also agree about which emotion is the more intense, such as which of two angry people seems the more angry.

The Innate School Marm

Even though Lorenz was a forceful advocate of the concept of instinct, he certainly did not deny the importance of learning. On the contrary, he gave great prominence to developmental processes, such as behavioral imprinting, by which birds formed their social and sexual preferences. However, Lorenz saw such learning processes as being under the control of what he referred to as the *innate school marm*. This metaphorical lady represents the highly regulated acquisition of information from the environment just when it is most adaptive for the individual to get it. He thought of instincts, whether they organized behavior directly or were the processes that changed behavior through learning, as inherited neuronal structures, which remained unmodified by the environment during development (Lorenz, 1965). Behavior resulting from learning was seen as being separately organized in the brain from the instinctive elements. At their most complex, then, instincts were thought to provide the basis by which the individual gathers particular types of information from the environment in the course of learning.

The acquisition of language by humans has been thought about in much the same way as Lorenz thought about the innate schoolmarm. In this respect Lorenz's ideas were remarkably similar to those of Chomsky (2000). It is obvious that the differences in spoken language between a French person and a German are not due to genetic differences. Therefore, apart from the act of speech itself, the proposed universal and instinctive characteristics of all humans are not going to be discovered in the surface organization of such behavior. In both Lorenz's and Chomsky's minds, however, the predispositions to behave in particular ways spring fully armed from the genome of each individual and were unaffected by experience.

Critique of Classical Ethology

Despite all the empirical evidence that some elements of behavior can develop robustly without opportunities for learning, the ethologists' notion of instinct attracted strong criticism in the 1950s from a group of American comparative psychologists who studied animal behavior and were strongly influenced by the thinking of Schneirla (1956). The critics laid out a quite different agenda in which a major focus was on behavioral development with no sharp distinction drawn between the specific and general consequences of experience (P. Bateson, 1976). The attack on the ethologists came most powerfully in an article by Lehrman (1953), who argued that

> The problem of development is the problem of the development of new structures and activity patterns from the resolution of the interaction of existing ones, within the organism and its internal environment, and between the organism and its outer environment. At any stage of development, the new features emerge from the interactions within the current stage and between the current stage and the environment. The interaction out of which the organism develops is not one, as is often said, between heredity and environment. It is between organism and environment! (p. 345; see also Lehrman, 1970)

This standpoint set the scene for a major change in the thinking of ethologists about development. Hinde was particularly influential in synthesizing the views of ethologists and comparative psychologists (Hinde, 1970). Advances in scientific thought in relation to the transactions between the individual organism and its environment had also occurred in the psychological literature (Lerner, 1984; Overton, 2006; Sameroff, 2010).

DIFFERENT PROBLEMS, DIFFERENT QUESTIONS

Children are studied in many ways because people become absorbed in different types of problem. Some want to know, for instance, how a particular character or system benefits the child, while others want to know how it works. The variety of different conceptual approaches to development is remarkable (Overton, 2013, Chapter 2, this *Handbook*, this volume). Clearly, then, a number of fundamentally different types of problems are raised when studying psychology and biology. Among ethologists, who study the biology of behavior, the most useful and widely accepted classification was formulated by the Nobel Prize–winning ethologist, Niko Tinbergen (1963). He had accepted Lehrman's critique of Lorenz's ideas about instinct. In a famous paper dedicated to Lorenz on his 60th birthday, he pointed out that four distinct types of problem are raised when studying behavior: current processes, ontogeny, function, and evolution (Tinbergen, 1963). These then relate to four different questions that can be asked about any feature of any organism including a child: How does it work? How did it develop? What is it for? and How did it evolve? Tinbergen's article followed shortly after Mayr's (1961) distinction between proximate and ultimate causation, and Tinbergen's biological function and evolutionary issues have often been characterized as "why questions" and current process and developmental issues as "how questions" (e.g., Klopfer & Hailman, 1972). However, Mayr's deployment of "ultimate causation" was ambiguous, simultaneously seeking to encapsulate both the "function" of a character and its "evolutionary history" (Laland, Odling-Smee, Hoppitt, & Uller, 2012). In contrast, Tinbergen's formulation has the advantage of clearly distinguishing between the present and the past (see Table 6.1).

Unlike Mayr's scheme, Tinbergen's framework has attracted little criticism, and has stood the test of time (P. Bateson & Laland, 2013). The general point about the distinctions made by Tinbergen and repeated in almost every modern textbook about animal behavior is the valuable clarifications they brought to discussions among both biologists and psychologists. Biological function and current process were often confused and often still are. Consequently, when one scientist had been considering the current utility of a characteristic another might have thought the discussion was about the current processes that underlie that characteristic. Such misunderstandings can be avoided by appreciating that, unsurprisingly, different perspectives raise different questions. Indeed, the four questions apply broadly to any feature of living (and even some nonliving) systems. For instance, traffic lights could be thought of in terms of how they worked, how they were assembled, how their design evolved over time, and how their use increases the chances of survival of road users (Martin & Bateson, 2007).

TABLE 6.1 The Four Questions of Behavioral Biology and Psychology

	Current	Historical
Proximate	How does it work?	How did it develop?
Ultimate	What is it for?	How did it evolve?

Tinbergen (1963) posed four distinct questions that may be addressed when examining a biological or psychological phenomenon. Questions about current process and biological function deal with the present. Questions about evolution and development deal with the past. The mechanistic and developmental questions are sometimes called proximate and those about function and evolution are sometimes called ultimate.

Source: From *Measuring Behaviour: An Introductory Guide* (3rd ed.), by P. Martin and P. Bateson, 2007, Cambridge, England: Cambridge University Press.

Although Tinbergen's inclusion of development in his list of problems was important, he was not much interested in this aspect of ethology. Others were, however. Developmental ethologists, psychiatrists and psychobiologists formed strong links, leading to productive investigations of topics such as constraints on learning (Hinde & Stevenson-Hinde, 1973) and attachment of young to their parents (P. Bateson & Hinde, 1976; Bowlby, 1969). The interdisciplinary character of the work is apparent in two volumes of essays published in the early 1980s. They demonstrated that the problems of development have to be expressed very differently from the ways in which the ethologists had originally thought about them (P. Bateson & Klopfer, 1982; Immelmann, Barlow, Petrinovich, & Main, 1981). The book edited by Immelmann et al. emerged from a year-long meeting held in Bielefeld in Germany. The first editor and organizer of the meeting, Immelmann was trained as an ethologist, but the contributors to the book included theoreticians and child developmental psychologists.

The book edited by myself and Klopfer also included authors from a wide variety of disciplines, embracing the experimental analysis of behavior and theories of life history. It was already becoming obvious that highly beneficial interactions were developing between different disciplines, particularly between ethology and developmental psychobiology (Michel & Moore, 1995). The relevance of these interdisciplinary efforts to studies of human development has often been emphasized (Gottlieb, Wahlsten, & Lickliter, 2006).

BIOLOGICAL FUNCTION

Despite the broadening out of ethology, many research workers on animal behavior retained a strong interest in the adaptive value of behavior. Indeed this became the dominant focus of the behavioral ecologists. Even though the distinction between "what is it for?" and "how did it develop?" is a logical one, benefits flow from asking them simultaneously are often apparent. A growing number of examples have been found in both plants and animals of how the organisms characteristics are radically influenced by ecological conditions (Badyaev, 2009; Gilbert & Epel, 2009; West-Eberhard, 2003). These cases raise the question: Do plastic developmental responses represent adaptations to the environments in which they are found?

An example of the functional approach to development is provided by the changes that occur as a child develops.

Many aspects of body and behavior obviously change, sometimes relatively suddenly, during the course of an individual's development. Sudden discontinuous change is most obvious during the first two decades of a human life—for example, at birth and puberty. Such discontinuities are not mysteries. Many physical and biological systems are capable of changing in an abrupt, discontinuous way. Steadily increasing the pressure on a light switch does not produce a steady increase in the brightness of the bulb it controls. The switch has a point of instability, so that one moment the bulb is dark and the next moment it is fully lit. Similarly, a relatively small internal or external change can quickly transform a developing organism's characteristics to something that looks quite different. For instance, the fertilized egg of a mammal rapidly divides becoming a ball of cells, the blastula. The cells continue to divide, but do so at slightly different rates. The steady change is such that the blastula suddenly seems to collapse on one side like a deflated rubber ball and a two-layered structure called the *gastrula* is formed. The embryo has changed its appearance dramatically as a result of a process of continuous growth.

Adaptations to Early Life

Sudden shifts in behavior during an individual's development may have biological function, reflecting the changing ecology and needs of the individuals as they get older. Despite parental care, most individuals have to support themselves in at least some respects long before they are fully mature. Furthermore, they are emphatically not miniature adults. Given that the young have to survive in an environment that is radically different from that of the adult, it follows that they are likely to have specialized features for the conditions in which they live. The adaptations of larval forms with totally different phenotypes from those of adults provide the most striking examples. The caterpillar is specialized for eating and has none of the reproductive roles exhibited by the butterfly or moth that it will subsequently become. These changes over the course of the life history are found in invertebrates and in amphibia such as frogs. Mammals also have their juvenile adaptations. In rats the control system involved in suckling is distinct from that involved in adult eating (Hall & Williams, 1983). The suckling system cannot be satiated easily and time since the last meal does not affect the readiness of the pup to take a nipple and suck. Presumably the more milk the offspring can get, the better off it is. The end of a bout of feeding is provided by the mother's limitations in providing milk. Within a few days of birth and long before the weaning process starts, the pup can be induced to lap milk like an adult. When it feeds in this way, time since the last meal *does* affect its responsiveness. In other words, both juvenile and adult feeding systems are independent, work differently and are fully developed at the same time. Normally the rat's adult feeding system does not come into operation until at least 2 weeks after the juvenile one. The same point that suckling is a special form of feeding adapted for early life has been made in relation to human babies (Alberts & Pickler, 2012).

Behavior in Development as Scaffolding

Does a given behavior pattern function as part of the assembly process, falling away like scaffolding round a building when the animal matures? The biological function of some of the behavioral processes found in many developing animals seems to be the gathering of information. For instance, precocial birds such as chicks and ducklings actively work to present themselves with a form of input that will start off the process of behavioral imprinting (P. Bateson & Reese, 1969). Another plausible example is mammalian play. The duration and frequency of play categories have been found first to increase with age and then to decline (P. Bateson & Martin, 2013). Adults may not give up playing altogether, but unquestionably they do less of it than juveniles.

Play may enhance skills involved later on in life and have an impact on the child's creativity (P. Bateson & Martin, 2013). In such cases play has delayed benefits and is a preparation for the challenges of adult life. This being so, play does, indeed, function as scaffolding that has little use once the edifice of skills have been assembled. Some of the benefits of play may, however, be immediate and in such cases play should be thought of as partly a juvenile specialization. In short, many of the things that the young do are not incompetent or incomplete versions of adult behavior. The growing awareness of such facts has been an important benefit of adopting a functional approach to development that focuses on the usefulness to the individual in terms of its survival and reproductive success.

Adaptations Leading to Individual Differences

The variation in behavior found in most if not all species commonly arises because individuals have the capacity to respond in more than one way according to the state of the local environment or their own body. Individuals have many latent capacities that are expressed only under certain conditions. The developmental processes of *plasticity* that are elicited by those conditions normally provide useful adaptations to the environment. The implication of many of the examples of developmental plasticity is that environmental induction provides a forecast about the conditions of the world that the individual will subsequently inhabit. In mammals the best route for such a forecast may be via the mother. Vole pups born in the autumn have much thicker coats than those born in spring; the cue to produce a thicker coat is provided by the mother before birth (Lee & Zucker, 1988). The value of preparing in this way for colder weather is obvious. The individual may be likened to a jukebox, capable of playing many tunes but, in the course of its life, possibly playing only one of a set. The particular suite of adaptations that is expressed is elicited by the conditions in which it grows up or even by the conditions to which the individual's parents and grandparents were exposed.

Maternal forecasting by induction is now thought to be important in human biology and has important implications for adult health when, because of large changes in economic conditions, the maternal forecast is wrong (P. Bateson et al., 2004; Gluckman & Hanson, 2006). Generally such systems of developmental plasticity work well, but in a changing environment they generate poorly adapted phenotypes because the environmental forecast proved to be incorrect. The triggering of normally appropriate modes of response provides a fresh way of thinking about individual differences.

The functional argument is that the pregnant woman, living on a relatively low plane of nutrition, unwittingly signals to her unborn baby that the environment her child is about to enter is likely to be harsh. This weather forecast from the mother's body results in her baby being born with adaptations, such as a small body and a modified metabolism, thereby helping the child to cope with a shortage of food if the forecast is correct. These individuals, having small bodies and specialized metabolisms adapted to cope with meager diets, run into problems if, instead, they end up growing up in an affluent industrialized society to which they are poorly adapted. Among a group of individuals, who were born at term and breastfed as babies, those who had the lowest weights at birth had the highest death rate from cardiovascular disease (Barker, 1995). The argument is that mothers on a low level of nutrition signaled to their unborn child that the environment outside would be harsh. As a result, the babies were born with the suite of adaptations that would have suited them well to diets low in carbohydrates and fat. However, they were poorly adapted to the affluent environment in which they subsequently grew up. A great many other studies from around the world have supported this conclusion and shown that many conditions such as type 2 diabetes are exhibited by people born small but subsequently reared on rich diets. The opposite side of the coin is that people who grow up in plentiful environments may be at greater risk during periods of prolonged famine than those who were born as low-birth-weight babies. Children born to affluent parents are more likely to suffer adverse effects if they are starved in adulthood. In concentration camps and the worst prisoner-of-war camps, anecdotal evidence suggests that the physically large individuals died first whereas at least some of the small individuals survived. In a famine-exposed Ethiopian population, higher birth weight was associated with a ninefold higher risk of rickets (Chali, Enquselassie, & Gesese, 1998). This might have been caused by the children with large bodies having higher needs for calcium and vitamin D than those with smaller bodies, but the point is that these children were at greater risk and had a lower chance of reproducing successfully than the smaller children. Many other forms of plasticity exist each depending on environmental contingencies and each generating further differences between individuals (P. Bateson & Gluckman, 2011).

MEANINGS OF INNATENESS AND INSTINCT

Despite the healthy links that have been formed between different disciplines, the debate about development has been confused because the term *instinct* means remarkably different things to different people. To some, instinct means a distinctly organized system of behavior patterns, such as that involved in searching for and consuming food (Tinbergen, 1951). For others, an instinct is simply behavior that is not learned (Lorenz, 1965). Instinct has also been used as a label for behavior that is present at birth (the strict meaning of *innate*) or, like sexual behavior, patterns that develop in fully expressed form at a particular stage in the life cycle. Another connotation of instinct is that once such behavior has developed, it does not change. Instinct has also been portrayed as behavior that develops before it serves any biological function, like some aspects of sexual behavior (Hogan, 1988). Instinct is often seen as the product of Darwinian evolution so that, over many generations, the behavior was adapted for its present use (Lorenz 1965). Instinctive behavior is supposedly shared by all members of the species (or at least by members of the same sex and age) (Berridge, 1994). It has also been used to refer to a behavioral difference between individuals

TABLE 6.2 The Different Meanings of Innateness and Instinct

Present at birth or particular stage of development
Not learned
Genetic—highly heritable
Adapted during evolution
Develops before function is established
Shared by all members of species/sex/age group
A functional behavioral system
Controlled by a specialized neural module
Developmentally robust—well-canalized

Evidence for one of these meanings does not necessarily imply evidence for another.
Source: From "Developmental Approaches to Behavioural Biology," by P. Bateson and J. C. Curley, 2013, *Nova Acta Leopoldina*, *111*, 89–110.

caused by a genetic difference (Hinde, 1969). Confusions arise, therefore, because instincts are seen both universal and part of individual differences (see Table 6.2).

The overall effect of the multiple meanings and multiple origins is, to say the least, muddling (P. Bateson & Curley 2013; P. Bateson & Mameli, 2007; Blumberg, 2005; Mameli & Bateson, 2006, 2011). The conflation of different meanings appeared to justify the view that a single coherent and unitary notion of instinct is needed. If one defining characteristic of instinct has been found, then the rest will also be found. In practice, many behavior patterns have some, but not all, of the defining characteristics of instinct, and the unitary concept starts to break down under closer scrutiny. The various theoretical connotations of instinct—namely that it is not learned, caused by a genetic difference, adapted over the course of evolution, unchanged throughout the life span, shared by all members of the species, and so on, are not merely different ways of describing the same thing. Even if a behavior pattern is found to have one diagnostic feature of instinct, it is certainly not safe to assume that it will have all the other features as well.

In addition, many of the theoretical implications of the classical concept of instinct are difficult to test in practice. If instinct is defined as behavior that does not involve learning in its development, experiments to exclude all opportunities for learning are harder to conduct than might at first appear. One formidable obstacle to proving that a behavior pattern is not learned is the capacity that individuals have to acquire the necessary experience in more than one way. When an individual is isolated from one particular form of experience that is thought necessary for development, the behavior pattern may nonetheless develop by an alternative route (Martin & Caro, 1985). It is difficult to draw a clear distinction between experiences that have specific effects on the detailed characteristics of a fully developed behavior pattern and environmental influences that have more general effects on the organism, such as nutrition or stress. Experiences vary in the specificity of their effects (P. Bateson, 1976). Even if all obvious opportunities for learning a particular behavior pattern are excluded, a major problem remains. This problem is that individuals can readily generalize from the effects of one type of experience to another. It is therefore difficult to know whether an individual has transferred the effects of one kind of experience to what superficially looks like a quite different aspect of their behavior. For example, if somebody draws a letter of the alphabet on your hand while your eyes are shut, you should still be able to visualize the letter, even though you have not seen it. In doing this you will have demonstrated a phenomenon called cross-modal matching (Proops & McComb, 2012).

Another pitfall in the quest for instinct is that developing individuals cannot be isolated from themselves, and some of their own actions may provide crucial experience that shapes its subsequent behavior (Gottlieb, 1971, 1991). Finally, in human babies preference for the mother's distinctive voice at birth depends on experience that occurred before birth (DeCasper & Fifer, 1980). The use of different developmental routes to the same endpoint, cross-modal matching, the impact of self-stimulation, and experience at times that had not seemed likely to affect behavior all sound notes of warning. It is not as easy as it might seem to demonstrate that a behavior pattern has not been shaped by some form of experience that has a particular influence on the behavior.

In summary, then, the clutter of ideas associated with the uses of innateness and instinct has not served well the study of behavioral development. If innate behavior is defined as that which is not learned, what is it to be called if it is subsequently modified by learning? *Innateness* conflates different properties that ought to be kept separate according to the best biological and psychological knowledge. As these issues are clarified, many nativists and antinativists who thought they disagreed with each other will find that they do not (Mameli & Bateson, 2011).

Evolutionary Psychology

Despite all the difficulties, the idea that instinct is in some sense "genetic" was deeply embedded in conventional thinking and survives to this day particularly in the writings of some evolutionary psychologists and cognitive psychologists (e.g., Belsky, 2012; Ellis, Schlomer, Tilley, & Butler, 2012; Pinker, 2002; Tooby & Cosmides, 1992). Central to their thinking has been that adaptations to an earlier phase of human history continue to be inherited and the mode of transmission is genetic. When a pattern of behavior is referred to as being "genetically encoded," the metaphor of coding implies a one-to-one relation and seems warranted when talking about the way DNA sequences are related to some of their immediate molecular products, such as polypeptide chains. However, the idea that DNA codes for behavior is highly implausible given what is known about the dynamics of development. A genetic difference between two individuals may give rise to a behavioral difference, but that does not imply that in either individual a gene codes for that individual's distinctive behavior (e.g., P. Bateson & Martin, 1999; Charney, 2012; Johnston & Edwards, 2002; Keller, 2010; Lickliter & Honeycutt, 2010, Chapter 5, this *Handbook*, this volume; Oyama, 1985; Slavich & Cole, 2013).

If it is argued that a characteristic is genetically determined if and only if genes and nothing but genes are involved in its development, the notion of genetic determination relates to no phenotypic characteristic other than proteins. Moreover, if it is argued that the development of a characteristic involves gene expression, the notion of genetic involvement applies to virtually all of an individual's characteristics (Mameli & Bateson, 2006). Those who concern themselves with developmental processes mostly agree that, except for the immediate molecular products of DNA processing, all adult characteristics are the result of causal processes that involve both genetic and nongenetic factors (P. Bateson & Gluckman, 2011; Oyama et al., 2001; Sterelny & Griffiths, 1999). The much more holistic approach to development among behavioral biologists complemented what had been happening in other fields (Lerner, 1984; Lerner & Overton, 2008; Overton, 2013, Chapter 2, this *Handbook*, this volume; Overton & Lerner, 2012).

As a result of changes in thinking about development, much criticism has been directed at the arguments of the evolutionary psychologists (Rose & Rose, 2000). But some the critics have treated evolutionary arguments as though they were alternatives to developmental ones. As clearly recognized the "How did it evolve?" question should not be confused with the "How did it develop?" question. They are complementary. Even developmental analyses of forms of behavior that involve great plasticity leaves open the issue of how it might have evolved. To take a striking example from the modern literature, humans are much more likely to behave ethically if they are unconsciously aware of a pair of eyes watching them. M. Bateson and colleagues found that when members of their laboratory were asked to pay for the coffee and milk on a weekly basis, they contributed 3 times as much when the request was accompanied by a picture of eyes instead of a picture of flowers (M. Bateson, Nettle, & Roberts, 2006). Remarkably, the milk and coffee consumers were unaware that they had been manipulated in this way. In a subsequent experiment pictures of eyes in a bicycle shed significantly reduced the number of thefts of bicycles in the shed (Nettle, Nott, & Bateson, 2012). These findings invite the question, how did such an effect of eyes on human behavior evolve and, quite independently, how did it develop in each individual.

One of the difficulties in this field has been how explanations for one type of evidence in this field immediately evoke seemingly contrary explanations and even disbelief in the evidence that was being explained in the first place. Such academic disputes are not new. Oppenheim (1982), in an extensive and scholarly review of the back and forth debates about development, showed how people who espoused a nuanced view were often accused of being more extreme and more radical than in fact had been the case.

HERITABILITY

The concept of heritability is often mentioned in connection with the confused concept of innateness, particularly when it is used in the sense of behavior that is inherited. Given that behavioral development depends on both genes and the environment, many scientists have sought to partition the influences of the two classes of influence (Bouchard, Lykken, McGue, Degal, & Tellegen, 1990; Downes & Machery, 2013; Loehlin, Willerman, & Horn, 1988). The connection between the idea that a characteristic is innate and the idea that the same characteristic is hereditary seems obvious to many people even though the implication is incorrect. Some clarification is needed. In fact, heritability is not a single concept but a family of concepts. Broad heritability is defined as the ratio of the variance of the phenotype due to genetic variation to the total variance of the phenotype in the population. That is, a characteristic has high broad heritability in a population to the extent that the existing variation for that characteristic in the population is due to genetic variation. Narrow heritability gives the extent that the existing variation for the phenotype is due to variation in genes considered independently of their interactions with other genes at the same or at different loci. Selectional heritability, used by evolutionary biologists, measures the phenotype's response to Darwinian natural selection relative to the intensity of the pressure for change. Covariational heritability measures the strength of the correlation between close relatives for the phenotype in the population under study; this concept is most closely related to colloquial ideas about inheritance. Many textbooks (e.g., Futuyma, 1997; Ridley, 2003) claim that narrow heritability, selectional heritability, and covariational heritability are effectively equivalent. This is an oversimplification that can lead to the ignoring of important biological and psychological phenomena and the dynamics of development (Falconer & Mackay, 1996; Lynch & Walsh, 1997).

The focus now is on broad heritability because this is the concept most commonly used in discussions of human development. It has seemed, to those who use it, to be a helpful way of side-stepping the age-old nature-nurture conflict. Heritability is a *statistical concept* that applies to the variation in a given phenotype existing in a population at a given time. The question is how much of the variation found within a population in a given characteristic is due to differences in their genes, and how much is due to differences in their environments. Within a single individual this question cannot be answered, but it can be posed for a population of individuals (P. Bateson & Gluckman, 2011; P. Bateson & Martin, 1999; Keller, 2010; Lewontin, 1974).

The concept of broad heritability is best illustrated with an uncontroversial characteristic such as human height, which clearly is influenced by both the individual's lineage (genetic influences) and nutrition (environmental influences). The variation between individuals in height that is attributable to variation in their genes may be expressed as a proportion of the total variation within the population sampled. This index is known as the heritability ratio. If people differed in height solely because they differed genetically, the heritability of height would be 1.0; if, on the other hand, variation in height arose entirely from individual differences in environmental factors such as nutrition, then the heritability would be 0.

Calculating a single number to describe the relative contributions of genes and environment has obvious attractions. Estimates of heritability are of undoubted value to animal breeders, for example. Given a standard set of environmental conditions, the genetic strain to which a pig belongs will predict its adult body size better than other variables such as the number of piglets in a sow's litter. If the animal in question is a cow and the breeder is interested in maximizing its milk yield, then knowing that milk yield is highly heritable in a particular strain of cows under standard raising conditions is important.

Behind the deceptively plausible ratios lurk some fundamental problems (P. Bateson & Martin, 1999; Lewontin, 1974). For a start, the heritability of any given characteristic is not a fixed and absolute quantity—tempted though many scientists have been to believe otherwise. Its value depends on a number of variable factors, such as the particular population of individuals that has been sampled. For instance, if heights are measured only among people from affluent backgrounds, then the total variation in height will be much smaller than if the sample also includes people who are small because they have been undernourished. The heritability of height will consequently be larger in a population of exclusively well-nourished people than it would be among people drawn from a wider range of environments. Conversely, if the heritability of height is based on a population with relatively similar genes—say, native Icelanders—then the figure will be lower than if the population is genetically more heterogeneous; for example, if it includes both Icelanders and African Pygmies. Attempts to measure the relative contributions of genes and environment to a particular characteristic are highly dependent on who is measured and under what conditions.

What Does Heritability Explain?

The heritability ratio says nothing about the ways in which genes and environment contribute to the biological and psychological processes involved in an individual's development. This point becomes obvious when considering the heritability of a characteristic such as "walking on two legs." Humans walk on less than two legs only as a result of environmental influences such as war wounds, car accidents, disease, or exposure to toxins before birth. In other words, all the variation within the human population results from environmental influences, and consequently the heritability of walking on two legs is zero. And yet walking on two legs is clearly a fundamental property of being human, and is one of the more obvious biological differences between humans and other great apes such as chimpanzees or gorillas. It obviously depends heavily on genes, despite having a heritability of zero. A low heritability clearly does not mean that development is unaffected by genes. If a population of individuals is sampled and the results show that one behavioral pattern has a higher heritability than another, this merely indicates that the two behavioral patterns have developed in different ways. It does not mean that genes play a more important role in the development of the behavioral pattern with the higher heritability. Important environmental influences might have been relatively constant at the stage in development when the more heritable pattern would have been most strongly affected by experience.

The most serious shortcoming of heritability estimates is that they rest on the implausible assumption that genetic and environmental influences are independent of one another and do not interact. The calculation of heritability assumes that the genetic and environmental contributions can simply be added together to obtain the total variation. In many cases this assumption is clearly wrong. This type of interaction between the organism and its environment is fundamental to understanding behavioral development. In the postgenomic era, the simplistic notions that lie behind heritability estimates are increasingly criticized (e.g., Charney, 2012; Gottlieb et al., 2006; Greenberg, 2011; Joseph, 2010; Keller, 2010; Overton, 2013, Chapter 2, this *Handbook*, this volume; Partridge, 2005; Wahlsten, 2012).

Importance of Person ←→ Environment Coactions

It is only fair to say that nobody who studies the effects of genetic variation denies that nonlinear statistical interactions between genetic and environmental sources of variation can occur. Nonetheless, those with a strong commitment to using heritability estimates will go to great lengths to eliminate multiplicative interactions by rescaling their data. Unfortunately, independent grounds for validating a particular method of rescaling are rarely available. As a consequence, eliminating statistical interactions becomes the sole justification for transforming the data. Take for instance the advice given by Mather and Jinks (1971) in the standard work on biometrical genetics:

> The scale should preferably be one on which the analysis is as simple as possible, which means one on which interactions among the genes and between genotype and environment are absent, or at any rate as small as they can reasonably be made. (p. 64)

The trouble with following this recommended procedure is that awkward evidence is removed from sight. A superficial glance at the literature would suggest that the assumption of additivity had been justified (e.g., Broadhurst, 1979). The practice also meant that heritability estimates were given a much greater dignity than they ever deserved. Worst of all, the rescaling practice encouraged the view that the influences on the outcome of development act directly and straightforwardly, adding together but rarely coacting in combinatorial or reciprocal, bidirectional (←→) fashion. The widespread habit of using powerful statistical tools such as Analysis of Variance has also led to a confusion of statistical interaction with the coactions of actual process. It is all too frequently supposed that absence of statistical interaction means no interplay. The misconceptions and false inferences that can arise are many (Rutter, 1983).

In studies of children who have been adopted, it is sometimes possible to compare their performances on a given scale of measurement with those of their adopting parents and their true parents. In such studies it commonly seems to be the case that no statistical interaction is found between the scores of the two types of parents (see Plomin, DeFries, & Loehlin, 1977). The effects of the genes, provided by the true parents, and the effects of the environment, provided by the adopting parents, seem to add together in simple linear fashion. However, the quality of the environment provided by the adopting parents might not merely depend on their own IQs but also on the difference between their characteristics and those of the child. Disappointed adopting parents might provide a much less supportive environment for a dull child than those whose expectations were fully satisfied by the responsiveness of a bright child. It is highly likely that the expression of a child's potential depends on an interplay between her and the conditions in which she had been reared. A potentially bright child adopted by dull people might be much less challenged and much more frustrated than if she had been adopted by bright people. Here again the difference between the child and her adopting parents matters, but this time in the reverse direction. To test this idea properly it would be necessary to measure the child's abilities throughout development. However, if a true parent's IQ is taken as an indirect measure of a child's ability as it starts to influence and be influenced by her adopting parents, then the dynamics can be tested by examining the effect on the child of the absolute difference between the birth mother's IQ and the adopting mother's IQ.

When the appropriate analysis was carried out on data from Colorado provided by Plomin, the correlations between the children's Stanford-Binet IQ and the absolute difference between the true and adopting mothers' IQs were negative (−0.12 at 3 years of age and −0.23 at 4 years of age) (see P. Bateson, 1987). Though these negative correlations are far from being random associations, they are low. However, it would be surprising if, in the real world, the only sources of variation in IQ were the influences coming from the true and adopting mothers and the mismatch in IQ between them. An interesting feature is that the negative correlation was larger in the older children, suggesting that the dynamic approach would be profitable in such studies. In a subsequent simulation, Analysis of Variance failed to pick up the interaction between birth mother's IQ and the adopting mother's when the difference between them was great even though the dependent variable was affected by the difference between the independent variables (P. Bateson, 1989).

Much used analytical methods that look for statistical interaction can completely miss substantial interplay between the major factors that generate the measured outcome. This point has been made many times, but perhaps most amusingly by Levins and Lewontin (1985) in their spoof statistical analysis of data testing Newton's Laws of Motion. Additive models of development may make it easier to use the available statistical packages, but they are liable to be highly misleading in studies where nonlinear relations between variables are known to occur. What is worse, results that are inconvenient to the additive interpretation are all too easily swept out of sight.

The computer and its statistical packages do not magically generate the dynamics for the research worker. These are points that are well-known to the most influential people working on the genetics of human abilities, emphasizing the reciprocal bidirectional (←→) actions on each other of genes and environment (Plomin, Loehlin, & DeFries, 1985). Their arguments certainly raise issues about the nature of developmental process. Similarly, Scarr and McCartney (1983) have recommended that research workers look at the way individuals with particular genotypes actively select the environments into which they fit best. Even though it is highly unlikely that a person's genotype expresses itself in the same way irrespective of conditions, Scarr and McCartney's (1983) suggestion would encourage the investigation of what happens to individuals during development.

On grounds of biological and psychological plausibility alone, the notion of genetic and environmental factors adding together to produce their effects should be treated with the utmost skepticism. On the positive side, scientists ought, at the very least, to think about the nature of the developmental processes and, in so doing, ask more interesting questions of the available data. Better still, they should actually study the processes in action. When this analysis is done, an important conclusion is that the way an individual develops usually depends on conditions, but the conditions also often depend on the individual's mutually influential relations with his or her context, that is, on individual ←→ environment relations.

ROBUSTNESS OF DEVELOPMENT

When Linnaeus developed his classification of living organisms in the 18th century, he was probably clear in his own mind just what constituted a species. Each one was clearly distinct physically and could be recognized as such. It was God-given. Even when the development of evolutionary theory took off with the publication of Charles Darwin's *On the Origin of Species*, biologists continued to use the familiar Linnean binomial of genus and species for each organism. This was because species recognition was assumed by many to be straightforward and because of the presumed continuity over time from distinct ancestor to distinct descendant. Such views were challenged at the time, most notably by the French biologist Jean-Baptiste Lamarck, and in modern times the definition of a species is a source of much controversy among biological theorists. Nevertheless, the readily recognized features of a given species are generally familiar to anyone who has used one of the innumerable field guides or botanical keys. Something about a sparrow ensures that no member of its species becomes a crow. Gross atypical morphologies occur, but they are usually dysfunctional and in the past were termed *monsters*. Many structural attributes of an organism, such as the number of limbs or digits, are invariant and the molecular basis of this consistency of developmental pattern is increasingly understood (Carroll, 2005).

The resistance of bodies to deviation from the form or forms that are typical for the species is also expressed in behavior. The views of the founders of modern ethology, Lorenz and Tinbergen, on instinct were based on many compelling observations of animals' behavior in both captive and natural conditions (Burkhardt, 2005). These have been added to by a great wealth of evidence in subsequent years, and many examples of courtship, defensive behavior, specialized feeding methods, communication, and much else have become familiar to a wide audience through remarkable television films. Some behavior patterns are highly stereotyped in their form and are stable across a wide range of environmental conditions.

Insensitivity to Changes in the Environment

Beyond species-level consistency, the constancy of an individual's characteristics is maintained in the face of both environmental and genetic variation. The developmental biologist Nijhout has proposed a formal approach to *robustness* in which he suggested that the developing organism is robust if it is unable to detect changes in the environment or is resistant to them (Nijhout, 2002). If a developing organism cannot detect an environmental change, then it cannot respond to it. The organism may not have the sensory equipment that is sensitive to change, or a barrier may exist between itself and the change. For example, the dependence of the bird embryo on its yolk sac for nutrition means that it is insensitive to changes in the nutritional environment of the mother after the yolk sac has been formed. In that respect the bird embryo differs from the mammalian fetus, which is sensitive to some aspects of the nutritional environment of its mother throughout gestation.

A multicellular organism cannot maintain infinite plasticity in all its attributes. Stability of organization requires a series of irreversible steps; for example, the differentiation of embryonic stem cells into particular cell types is a fundamental aspect of development. Once committed to differentiation, cell lineages do not normally dedifferentiate. Rapidly dividing cancer cells were thought to be an exception to this rule, but most cancers arise from latent stem cells rather than dedifferentiation of specialized cells (Rosen & Jordan, 2009). In most sexually reproducing species, sexual differentiation is irreversible and sets a constraint on what can subsequently occur; some fish such as the wrasse being notable exceptions.

As a result, some changes in form and state may simply not be possible. Some constraints are imposed temporally by what has happened earlier in development and the architecture of the underlying molecular networks (Arthur, 1997). The analogy to a building is obvious: Just as it is impossible to redesign the foundations once a skyscraper is almost complete, once the basic organization of an organism is established, it cannot be revisited. Even when the organism changes its form through metamorphosis, the basic generalized body plan is maintained.

Other constraints are imposed by the provision of limiting factors such as nutrients. For example, the mammalian fetus is constrained in its growth by placental function and, in particular, nutrient and oxygen delivery. As a result of these processes, the mammalian fetus generally does not grow at a maximal rate; rather, fetal growth is coordinated with maternal size. Maternal constraint can be demonstrated by embryo transfer experiments. If an embryo is transplanted into a larger uterus, the fetus will grow larger, demonstrating the importance of nutrient supply in determining birth size. The classic demonstration of this principle was the work of Walton and Hammond (1938) studying the outcome of crossbreeding between small Shetland ponies and large Shire horses. The fetus of a crossbreed grew proportionately to the size of the dam. The fetus of a Shire mother crossed with Shetland father grew much larger than the fetus of the reciprocal Shetland mother/Shire father even though the genetics of each cross were similar. Since the 1990s the nongenetic nature of this phenomenon has been well established in embryo transplant experiments, so that in human pregnancies conceived using donor eggs, birth size is more closely related to the recipient mother's size than to the donor mother's size (Brooks, Johnson, Steer, Pawson, & Abdalla, 1995).

Constancy Resulting From Elasticity and Intrinsic Stability

Elasticity is a term that originally came from the analysis of inanimate materials and was used in contrast to plasticity. It was used to define a structure that can be deformed by a physical force, but once the force is removed, the structure would regain its previous form. For example, a rubber band can be stretched but will then revert to its original size. Some of the resilience or robustness seen in organisms after an initial response to a change in the environment might be explained in similar terms, although other aspects of such resilience, such as wound repair or catch-up growth after starvation or disease, probably involve active regulation.

Another proposal for robustness comes from dynamical systems theory (see Witherington, Chapter 3, this *Handbook*, this volume). Certain states are more stable than others, so that in dynamic systems they will be favored over time, thus acting as attractors. For example, a swinging pendulum will invariably come to rest in the same position—perpendicular to the ground—regardless of the position from which it was released. In biological terms, the characteristics of a system are stabilized by its attractor, and in that sense the system is robust. Attractors draw to themselves phenotypic characteristics that might have ended up in a variety of different places depending on local conditions (Huang, 2009). When formalized mathematically, an attractor can be a point, a curve, or a complicated set known as a "strange attractor." The way in which the phenotypic characteristics of an organism are drawn to an attractor does not have to satisfy any special constraints. The process might involve straightforward physical principles, as Newman (2007) has argued with respect to the formation of segments in the embryo.

Different Routes to the Same Endpoint

Usually the explanation for robustness based on attractor theory does not propose a particular process, but simply states that attractors are a fundamental feature of complex systems. However, feedback loops and dynamical interactions may limit the number of end states that are possible (Nijhout, 2002). Such explanations offer another way of thinking about how a specific end state can be achieved in many different ways—that is, the phenomenon of *equifinality* that interested the first systems theorists (von Bertalanffy, 1974). To take a biological example, cats can acquire and improve their adult predatory skills via a number of different developmental routes: by playing with their siblings, by playing at catching prey when young, by watching their mother catch live prey, by practicing catching live prey when young, or by practicing when an adult. Hence a kitten deprived of opportunities for play may still develop into a competent adult predator, but by a different developmental route (Martin & Caro, 1985). The general point is that organisms may reach the same endpoint via many different pathways.

In complex machines designed by humans, such as an airplane, back-up systems are commonly provided so that if one fails another can be brought into operation. Human lives depend on them. Such redundancy is also found in organisms. The provision of alternative systems protects against failure, and from time to time animals will inevitably be faced with the situation where no amount of tactical maneuvering will enable one of their developing systems to proceed along a particular route. Such an animal is in a position similar to a human arriving at a railway station only to find that the trains have been canceled. The traveler can still reach his or her destination but only by choosing a different method of getting there. The idea of *equifinality* is essentially an hypothesis about the existence of redundant processes, without specifying how they work.

One of the most unexpected aspects of studies in functional genomics has been the number of cases where the removal of a gene by way of recombinant technology, leading to the "knockout" of a gene in a mouse or other model organism, had no obvious effect on the phenotype. For example, mice lacking the *Hox C* gene cluster, which is known to be involved in body pattern formation, still possess the correct overall body plan (Suemori & Noguchi, 2000). Redundancy is common at the molecular level. Many genes are duplicated, particularly in vertebrate evolution. Gene duplication is a common phenomenon in molecular evolution, and up to 5% of the human genome consists of duplicated segments (Eichler, 2001).

Many organ systems are capable of a degree of robustness through repair, which manifests as hypertrophy (e.g., heart muscle), hyperplasia (e.g., skin, bone) or activation of stem cells (e.g., bone marrow). In vertebrates, one of the most dramatic examples is that of limb regeneration in the salamander. Uniquely, these animals can fully rebuild a lost limb even in adulthood. In contrast, other amphibians such as frogs may be able to do so in the larval form but not in the mature form. Some evidence suggests regenerative capacity even in the mammalian embryo (Stocum, 2006).

Regulation

The well-regulated body has been a hallmark of physiology since Claude Bernard's writing about the maintenance of *le milieu intérieur* in the 19th century and Cannon's elegant exposition of *homeostasis* in the first part of the 20th century. Stability is an inherent feature of feedback loops and many physiological systems involve direct or indirect feedback, creating a relatively robust state. The set point of a physiological feedback loop is central to the concept of homeostasis and provides one form of robustness. These set points may change across the life course in a process known as *homeorhesis* in a developmental context (Waddington, 1957), or as *rheostasis* for all cases where the physiological set point can change (Mrosovsky, 1990).

External feedback may also involve other individuals. If a goat has twins, the mother will lick the stronger of the twins, pushing it away from her teats and so promoting the weaker one's development. As the initially weaker kid receives more milk and outpaces its sibling's growth, the mother will now lick it more intensively to allow the now less vital sibling to have more milk; this reciprocal feedback between mother and her two kids continues until the kids have viable independence (Klopfer & Klopfer, 1977).

In the development of an individual, the maturation pattern of organs and behavior is well-regulated. In presenting his image of developmental canalization, Waddington (1957) offered a visual aid to those who have difficulty in grasping the abstractions of a purely mathematical model. He represented the development of a particular part of an embryo from a fertilized egg as a ball rolling down a tilted plane which is increasingly furrowed by valleys (see Figure 6.1).

He called the surface down which the ball rolls the *epigenetic landscape*. The mounting constraints on the way in which the phenotypic character can develop are depicted by the increasing restriction on the sideways movement of the ball as it rolls toward the front lower edge of the landscape. The landscape therefore represents the processes that regulate development. Waddington's model is attractive to

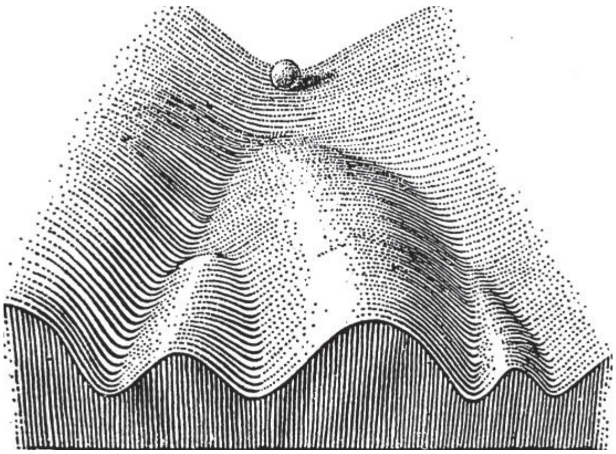

Figure 6.1 The epigenetic landscape as envisaged by Waddington (1957). The ball at the back of the drawing represents an undifferentiated cell. As the ball rolls down one of the valleys, its fate is increasingly determined and constrained as it reaches each choice point in the landscape. Study of the factors that determine the choices and the character of the differentiated cell are all part of the subject that Waddington called epigenetics.

the visually minded because it provides a way of thinking about developmental pathways and the astonishing capacity of the developing system to right itself after a perturbation and return to its former track. The phenotypic character is developmentally *canalized*. He regarded canalization as the capacity of development to produce a particular definite end-result in spite of a certain variability both in the initial situation from which development starts and in the conditions met during its course (Waddington, 1957).

I once tried to illustrate Waddington's landscape to students by stretching a sheet of elastic across a wooden framework and then, as in another of Waddington's famous illustrations in his 1957 book, tying strings from the undersurface of the elastic to pegs representing genes. Try as I might, it proved impossible to create more than one valley by varying the length of the strings. To create the multiply furrowed landscape I had to have strings attached to hooks above the elastic surface. I thought that this made a nice didactic point about the multiple factors, some internal and some external, influencing development. However, an even more interesting issue emerged when I experimented with cutting the strings from above or below. Sometimes nothing changed and the surface still retained its original shape. Cutting others of the strings had a dramatic effect and the shape of the surface was radically altered (see P. Bateson, 2013). Sometimes the course of development is unaffected by changes in the environment or the genome, but sometimes it can be massively altered.

Many Processes Leading to Robustness

Overlapping with the concepts of redundancy and regulation in providing ways of generating robustness is that of *developmental selection*. Throughout the process of forming the body and the brain, and hence behavior, the characteristics that develop are the ones that work best as an integrated whole. According to this view, integration of the whole body involves differential survival of particular functional systems and their subcomponents. A normal component of brain growth involves the formation of many more neurons than are required. Only those neurons that are attracted to others, and that form connections appropriately and establish functional networks are maintained. Cell death and neuronal pruning are well under way from before birth in species such as the human. Use modifies the rate and pattern of loss and confers a robustness of function.

Robustness is not necessarily an all-or-nothing phenomenon, need not affect all systems or organs of the organism in the same way, and has multiple dimensions. Many different processes, working in different ways, can ensure that members of the same species end up looking alike. These processes can operate at many different levels, ranging from the molecular to the behavioral.

PLASTICITY IN DEVELOPMENT

The term *plasticity* refers to the changeable character of matter. It is used in physics for inanimate materials and there it is contrasted with *elasticity*. If a coiled spring is pulled beyond the limits of elasticity, it will be permanently elongated. Provided that the spring does not break, the change is plastic. In the 19th century, the term was introduced into medicine to refer to the renewal of injured tissue and into popular literature to refer to impressionable minds. Plasticity was a dominant theme of James Mark Baldwin's (1902) book. It has returned in many other works about behavior and the nervous system (e.g., Gollin, 1981; Horn et al., 1973; Lerner, 1984; Rauschecker & Marler, 1987). It has been the subject of several symposia (Foster & Sih, 2013; Kappeler, Barrett, Blumstein, & Clutton-Brock, 2013).

Nowadays, plasticity, defined broadly in terms of malleability (see Pigliucci, 2001), is applied across a broad range of biological phenomena, and this extensive usage can cause confusion if the particular use is not well-defined. Muscles that are not used diminish in size and those that are exercised become larger. These are reversible phenomena. Many other cases occurring early in development usually are not. When one kidney fails to form, the other kidney undergoes compensatory hypertrophy and the outcome is stable. The behavioral repertoire of an individual can be changed by one of the many different types of learning, and at the molecular level the immune system responds to infection by developing a long-lasting reaction to the specific virus or parasite that caused the infection. In social insects, the particular way in which the larvae are nourished establishes whether the individual devotes her life to reproduction or to caring for the colonial nest. Such induced qualitative differences (that is, discontinuities in the range of phenotypes induced) that are found between members of the same species are sometimes referred to as *polyphenisms* (Mayr, 1963) or *morphs*. Alternatively the plastic response may induce quantitative differences across a continuous range and these are referred to as *reaction norms* (Stearns, 1992).

Examples of plasticity include coping with disruption of normal development, different phenotypic outcomes generated by different cues early in development, learning, and the plasticity found in the nervous and the immune systems. The key question is whether these vastly heterogeneous phenomena have anything in common with each other. Whether they are necessarily or even plausibly related, however, they are all of great biological and psychological significance.

Accommodating to Disruption of Normal Development

An individual whose body has been damaged in an accident or who is burdened with a mutation that renders his or her body radically different from other individuals may be able to accommodate to such abnormality (West-Eberhard, 1983). In doing so the individual may develop novel structures and behavior not seen in other individuals of the same species. Such accommodation can be particularly marked when it occurs early in development. An oft-cited example is that of a goat born without forelimbs that walked about on its hind legs and developed a peculiar musculature and skeleton (Slijper, 1942). The coping ability shown by the bipedal goat and the resulting effects on its behavior and skeleton illustrate one form of plasticity that is termed *phenotypic accommodation*. The organism has coped with an abnormality by accommodating to it. Similarly, humans born with limb abnormalities as a result of exposure to a teratogen such as thalidomide develop strategies to cope, for example by handling objects using their feet or teeth in ways for which others might use their hands (von Moltke & Olbing, 1989).

The ability of adult humans to deal with serious injury through accommodation can be remarkable. One case was that of Jesse Sullivan, who worked on high-voltage electricity lines as a technician for a power company. When in his 50s, he was badly electrocuted. Both his arms were terribly damaged and had to be amputated. In due course he had prosthetic arms fitted. One of these, the left arm, was a marvel of mechanical and electrical engineering. Electrodes from the artificial arm were attached to his chest muscles and within 6 months he was able to control the movements of the artificial left hand (McGrath, 2007). Such was his ability to accommodate that he was able to do something quite new and different with muscles that had never been required for such tasks during human evolution.

Another form of coping, found especially during early development, arises when the organism must make immediate responses to survive a challenge but, in contrast to accommodation responses, the normal developmental sequence is not disrupted. Although these responses may involve either structural or temporal changes in the course of development, in contrast to phenotypic accommodation they do not entail a fundamental change in the normal pattern of development. Thus the phenotypic consequences are not as dramatic as those that involve accommodation, but may have a cost and become disadvantageous to the individual later in life (Gluckman, Hanson, Spencer, & Bateson, 2005).

If the mother is undernourished or if the placenta is not delivering optimal nutrition, the offspring may be born smaller than usual, with the consequences of greater infant mortality and lower fitness in later life resulting from persistent growth failure (Gluckman et al., 2005). In polygynous species, such as red deer, the fitness costs may be severe because a small male is less able to compete with larger males for mates and, as a consequence, has a much lower chance of fathering offspring. Nevertheless, survival means that the small male does have some possibilities for mating unobtrusively when larger males are not looking (Kruuk, Clutton-Brock, Rose, & Guinness, 1999). In humans, growth retardation following placental insufficiency may be associated with reduced muscle mass, bone density, adult size, and cognitive and attentive function. These neurological effects may be related to a trade-off between investing for the long term in neural capacity and the need to expend the limited energetic supply for immediate survival (Gluckman & Hanson, 2006).

Adaptations to Local Conditions

In some plastic responses induced in early life may have delayed benefits, so that their primary or only adaptation is expressed at a much later stage in the life cycle. Such anticipatory responses rely on the cue in early life predicting some characteristic of the future environment. Many animals and plants develop defensive structures if they are exposed to cues associated with predators early in life, thus conferring potential advantages. A well-studied example is the small freshwater crustacean, *Daphnia*, which develops a defensive helmet and tail spike only if its mother has come into contact with water containing the body fluids of other *Daphnia* that had been eaten by a predatory midge (Laforsch, Beccara, & Tollrian, 2006). Many other induced defensive responses to predation are seen in much more complex animals (Gilbert & Epel, 2009). The crucian carp found in lakes containing predatory pike have much deeper bodies than those found in lakes without pike, and are consequently more resistant to attack. Experiments showed that this morphological difference was induced by the presence of pike (Brönmark, Pettersson, & Nilson, 1999). The migratory locust can be found as one of two common morphs, with some intermediate forms. If the population density is high, the locust will develop into the migratory morph with large wings, gregarious behavior, and an omnivorous diet. In contrast, when the population density is low, the locust develops into a solitary morph with small wings, reclusive behavior, and a selective diet (Applebaum & Heifetz, 1999). At the larval stage of development, when the trajectory that will determine the adult form is induced by environmental cues, neither form confers a particular advantage under the local conditions. The advantage comes later when, depending on conditions, it pays either to migrate or to stay put.

Handling Rats

The study of the impact of early experience on the stress response of the rat has a long history. Levine (1957) reported that handling rat pups caused them to develop in quite different ways from nonhandled pups. He subsequently found that when humans came through the animal house, the rats that had been handled in early life were at the front of their cages and the nonhandled rats, apparently more frightened, were at the back of their cages (Levine, 1969). The effects of the early experience were referred to as *programming* of the rats (Whimbey & Denenberg, 1967), foreshadowing the use of this slightly unfortunate term in the literature on the developmental origins of health and disease (DOHaD).

For many years the nonhandled rats were regarded as the control group. However, in a laboratory animal house where food is available all the time, and temperature, humidity and so forth are constant, rat mothers do not care for their pups as much as they would in natural conditions. The deprivation of maternal contact has a major effect on the offspring's behavioral temperament (Thoman & Levine, 1970). The adverse long-term effects can be prevented if the pups are handled by humans while they are still with their mother. The presumption is that the handled pups emitted ultrasonic distress calls that stimulated the mother to behave more as she would have done in the natural environment. Rats handled in early development, or born to mothers that exhibit high levels of grooming, subsequently have lower levels of adrenocorticotropic hormone than the nonhandled rats, indicating a major influence of the early experience on the hypothalamic–pituitary–adrenal axis as well as on behavior. The handled rats in the early studies were probably more like those found in natural conditions than the nonhandled rats were.

Subsequently, the role of the mother rat in stimulating development of her pups has been studied extensively by Meaney (2001) and his collaborators. A mother that licks her pups a lot has offspring which, when adult, lick their offspring a lot. Conversely mothers who are low groomers have offspring who grow up to be low groomers. In this way, a characteristic style of maternal behavior is transmitted from one generation to the next. Cross-fostering a pup born to a low-grooming mother to a naturally high-grooming mother switched the adult pattern of the pup to that of the foster mother (Champagne, Francis, Mar, & Meaney, 2003), showing that this is not a genetically transmitted characteristic but an acquired one. The mother's behavior toward her unweaned young can induce a behavior in the offspring that is likely to be appropriate for them if the environment remains threatening when they are adults.

When pregnant mother rats are given restricted diets, their offspring are smaller when they are born, but if these offspring are then given plentiful food they become much more obese than the offspring of mothers given an unrestricted diet (Jones & Friedman, 1982). This early observation has been followed by further extensive work on rats in many laboratories. Offspring born to undernourished rats develop increased appetites (Vickers, Breier, Cutfield, Hofman, & Gluckman, 2000), and show accelerated sexual maturation (Sloboda, Howie, Pleasants, Gluckman, &

Vickers, 2009). Even though the undernourished rats are more sedentary when kept in standard laboratory cages (Vickers, Breier, McCarthy, & Gluckman, 2003), their behavior differs in another striking way from the control animals. When given a choice between pressing a lever to obtain food and running in a wheel, they are significantly more likely to run in the wheel (Miles et al., 2009). Whatever the explanation, the behavioral differences between rats that were undernourished during fetal life and those that were well-nourished are remarkable.

Relevance to Humans

The work on rodents is now being related to striking discoveries that have been made about human biology that have already been discussed. Epidemiologists found that the smaller a baby at birth, the higher its risk of diabetes mellitus type 2 and cardiovascular disease later in life (Barker, 1995). An extensive field of enquiry then emerged, focusing on the relevance of early developmental plasticity in humans to the individual's subsequent health and risk of disease. This domain of research is often termed *developmental origins of health and disease* (DOHaD) (Gluckman & Hanson, 2006). Those individuals whose mothers had been on a lower plane of nutrition had a greater propensity in later life to lay down fat and to develop insulin resistance and high blood pressure in an affluent environment; consequently, vascular and metabolic pathology was more likely to develop. Subsequent studies showed that such effects were not limited to those of small birth size and, indeed, birth size is now considered as simply a crude index of the fetal experience (Gluckman, Hanson, & Buklijas, 2010). This is because maternal experiences such as nutritional intakes can affect the offspring's biology independent of birth weight effects. Alterations in infant feeding also have effects later in life (Plagemann et al., 2009).

Neural Plasticity

In humans who are subject to neurological injury, considerable neural plasticity may occur, particularly if the injury occurs early in life. Some children with brain injury *in utero* or at birth may be functionally relatively normal as a result of co-option of other neural elements. In adults who have strokes that lead to the death of neurons, over time the impact of the injury may lessen as new neural connections are formed and other neurons are co-opted to serve the lost functions. The remarkable reorganization that can take place is shown by brain scans of some people who had hydrocephalus early in development. The cerebral cortex is extremely thin, yet the person may be behaviorally normal (Feuillet, Dufour, & Pelletier, 2007). In this case, neural plasticity generated robustness of behavioral function.

The lack of use by one sensory modality may involve the takeover of part of the brain by another modality. In individuals who have been blind from an early age, tactile cues stimulate parts of the primary visual cortex. The change in brain organization was revealed by an experiment in which strong magnetic fields were used to disrupt the function of different cortical areas in people who had been blind from an early age (Cohen et al., 1997). Disruption of the visual cortex disrupted their ability to read Braille or embossed letters. In contrast, transient disruption of the visual cortex in sighted people had no effect on their ability to perform tactile tasks. Evidently the brains of the blind people had been reorganized in response to their particular experience of the outside world.

Learning

Clearly the developing organism has a particular capacity to demonstrate plasticity, and for many systems the capacity to be plastic later in life is much more limited both by functional considerations and because it may be energetically inefficient to maintain plasticity into later life. Nevertheless, some aspects of the phenotype, such as muscle or fat volume, are plastic throughout life. The most common form of plasticity in adults is seen in their behavior. Learning is the most obvious way in which individuals after birth interact with, and are changed by, their environment. Learning is entwined in the processes of behavioral development, adapting individuals' behavior to local conditions, enabling them to copy the behavior of more experienced individuals, and fine-tuning preferences and actions that were inherited from previous generations. Snell-Rood (2013) distinguishes between developmental plasticity occurring in early life and what she calls *activational plasticity* by which an individual can change its characteristics throughout life.

William Homan (Thorpe, 1956) brought together the insights of European ethology and holistic psychology with the vast corpus of work on the various processes of learning from American and Russian laboratories, as well as those from psychology departments worldwide. Thorpe classified learning into five categories: habituation, classical conditioning, instrumental conditioning, latent learning, and insight learning. Some forms of learning such as behavioral imprinting, which Thorpe discussed in his chapter on insight learning, and the acquisition of song in birds may be restricted to early development, but most can take place throughout life.

One of the most primitive changes in behavior in response to experience is nonspecific. Sensitization usually results from exposure to an alarming stimulus (such as a blow-up toy snake suddenly becoming inflated), which elicits a variety of defensive or aversive reactions from the animal. Subsequently, many other potentially aversive stimuli (such as loud sounds) will have the same effect even though this would not have been the case had the animal not been previously sensitized.

Habituation is defined as a decrease in response occurring as the result of prolonged stimulation, which cannot be attributed to fatigue or sensory adaptation. The phenomenon has been described widely, from single-celled organisms to humans. In some cases, the underlying process is simple and in other cases experiments suggest that the subject establishes a specific representation of the stimulus in its nervous system. So if the animal has been habituated to a sound of a specific duration and then tested with a sound that is shorter in duration, a nonhabituated response is elicited when the end of the shorter sound is reached. When a sound of longer duration is used, a nonhabituated response is elicited at the end of the habituated sound (Sokolov, 1963).

Establishing a neural representation is key to the form of learning that leads to a categorization of the sensory world. Here again such perceptual learning is found widely across the animal kingdom. In humans, it leads to the recognition of faces and places. The ability to distinguish between the vast array of objects, people, and scenes experienced in a lifetime is of inestimable value and happens simply as a result of exposure. The memory's capacity is extraordinary. In one experiment, human subjects were shown up to 10,000 different slides projected onto a screen in quick succession. Days later they were able to recognize thousands of those images. Some of the images, such as a dog smoking a pipe or a crashed airplane, were particularly striking. In these cases the recall was even better and the subjects seemed to have a virtually limitless capacity to store them (Standing, 1973).

The best-known type of *associative learning* process was made famous by Ivan Petrovich Pavlov a century ago. Pavlovian (or classical) conditioning allows the individual to predict what will be of real significance in the confusing world of sights, sounds, and smells. Pavlov's famous experiment was to teach a dog to expect food by repeatedly alerting it with a buzzer before the food was presented. Pavlov measured how much saliva the dog produced. As the dog was conditioned by the predictable association between the buzzer and the food, it came to produce saliva in response to the sound of the buzzer alone.

A different form of associative learning acts to control the environment. If a rat presses a bar and its action is swiftly followed by the delivery of food, it will repeat the action and will do so with increasing frequency if each time the action elicits the reward. As the action is strengthened, it may be repeated many times even in the absence of the reward (or *reinforcer*). As learning proceeds, the conditions in which the action generates a reward become in themselves rewarding. Subsequently, the individual may perform a quite different act to achieve the conditions that are associated with getting the primary reward. By degrees a whole chain of different behavior patterns can be established—a fact that is made use of by circus trainers.

In an idiosyncratic but highly original review, Moore (2004) identified 97 different processes of learning, some of which are highly complex, including abstract concept formation and cross-modal imitation. He may well have exaggerated but his survey serves to emphasize the heterogeneity of all those processes that are lumped under the general heading of *learning*.

Complex Processes

At one time psychologists were encouraged to interpret the behavior of animals in the simplest possible way until they had good reason to consider otherwise (a precept also known as Lloyd Morgan's canon). Many people—for a variety of reasons—have rejected this advice, focusing on those aspects of animals that resemble the conscious behavior of humans. This might seem questionable, given that much of human behavior is unconscious and that humans differ from other animals in some respects, such as size and complexity of the nervous system. Nevertheless, the so-called cognitive revolution in the study of behavior has undoubtedly greatly enriched the toolbox for understanding learning processes (Shettleworth, 2010). What Thorpe (1956) called *insight learning* related to, among other things, the experiments of Wolfgang Köhler (1925) on chimpanzees in the early part of the 20th century. Among many other experiments, Köhler provided the animals with interlocking sticks. The chimps learned to assemble longer sticks which then enabled them to reach bananas suspended high above them and otherwise beyond their reach.

Modern examples include food caching by blue jays. If they have been observed while caching food by other birds they move the food, but not otherwise (De Kort, Tebbich, Dally, Emery, & Clayton, 2006). Rooks are able to reach initially inaccessible food floating on the top of water in a plastic tube by dropping stones into the water and thereby raising its level in the tube (Bird & Emery, 2009). Parrots have been found to develop abstract concepts of color, shape, or material content (Pepperberg, 2008). Ways in which one individual learns from another range from the simple examples of social facilitation of behavior already established as a capacity in the individual, and enhancement of local cues, to cases where actions are observed and then copied (Laland & Galef, 2009). The study of complex cognition in animals, involving the plastic processes of learning, has expanded greatly and is very well summarized by Shettleworth (2010). The most complex forms of learning clearly involve plasticity of considerable elaboration and it is not surprising, therefore, that a growing body of evidence links these capacities to the relative brain size of the species concerned (Reader & Laland, 2002). These complexities have to develop and may often be derived from playful experiences earlier in life (P. Bateson & Martin, 2013).

The Immune Response

In the immune system of humans and vertebrate animals, molecular plasticity takes the form of generating new antibodies to foreign proteins that hitherto have not been encountered by the individual. Antibodies are immunoglobulins used by the immune system to identify and neutralize foreign pathogens such as bacteria and viruses, preventing them from causing disease. A small region at the tip of the critical immunoglobulin is extremely variable in amino acid sequence, permitting the existence of millions of antibodies with slightly different tip structures. Each of these variants can bind to a different protein (or antigen). The diversity of antibodies allows the immune system to recognize an equally wide array of antigens (Male, Brostoff, Roth, & Roitt, 2006). Recognition and binding of an antigen by an antibody provides a marker that enables it to be attacked by other cells of the immune system.

The hugely diverse population of antibodies is generated by random combinations of a set of gene segments that encode different antigen binding sites, followed by random mutations in this area of the antibody gene, which create yet further diversity. Each form of antibody is made by a different clone of B-lymphocytes. The antibody is specific to the part of the antigen recognized by the immune system. Once a particular clone is stimulated by contact with an antigen, it undergoes massive proliferation to produce more antibodies and long-lasting immunity.

On the face of it, the foreign protein might have instructed the process that generated the antibody in the sense that unique information carried by the protein provides the template on which the antibody is synthesized. However, the plasticity of the immune system involves selection rather than instruction since, by extremely rapid mutation and recombination within the histocompatibility complex, the immune system finds a match for the foreign antigen and this then sets in train rapid synthesis of the antibody from the mutated gene that provided the match (Neuberger, 2008). The gene has been selected by the challenge from outside the host's body.

Many Processes Involved in Plasticity

The plastic phenomena are without question biologically important, but do they have anything in common? Plasticity operating at different levels of organization often represents different descriptions of the same process. Underlying behavioral plasticity is neural plasticity, and underlying that is the molecular plasticity. Edelman (1987) suggested that the immune system provides a model for understanding the processes that underlie learning. The plasticity of the immune system relies on a selective process. In contrast, at the level of the whole organism, the processes of learning that change behavior seem to involve instruction. Whether the same selective process could be involved in any or all of the myriad examples of learning is, however, much more controversial. In the case of associative learning, for example, a cue from the environment instructs the individual about the causal nature of its environment, providing a link between something that is biologically significant and something that had hitherto been neutral. As yet, the underlying processes involving changes in neural connectivity is not readily attributable to a process that involves selection.

The image of selection might fit better with the examples of *polyphenisms* and *reaction norms*, whereby the genome is capable of giving rise to a variety of phenotypes depending on the individual's experience. In many cases of developmental plasticity that abound across the animal and plant kingdoms, the individual starts its life with the capacity to develop in a number of distinctly different ways. Like a jukebox, the individual has the potential to play a number of developmental tunes. The particular developmental tune played by the individual is triggered by a feature of the environment in which it has grown up—whether it is the odor of its predators, the available quality of food, or the presence of other males. Furthermore, the particular tune emanating from the developmental jukebox is adapted to the conditions in which it is played (P. Bateson, 1987; P. Bateson & Martin, 1999). The jukebox analogy has its drawbacks because it implies that the tune is preformed somehow (Oyama et al., 2001); but, like everything else, the predispositions have to develop. However, the image does draw attention to what may be a useful distinction between forms of plasticity that involve selection and those involving instruction.

Plasticity can be viewed in many ways and along many different dimensions. The temporal dimension, the dimension of different organizational levels, the dimension of whether plasticity involves selection or instruction, and the functional and evolutionary issues are all part of the picture. A multidimensional view is essential if the ways in which the organism responds to environmental cues and challenges are to be understood. However, the understanding needs to be broadened to take account of the ways in which plasticity is constrained and regulated.

INTEGRATION OF ROBUSTNESS AND PLASTICITY

The developmental processes of robustness and plasticity that give rise to an individual's characteristics are not polar opposites, nor are they independent of each other; instead they stand in a relational context to each other (Overton, 2013, Chapter 2, this *Handbook*, this volume). Indeed, plasticity is often regulated by robust processes and robustness is often generated by plasticity. In the case of sensitive periods in development, in which experience can have a particular impact on the phenotypic characteristics of an organism. The environmental cues are often highly specific and are often referred to as predispositions. Learning is the archetype of plasticity. Yet learning processes are highly regulated by robust rules.

Robustness at one stage of development does not necessarily imply robustness at another. A characteristic that is robust up to one stage may not continue to be robust thereafter, and vice versa. Developmental malleability may be followed by nonmalleability, as in many examples of alternative phenotypes found throughout the animal kingdom, including humans (Gilbert & Epel, 2009). Conversely, developmental nonmalleability may be followed by considerable malleability, as in the case of the human smile, which reliably appears in infants during the fifth or sixth week after birth and is subsequently greatly modified by social interactions and cultural influences (P. Bateson & Martin, 1999).

One of the public health triumphs of genetics was the discovery that the expression of an inherited disease, phenylketonuria, could be prevented by providing the patient with an appropriate diet from an early age. The affected people have a mutated gene that meant that an enzyme, phenylalanine hydroxylase, was deficient; therefore, the amino acid phenylalanine could not be converted to tyrosine and instead was converted to toxic phenylpyruvate. The poison caused brain damage, resulting in great loss of cognitive ability, seizures, and other behavioral disorders. These dire consequences could be prevented by genetically testing neonates at birth and feeding children with the mutation a special diet that did not contain phenylalanine (Centerwall & Centerwall, 2000).

Another example of how the phenotypic consequences of a genetic change can be prevented by a change in the environment involved a knocked-out gene that normally codes for an important neurotransmitter (Rampon et al., 2000). When mice with the missing gene were kept in standard bare laboratory cages they developed a profound loss of the ability to recognize objects, loss of olfactory discrimination, and absence of memories of noxious events. However, when the mice were exposed daily to cages containing toys, running wheels and tunnels, and other forms of environmental enrichment, all these behavioral deficits were lost. The behavioral effects of the enrichment were accompanied by an increase in the synaptic density in a particular region of the hippocampus.

The examples of the interplay between genetic background and experience of the environment might seem to justify the phrase *gene–environment interaction*. In the popular domain, Shenk (2010) has described how each individual interacts with his or her environment in such a way that potentialities may be revealed or suppressed by circumstances. The message is optimistic and has major implications for public policy. Shenk's perspective was presented as an interaction between genes and environment; an image which he drew from the scientific literature (Meaney, 2010). The interaction is often abbreviated as $G \times E$. Some problems arise from this formulation because it conflates ideas about sources of variation in populations with those about an individual's development. It is the person who interacts with the environment, not his or her genes (Lehrman, 1953). Although genes are definitely activated or repressed by some environmental conditions, individuals can change their environments without necessarily producing changes in the expression of its genes. This has been termed *niche construction* (Odling-Smee, Laland, & Feldman, 2003). Furthermore individuals can choose to inhabit environments that match their characteristics, referred to as *niche picking* (Scarr & McCartney, 1983). For all these reasons it is more satisfactory to refer to organism ←→ environment coactions when considering the integration of plasticity and processes that generate robust outcomes.

Sensitive Periods

Charles Stockard (1921), a leading embryologist of his time, observed that the embryos of many species could resist oxygen deprivation at some stages of their development, but that at times of rapid embryonic growth, oxygen deprivation could induce gross malformations such as two heads. Tissues are particularly vulnerable to disruption at times of rapid growth. In humans, much organ formation occurs during the first 8 weeks after conception. The science of teratology is replete with examples of how toxins exert their effect at a specific stage of development, the impact of the drug thalidomide on limb development being one of the most famous.

By way of contrast to the examples described earlier, many sensitive periods in development exist within which the organism acquires information from its environment in order to develop normally or in a way that is appropriate to that environment. This information can play a crucial role in determining which of several alternative developmental courses the individual will adopt. For example, on the basis of the nutrition they receive in early life, female social insects are either capable of reproduction or adopt one or more sterile forms that perform specialized jobs in the service of the colony (Wilson, 1971). The sisters differ enormously in subsequent phenotype due to this one environmental exposure within a sensitive period in development (Maleszka, 2008).

Unlike other vertebrates, sex is not determined by chromosomes in some reptiles, such as the turtles and crocodiles. Instead the temperature of the sand in which the egg is buried is crucial. Each individual starts life with the capacity to become either a male or a female. If the egg from which it hatches is buried in sand at a temperature below 30°C, the young greenback turtle becomes a male. If, however, the egg is incubated at above 30°C, it becomes a female. Temperatures below 30°C activate genes responsible for the production of male sex hormones and male sex hormone receptors; incubation temperatures above 30°C activate a different set of genes, producing female hormones and receptors instead. It so happens that in alligators the sex determination works the other way round, such that eggs incubated at higher temperatures produce males. The outcome depends on environmental temperature during the middle third of embryonic development (Yntema & Mrosovsky, 1982).

The developmental processes involved in the start of a sensitive period correspond with changes in the ecology of the developing individual. These changes are linked to developmental processes of regulation and cellular replication. The processes that bring the sensitive period to an end may reflect the passage of normal growth and temporal constraints on development in other related processes. Hypothalamic maturation in mammals needs to be largely completed before weaning because the hypothalamus controls so many aspects of homeostasis, and maintaining plasticity in some pathways might constrain fixation of others. Sometimes the terminating processes are related to the gathering of crucial information and, except in extreme circumstances, do not shut down until that information has been gathered. In these cases the ending of the sensitive period reflects the variable opportunities for gathering such domain-specific information in the real world. For example, in cold weather, ducks brood their hatched young for longer than in warm weather, and the ducklings delay the process of learning the characteristics of their mother (P. Bateson & Martin, 1999). A limit must be set on such flexibility, however, because so much else has to be done in development. If the relevant information remains unavailable for too long, the individual may eventually have to "make the best of a bad job" and develop without acquiring that information.

Sensitive periods may be limited because of what has happened previously to the individual. For example, structures in the brain that have been altered by earlier experience may preempt the formation of new structures. The brain processes involved in visual development have been analyzed in cats and monkeys. The capacity of a cat's eye to activate neurons in the visual cortex depends on whether that eye had received visual input during the first 3 months after birth (Freeman, Sengpiel, & Blakemore, 1996). If one eye is visually deprived during this period it largely loses its capacity to excite cortical neurons. The other eye then becomes dominant and, once established, usually remains dominant for the rest of the individual's life. Once one set of neurons has established a connection, they exclude others from doing so thereafter. Specific neurobiological processes, involving noradrenergic receptors at the site of this plasticity, are required for such preemptive developmental changes to occur. Once a stable pattern of responding has developed normally, these processes fall away. If the brain is not stimulated in the normal way through the visual pathways, then the reduction in the number of these receptors is delayed until the necessary interconnections between neurons have been established (Liu, Jia, Gu, & Cynader, 1994).

In general, neural plasticity during sensitive periods is likely to involve a variety of different processes (Hensch, 2004). Moreover, many such sensitive periods are not infinitely flexible. At some point, other developmental processes within the brain constrain plasticity. If the lack of visual experience goes on long enough, the period of sensitivity will terminate and the animal will end up with a brain that differs from the normal. In humans the development of binocular vision is seriously affected if a child has an uncorrected squint in the first few years of life. The child accommodates to the squint by becoming dependent on one eye and not using the other eye. The squint can be corrected by surgery, in which case the child usually develops normal binocular vision, but only if the surgery is performed sufficiently early in development. If it is left until much after the age of 3 years, surgery will do no good and the child will be left with permanently impaired vision in the affected eye (Campos, 1995).

The nature of such sensitive periods shows that experience at a given stage in development can fundamentally shape the individual's subsequent development. In general, the organization that underlies the existence of such periods, such as in temperature-dependent sexual differentiation, is highly robust. In turn, after the plastic changes have been initiated during a sensitive period, the phenotypic outcome can be extremely robust, again as in the case of sex determination. The intertwining of developmental processes is complete.

Ethological Studies of Birds

Behavioral imprinting has been much studied by ethologists. It is the process by which a young animal rapidly learns the details of its mother's individual appearance and forms a social attachment to her (P. Bateson, 1966; Bolhuis, 1991; Lorenz, 1935). Some young animals, such as goslings and cygnets, learn to recognize their father as well, but this is less common because, particularly in mammals, fathers rarely play a substantial role in caring for their offspring. A distinction is drawn between filial imprinting and sexual imprinting whereby the animal's experience later in life affects its sexual preferences. These sexual preferences are for partners that are slightly different from those individuals (usually close kin in natural conditions) with which the animal is already familiar (P. Bateson, 1983). Behavioral imprinting of both kinds provides a good example of a process that starts within a sensitive period. It also demonstrates nicely how learning is guided by certain robust predispositions.

Birds respond to a pattern of stimulation, and characterization of the most effective stimulus must be cast in terms of clusters of features. Some features of the jungle fowl, the ancestral form of the domestic fowl, are particularly attractive to chicks. The head and neck is the crucial characteristic, but the head and neck of a small mammal is as effective as that of a jungle fowl (Horn, 1985). Plasticity is initiated by robustly developing predispositions, and that once strong attachments are formed, they may remain stable for the rest of the animal's life.

Another striking example of the ways in which predispositions influence learning is given by the acquisition of songs by birds. The process starts early in life. The typical pattern is for the young male bird to listen to and store sounds made by his father and other males during the first few months after he has hatched (Marler & Slabberkoorn, 2004). The following spring he produces a range of sounds and, by degrees, settles on songs he has heard before. When he is mature, he uses his songs to defend his territory and attract females. The range of songs acquired by each male is transmitted within the neighborhood from one generation to the next, in much the same way as language, customs, and ideas are transmitted across the generations in humans. Under laboratory conditions, hand-raised birds will learn sounds played back from tape recorders. Typically, however, they are much more likely to acquire songs made by their own species than songs made by other species, even when the songs are mixed up in the recordings (Marler & Peters, 1977). Marler (2004) referred to the readiness of birds to learn about particular features of their acoustic environment when developing their songs as an *instinct to learn*. Despite the unfortunate ambiguity of the term *instinct*, the concept of a hunger to learn about certain things is important when considering the interplay between plasticity and robust features of the animal.

Rules for Learning

As any dog-owner knows, a hungry dog will do many other things once it detects cues that predict the arrival of food: It will go to the food bowl, whine, wag its tail, jump up, and show all the familiar signs of expectation. When learning about the relevant cue that predicts the arrival of food, the sequence in which the events occur is crucial. If the cue comes *after* the presentation of food to a dog that has not yet been conditioned, it will not salivate or show any other expectant signs when the cue is subsequently presented. The link in time between the action and the outcome is crucial.

The interplay between the rules for learning and robust features of the animal's behavior can sometimes lead to amusing outcomes. Keller and Marian Breland (1966) were experimental psychologists who later became professional animal trainers. On one occasion they tried to train pigs to take a wooden coin from a pile and drop it into a piggy bank in return for a food reward. Initially the pigs learned the task well, but as they came to associate the pile of coins with food, the sequence broke down because the pigs started rooting in the pile of coins! Robust features of their behavior came to dominate the initial effects of learning.

Storing information about visual experiences requires a different set of rules from those involved in the prediction and control of the environment. Animate and inanimate objects in the real world are rarely flat and their appearance depends on how they are viewed. Friends or relatives are easily recognized from the front or the back, whether they are in the distance or close up. But they may not be so readily recognized if the photograph is taken from an odd angle such as from their feet. The recognizable features of a familiar person are fused together by the brain into a single category when these different views are seen in quick succession (P. Bateson, 2000). Time plays a different role in such perceptual learning than is usually the case in Pavlovian conditioning. The order in which different events are experienced is important when one event causes the other, but unimportant when the experiences are of different views of the same object. In the case of perceptual learning, just as in conditioning, profoundly important plastic processes are dependent on robust rules.

The Need to Understand the Processes

Modern understanding of an individual's development goes well beyond accepting that bidirectional relations between the organism and its environment are crucial. The conditional character of an individual's development emphasizes the need to understand the processes of development that underlie these coactions. This is what Waddington (1957) called the study of *epigenetics*. He distinguished epigenetics from the 18th-century term *epigenesis*, which had been used to oppose the notion that all the characteristics of the adult were preformed in the embryo. *Epigenetics* has become defined as the molecular processes by which traits defined by a given profile of gene expression can persist across mitotic cell division, but which do not involve changes in the nucleotide sequence of the DNA (Carey, 2012). This area of research is one of the most rapidly expanding components of molecular biology and has considerable implications for how the actions of genes are treated (Charney, 2012; Slavich & Cole, 2013). The term has come to describe those molecular processes through which both dynamic and stable changes in gene expression are achieved, and ultimately how variations in environmental experiences can modify this regulation of DNA (Gilbert & Epel, 2009; Gissis & Jablonka, 2011; Jablonka & Lamb, 2005). Robust processes of development and those that generate plasticity are closely intertwined by such interplay.

Variation in the context-specific expression of genes, rather than in the sequence of genes, is critical in shaping individual differences in phenotype (P. Bateson & Curley, 2013). This is not to say that differences in the sequences of particular genes between individuals do not contribute to phenotypic differences, but rather that individuals carrying identical genotypes can diverge in phenotype if they experience separate environmental experiences that differentially and permanently alter gene expression (Spector, 2012).

The molecular processes involved in phenotypic development were initially worked out for the regulation of cellular differentiation and proliferation. All cells within the body contain the same genetic sequence information, yet each lineage has undergone specializations to become a skin cell, hair cell, heart cell, and so forth. These phenotypic differences are inherited from mother cells to daughter cells. The process of differentiation involves the expression of particular genes for each cell type in response to cues from neighboring cells and the extracellular environment, and the suppression of others. Genes that have been silenced at an earlier stage remain silent after each cell division. Such gene silencing provides each cell lineage with its characteristic pattern of gene expression. Because these epigenetic marks are faithfully duplicated across cell division, stable cell differentiation results. These processes also have many other roles in development, including mediating many aspects of developmental plasticity.

Epigenetic research does raise questions about the ways in which data obtained from populations are interpreted. For example, in both medical and psychological research, attempts have been made to separate genetic from nongenetic effects by the comparison of identical and nonidentical twins. The correlation between a characteristic in “identical” monozygotic twins, who share all their genes in common, is compared with that in “nonidentical” dizygotic twins, who do not. The difference in correlation between the identical twins and that between the nonidentical twins is used to calculate the likely contribution of genes to that characteristic. The likelihood was, however, that identical twins shared a placenta and therefore had a more similar uterine environment than did nonidentical twins.

Some authors such as Jablonka and Lamb (2010) and most developmentally inclined ethologists like myself (P. Bateson, 2012; P. Bateson & Curley, 2013) continue to use Waddington’s broader definition of epigenetics to describe all the developmental processes that bear on the character of the organism. Critical issues arise over what an animal inherits at the beginning of its lifetime. Major understanding of extragenetic inheritance processes such as cytoplasmic effects, parental effects, including maternal and paternal genomic imprinting and other epigenetic impacts on gene expression, ecological legacies, behavioral traditions, and cultural inheritance (Danchin et al., 2011; Gilbert & Epel, 2009; Gissis & Jablonka, 2011; Jablonka & Lamb, 2005; Mousseau & Fox, 1998; Odling-Smee et al., 2003). These legacies mean that the processes shaping the character of an individual will often start before conception.

Many of the factors that influence individual development, be they social or ecological, have been amassed by the activities of multiple individuals over multiple generations (cultural knowledge, ecological legacies). Some of these influences on development may stretch back a long way. The presence of animal burrows, mounds, and dams—or, on a larger scale, changed atmospheric states, soil states, substrate states, or sea states (Erwin, 2008; Meysman, Middelburg, & Help, 2006)—persist or accumulate in environments, and can be crucial for normal development. Tracing backward in time to the origins of all these factors would probably be regarded as irrelevant to a modern study of development, except in that subset of cases where those legacies function to elicit epigenetic changes in the development of descendants (Badyaev, 2009). The spirit of the developmental question does push back the historical account of how the character developed to before conception, but, for practical purposes, probably not *too* far back. However, acknowledging the variety of factors that are inherited, and the manner in which parents construct developmental environments, is important for developmental studies.

EVOLUTION AND DEVELOPMENT

For many years the debate about the role of an individual’s development and its impact on its descendants was sharply polarized. The impact was seen as substantial by some and as nonexistent by others. Some evolutionary biologists (e.g., Ridley, 2003; Wallace, 1986) still hold to the view that genetics, and hence evolution, could be understood without understanding development. Briefly put, their opinion is that genes influence the characteristics of the individual; if individuals differ because of differences in their genes, some may be better able to survive and reproduce than others and, as a consequence, their genes are perpetuated. The extreme alternative is a caricature of Lamarck’s views about biological evolution and inheritance. If a blacksmith develops strong arms as a result of his work, so the argument went, his children will have stronger arms than would have been the case if their father had been an office worker. This view has been ridiculed by essentially all contemporary biologists. Nevertheless, as so often happens in polarized debates, the excluded middle ground concerning the evolutionary significance of development and plasticity has turned out to be much more interesting and potentially productive than either of the extreme alternatives. The way in which an organism’s plasticity could influence evolution has intrigued many authors (Avital & Jablonka, 2000; P. Bateson, 1988; Gottlieb, 1992; Hardy, 1965; Pfennig et al., 2010; Tierney, 1986; Wcislo, 1989). West-Eberhard (2003) has been a prominent advocate of the view that an individual’s plasticity plays an important role in evolution and she has been supported by other influential writers (e.g., Gilbert & Epel, 2009; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume; Pigliucci & Müller, 2010). A central role was given to development in evolutionary processes and has prompted researchers to wonder whether, and how, developmental systems fashion evolutionary outcomes (Badyaev, 2009; Moczek et al., 2011; Müller, 2007; Pfennig et al., 2010; Verzijden et al., 2012).

From Passive to Active

Organisms and proto-organisms were doubtless passive in the initial stages of biological evolution. However, as they evolved, they would soon have become active. This is the key conceptual point in understanding how plasticity and behavior can drive evolutionary change. Development depends on the constancy of many genetic and environmental conditions. If any of these change, as can happen to environmental conditions when organisms are mobile, the characteristics of the organism can also change. High mobility by animals, such as that involved in active exploration or migration, would have frequently placed them in conditions that revealed heritable variation not previously apparent in the population. By their mobility, in the case of animals, or facility to disperse in the case of plants (Donohue, 2005), organisms would have exposed themselves to new conditions that might reveal heritable variability, thereby opening up possibilities for evolutionary changes that would not otherwise have taken place.

A striking example of what can happen when an animal is mobile has been provided by the work on the three-spined stickleback (Foster & Wund, 2011). This fish moved from a marine environment to freshwater and thence from living near the surface in streams to much deeper water in lakes. As it moved from one environment to the next its morphological and behavioral characteristics changed.

When discussing his results of experiments on what he called *genetic assimilation* (Waddington, 1953), suggested that the heat shock, applied to the larvae of fruit flies, led to the expression of genes that were carried in only a part of the population. Waddington bred from the flies that had developed a particular character (lack of a cross-vein in the wings) as a result of their larval experience. He continued to apply heat shock in each generation and to breed selectively from the flies with cross-veinless wings. After many generations of heat shock and selective breeding, cross-veinless wings developed spontaneously in the absence of the external triggering condition of heat shock.

Waddington's finding involved expression of a novel character in a new environment, but the character was not an adaptation to the triggering condition. Because of artificial selection, however, it did confer some advantage on its possessor. Cross-veinless wings do not bear any functional relation to the environment, which supplied a heat-shock when the flies were larvae. Nor need such a relation exist under natural conditions. All that is required initially is that the environmental conditions trigger the expression of a phenotype that can be repeated generation after generation so long as the environmental conditions persist.

Waddington's fruit fly experiment is just one illustration of innumerable possible scenarios. The developmental breakout may provide radically new opportunities for those individuals equipped with the new phenotype (West-Eberhard, 2003). For that reason, behavior, along with other forms of dispersion, was likely to be important in initiating evolutionary change. In addition, behavioral adaptability of the animals would have helped buffer them against extinction in new conditions. West-Eberhard argues that after developmental disruption, the reorganization of the genome might have a much broader effect than that envisaged by Waddington. She suggests that major changes might evolve as the character in question became more variable; in other words it became developmentally less robust or less canalized. The umbrella term that she uses for all the heritable changes that might occur in the genetic regulation of development in response to environmental influences is *genetic accommodation*.

Choice

Charles Darwin (1871) argued that choice of a mate could drive evolution. He called the evolutionary process *sexual selection*. For nearly a century most biologists did not take sexual selection seriously. Subsequently, however, many experiments have supported Darwin's thinking. A famous study by Andersson (1994) involved artificially lengthening the tail of male long-tailed widow birds. He found that the males with extra-long tails attracted more mates. The reason why longer tails are not found in nature is probably because it carries a big cost for the male so that in rainy weather, a bird with an extra-long tail cannot drag the great encumbrance off the ground when attacked by a predator. The growth of interest in the subject has been rapid (Cornwallis & Uller, 2010). A total of 762 papers on sexual selection were published in the year 2000 alone. In 2010, an astonishing 1,427 papers on sexual selection were published and the numbers continue to rise year on year. In sexual selection, differential survival of individuals is not at issue; rather the process depends on differential reproductive success.

Another example of active choice is that involved in predators' choice of prey. When gazelle see a predator, they jump into the air, a behavior pattern called *stotting*. A suggested evolutionary process is that first some gazelle jump after noticing cheetah (Fitzgibbon & Fanshawe, 1988). Cheetah learned not to chase jumping gazelle because such effort would be a waste of time. The next step is that all gazelle jump after noticing cheetah. Some gazelle gain advantage by giving an exaggerated jump—a stott—after noticing cheetah. This is because cheetah learn not to chase stotting gazelle. Cresswell (1994) found that when skylarks were attacked by a merlin, those that sang most were least likely to be killed by the bird of prey, suggesting once again that the predator learned not to waste effort attacking the strongest individuals. Cresswell argued, therefore, that the predators' choices had driven the evolution of the antipredator responses of their prey.

Control of the Environment

The environment does not simply set a problem to which the organism has to find a solution. The organism can do a great deal to create an environment to which it is best suited. This should give pause if evolution is considered purely in terms of selection by external forces (Lewontin, 1983). By leaving an impact on their physical and social environment, organisms may affect the evolution of their own descendants, quite apart from changing the conditions for themselves. Some of the impact is subtle, such as when a plant sheds its leaves that fall to the ground and change the characteristics of the soil in which its own roots and those of its descendants grow. These ideas have been developed extensively and are now referred to as *niche construction* (Odling-Smee et al., 2003). One example is provided by beavers that change their environment by building dams and creating lakes for themselves. This activity sets up conditions that affected the subsequent evolution of the ancestral beavers' descendants. The artificially created aquatic environment led the beavers to evolve adaptations such as webbed feet that facilitated swimming.

The effect of behavioral control on evolutionary change could be especially great when a major component of the environmental conditions with which animals have to cope is provided by their social environment. A similar type of positive feedback to that flowing from the effects of mate choice could operate in such circumstances (Jolly, 1966). If individuals compete with each other within a social group and the outcome of the competition depends in part on each individual's capacity to predict what the other will do, the evolutionary outcome might easily acquire a runaway property. In discussing the social function of intelligence, Humphrey (1976) suggested that an evolutionary *ratchet* was set up, acting to increase the general intellectual standing of the species. As he noted, such an explanation makes sense of the astonishing rate of increase in the cranial capacity of humans, if it is assumed (reasonably) that cranial capacity and intellectual ability are correlated. Here again the ideas have been developed extensively (Byrne, 2000).

A growing body of evidence suggests that the cultural environment of humans has affected the human genome (Laland, Odling-Smee, & Myles, 2010). A much-cited example is the way in which herding cattle and drinking their milk influenced the evolution of the gene that is required for the synthesis in adult life of lactase, the enzyme required for digesting milk. In human populations that are not descended from cattle owners, such as the Chinese, the gene is not expressed in adulthood and these people are unable to digest cow's milk (Gerbault et al., 2011).

The Adaptability Driver

The adaptability of the organism is likely to have played an important role in initiating evolutionary change. This hypothetical effect is often called the *Baldwin Effect* after Baldwin (1896). Two others published the same idea in the same year, namely Lloyd Morgan (1896) and Osborn (1896). At the time, the proposed evolutionary process was called *organic selection* and was thought to be original to the three authors. However, 23 years before, Spalding (1873) had published the same hypothesis in *Macmillan's Magazine*. This was not an obscure publication—it was the predecessor of *Nature*, which continues to be published by Macmillan. Spalding's driver of evolution comprised a sequence of learning followed by differential survival of those individuals that expressed the phenotype more efficiently without learning. Given Spalding's precedence and the simultaneous appearance in 1896 of the ideas about organic selection, it seems inappropriate to term the evolutionary process the *Baldwin effect*. The trouble is that calling the proposed process the *Spalding effect* is not descriptive of what initiates the hypothetical evolutionary process; hence the term used here, the *Adaptability Driver* (P. Bateson, 2005).

Lloyd Morgan's account of the hypothetical adaptability driver process was particularly clear. He suggested that if a group of organisms respond adaptively to a change in environmental conditions, the modification will recur generation after generation in the changed conditions, but the modification will not be inherited. However, any variation in the ease of expression of the modified character that is due to genetic differences is liable to act in favor of those individuals that express the character most readily. As a consequence, an inherited predisposition to express the modifications in question will tend to evolve. The longer the evolutionary process continues, the more marked will be such a predisposition. Plastic modification within individuals might lead the process and a change in genes that influence the character would follow; one paves the way for the other.

As a possible example of the adaptability driver, the Galapagos woodpecker finch pokes sharp cactus spines into holes thereby obtaining insect larvae as food. Suppose it does so without much learning but that an ancestor did so by trial and error. In the first stage of the evolutionary process, a naive variant of the ancestral finch, when in foraging mode, might, for example, have been more inclined to pick up cactus spines than other birds. This habit spread in the population by Darwinian evolution because those behaving in this fashion obtained food more quickly. At this stage the birds still learned the second part of the sequence. The second step would have been that a naive new variant, when in foraging mode, was more inclined to poke cactus spines into holes. Again this second habit spread in the population by Darwinian evolution. The end result is a finch that uses a tool without having to learn how to do so. Simultaneous mutations increasing the probability of two quite distinct acts (taking cactus spines and poking them into holes in the case of the woodpecker finch) would be very unlikely. Learning makes it possible for them to occur at different times and in any order. Without learning processes, having one act but not the other has no value. As a matter of interest, it seems to be the case that the behavior of the woodpecker finch is halfway down the evolutionary road from fully learned to fully spontaneous because naïve birds readily pick up small sticks but then have to learn how to use them (Tebbich, Sterelny, & Teschke, 2010).

An early example of how the adaptability driver process might work was provided by the famous child psychologist and genetic epistemologist Jean Piaget, who began his career as a biologist and was much influenced by Baldwin (Piaget, 1979). He studied the freshwater snail *Limnaea* and found that in still ponds the coiled shell of the form known as *stagnalis* was elongated. In lakes where wave action could render such a shell disadvantageous, the shell of the form known as *lacustris* was much shorter and the snail could cling onto the substrate much more firmly. When the *lacustris* form was raised in a still aquarium, half of the snails developed the shell of the *stagnalis* form, whereas the other half developed the more compact *lacustris* form without needing to be exposed to the wave action of a lake. One interpretation of this result is that the population of snails living in the lakes was midway through an evolutionary change. On this view the *stagnalis* form was evolutionarily more primitive, and in the lakes with wave action, some snails developed the *lacustris* adaptation as a result of developmental plasticity, but the evolutionarily more advanced snails no longer required such plasticity to develop their advantageous shell shape. Although Piaget carried out this work early in his career, it did not come out in book form until the end of his life. In the terms used by Lloyd Morgan, the initial change could involve adaptability by the individual snail; the adaptability is won at some cost so that descendants expressing the character more efficiently would be more likely to survive.

An important empirical demonstration of adaptability driving evolutionary change is that of the house finch. In the mid-20th century, the finch was introduced to eastern regions of the United States far from where it was originally found on the west coast. It was able to adapt to the new and extremely different climate and spread up into Canada. The finch also extended its western range north into Montana, where it has been extensively studied. After a period involving great deal of plasticity, the house finch populations spontaneously expressed the physiological characteristics that best fitted them to their new habitats without the need for developmental plasticity (Badyaev, 2009). Initially the adaptive onset of incubation and the sex bias in the order of ovulation were affected by ambient temperature in the more northerly climes, but as evolution in the population occurred these behavioral and physiological effects were no longer dependent on the external cues for their expression. After initially using their adaptability to respond to the new environmental conditions, the house finch populations spontaneously expressed the physiological characteristics that best fitted them to their new habitats.

Generating Complexity

Paenke, Kawecki, and Sendhoff (2009) proposed a general framework that explained cases in which adaptability would increase behavioral complexity as well as those in which it would not. Spontaneously expressing a behavior that had been learned in previous generations could be costly if it meant that the animal lost all of its ability to learn. Some evidence from fruit flies suggests that this might well be the case, at least in simpler organisms (Kawecki, 2010). The benefit of expressing a behavior spontaneously was found to be outweighed by the cost of losing the capacity to learn about other things. The argument is much less cogent when applied to big-brained animals like birds and mammals with multiple parallel pathways involved in learning. In these animals, the loss of capacity to learn in one way has no effect on the capacity to learn other ways (P. Bateson, 2004).

The effect of plasticity on evolution is likely to have become increasingly powerful as animals, in particular, become more complex. When such complexity entailed a greater ability to discriminate between different features of the environment or a greater ability to manipulate the environment, the organism would benefit and would be more likely to survive and reproduce in the face of multiple challenges during its lifetime. Plasticity would promote much more rapid genetic evolution of complex sets of adaptive systems than can be accomplished by mutation alone. Theoretical studies have indicated how crucial plasticity could be in such an evolutionary process (e.g., Beltman, Haccou, & ten Cate, 2004; Dukas, 2013).

In general, an ability to cope with complex environmental challenges by means of plasticity opens up ecological niches previously unavailable to the organism. This would inevitably lead to the subsequent evolution of morphological, physiological, and biochemical adaptations to those niches and the likelihood of speciation (Pfennig et al., 2010; Pfennig & McGee, 2010). Where an environmental challenge involved greater processing capacity by the brain this organ, too, would be expected to evolve with greater rapidity. On the assumption that the larger brain relative to body size ensures greater learning capacity, the rate of evolution should correlate positively with the relative brain size. This expectation is given some support by the study suggesting that taxonomic groups evolving most rapidly have the biggest brains relative to body size (Wyles, Kunkel, & Wilson, 1983). The expectation is also supported by the correlation between behavioral innovation and brain size reported for birds (Sol, Lefebvre, & Rodríguez-Teijeiro, 2005) and primates (Reader & Laland, 2002).

Some theorists have argued that plasticity could dampen down the rate of evolution (e.g., Price, Qvarnström, & Irwin, 2003; Robinson & Dukas, 1999). Their idea was that, with every individual in the population coping plastically with an environmental challenge, natural selection would have had no variation on which to act. In some cases this might well have been true in the short run. However, if operating plastic processes involved time and energy costs, then individuals that expressed the adaptation spontaneously would readily invade the population and the dampening effect would be lost.

In summary, the organism's mobility, its choices, its construction of a niche for itself, and its adaptability, have all played important roles in biological evolution. All these activities should be contrasted with the essentially passive role often attributed to the organism by some evolutionary biologists (e.g., Ridley, 2003) and is implicit in Darwin's metaphor of *Natural Selection*.

Evo-Devo and Epigenetics

The view that development was irrelevant to an understanding of evolution was repeatedly challenged by Gould (1977, 2002), who referred to the *unity of type* as in the shared forelimb structure of all mammals from whales to bats. His views have been strengthened the growth of the evo-devo movement, which has shown how developmental toolkits can profoundly influence the course of evolution (Carroll, 2005). Knowledge of the constraints on an animal at all stages of its life cycle is important (Arthur, 2004; Brakefield, 2011; Danchin et al., 2011). Further support for the importance of development in evolution is provided by the rapidly expanding field of epigenetics and the variety of legacies, from gut bacteria to ecological habitat, that an individual can inherit (P. Bateson, 2012; Gilbert & Epel, 2009). Acquired characteristics can be passed to progeny without changing DNA sequences and such characteristics can be inherited for a period in the *absence* of the initial environmental trigger (Bonduriansky, 2012; Bossdorf, Richards, & Pigliucci, 2008; Gissis & Jablonka, 2011; Jablonka & Raz, 2009). In itself, this evidence does not relate to the thinking about biological evolution because the transgenerational epigenetic effects could wash out if the conditions that triggered them in the first place did not persist.

DNA silencing can be stable across generations. For example, in the plant *Linaria* the epigenetically induced phenotype does not change from one generation to the next (Cubas, Vincent, & Coen, 1999). Usually, inherited epigenetic changes are less stable than genomic variations. Even so, such heritable epigenetic effects might play an important role in evolutionary processes. The central question is whether the transmitted epigenetic markers could facilitate genomic change (Johnson & Tricker, 2010). The answer is that, in principle, they could if (a) they were transmitted from one generation to the next, (b) they increased the fitness of the individual carrying the markers, and (c) genomic reorganization enabled some individuals to develop the same phenotype at lower cost. Epigenetic inheritance would serve to protect the well-adapted phenotypes within the population until spontaneous fixation occurred. That much is exactly the same as has been proposed for the operation of the adaptability driver. However, another process could be at work. Evidence suggests that DNA sequences where epigenetic modifications have occurred are more likely to mutate than other sites (P. Bateson & Gluckman, 2011). The consequent mutations could then give rise to a range of phenotypes on which

Darwinian evolution could act. If epigenetic change could affect and bias mutation rates, such nonrandom mutation would facilitate fixation at the genomic level.

CONCLUSIONS

This chapter has provided an overview of how developmental processes are integrated from the standpoint of an ethologist, surveying some of the contributions that ethology has made to an understanding of human development and evolution and how these contributions are being integrated with modern studies of epigenetics. Although much coming together of different disciplines has occurred, ethologists are still distinctive in the way that they focus on biological function. The static view that divided behavior into the innate and the acquired has been replaced by a much more dynamic view of the underlying processes (P. Bateson & Gluckman, 2011). At the same time, the massive growth of epigenetics has provided understanding of how the molecular processes of development work.

Simplifications are necessary as aids to discovery, but the notion that the organism's characteristics are based on two sources of instruction: one from within and one from without is far too simplistic. Metaphors such as the supposed "hard-wiring" of the brain or the "blueprint" for development are equally unhelpful. The conventional opposition of nature and nurture relates to two different domains and should not be contrasted directly; indeed one is a state and the other a process. Nature properly refers to the fully developed characteristics of the child and these will depend on circumstances, and nurture should refer to the ways in which those characteristics were derived through development. What is required is understanding of the biological and psychological processes that build a unique adult from a fertilized egg.

When the phenomena of robustness and plasticity are examined in greater detail, they are both found to comprise bundles of distinct processes. Many different ways of generating robust outcomes have been found and equally many different forms of plasticity can be recognized. All these processes can operate at many different levels, ranging from the molecular to the behavioral. And different combinations of developmental processes can be involved in the emergence of different characteristics of the child.

As attention is focused on the development of behavior, more and more is being learned about the underlying processes. Many of the regularities found in development are amenable to analysis. Knowing something of the underlying regularities in development does bring an understanding of what happens to the child as it grows up. The ways in which learning is structured, for instance, affect how the child makes use of environmental contingencies and how the child classifies perceptual experience. It does not follow that as these regularities are uncovered, the outcome of development necessarily becomes more predictable. To understand why, consider a rule-governed game like chess. It is impossible to predict the course of a particular chess game from knowledge of the game's rules. Chess players are constrained by the rules and the positions of the pieces, but they are also instrumental in generating the positions to which they must subsequently respond. The range of possible games is enormous. The rules may be simple but the outcomes can be extremely complex. In the course of development the rules influence the course of a life, but they do not determine it. Like chess players, children are active agents. They influence their environment and are affected by what they have done. Furthermore, children's responses to new conditions will, like chess players' responses, be refined or embellished as they gather experience. Sometimes the normal development of a particular ability requires input from the environment at a particular time; what happens next or even much later in the life course depends on the character of that input. The upshot is that, despite their underlying regularities, developmental processes seldom proceed in straight lines. Big changes in the environment may have no effect whatsoever, whereas some small changes can have big effects even if not immediately manifest. The only way to unravel this path dependency is to understand the regulatory processes and their interplay with the processes that generate change.

Individuals play an active role in their own development. Moreover, their activities can have an impact on their descendants and how they involve. This awareness, which was fostered by ethologists, has led to a profound change in the way that biological evolution is considered. The advances in molecular understanding are also feeding into an understanding that links studies of development to those of evolution. A central question in considering evolutionary change driven by the environment is whether transmitted epigenetic changes induced by developmental exposures in one generation could facilitate genomic change in later generations. In principle they could if they increased the fitness of the individual carrying the markers and genomic reorganization enabled some individuals to develop the same phenotype at lower cost in fitness terms. Increasing empirical evidence exists for both male and female mediated epigenetic inheritance. It seems plausible that such epigenetic inheritance may serve to protect the well-adapted phenotypes within the population until spontaneous mutation leading to phenotypic fixation occurs.

By bringing together evidence from different levels of analysis, ranging from the molecular to the social, a much more powerful theoretical perspective can be formulated. Its impact is not only on scientific approaches to development and evolution, but also on how humans think about themselves and how they design public health measures when mismatches between themselves and their environment occur.

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CHAPTER 7

Neuroscience, Embodiment, and Development

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The brain is an immensely complex organ: One estimate puts the number of neurons in the adult human brain at about 100 billion (Pakkenberg & Gundersen, 1997), with perhaps 100 trillion synapses or connections between neurons. Despite this enormous complexity, the past decades have seen advances in theory and method that are leading to a greater understanding of brain function and the ways in which neuroscience relates to psychological science (Berntson & Cacioppo, 2009). However, neuroscience is clearly a large discipline and an umbrella term for a variety of subdisciplines that intersect with the field of psychology in various ways, and understanding these relations is not a straightforward endeavor (Rosvall & Bergstrom, 2010).

Advances in cellular, molecular, and electrophysiological methods have facilitated the rise of what has become known as *behavioral neuroscience* and have led to significant increases in knowledge concerning the neurobiology of learning, memory, and motivation, with a focus on animal models. In human work, various related subdisciplines have emerged such as *cognitive neuroscience* (Gazzaniga, 1995), *affective neuroscience* (Davidson & Sutton, 1995), *social neuroscience* (Cacioppo et al., 2007; Ochsner & Lieberman, 2001), and *social-cognitive neuroscience* (Adolphs, 2003; Frith & Frith, 2003). There has also been increasing interest in the development of the brain and nervous system in relation to cognitive, emotional, and social development (de Haan, Chapter 18, this *Handbook*, this volume; Nelson & Luciana, 2008; Zelazo, Chandler, & Crone, 2010).

The various areas of neuroscience have also attracted the attention of funding agencies, in light on the presumed importance of investigating what could be termed the *neural mechanisms* or *neural processes* involved in psychopathology, including developmental aspects. One salient example comes from the emphasis at the National Institute of Mental Health that the first step in the classification of mental disorders is not the clinical description of symptoms but rather "to inventory the fundamental . . . behavioral functions that the brain has evolved to carry out, and to specify the neural systems that are primarily responsible for implementing these functions" (Cuthbert & Insel, 2013, p. 4). From this perspective, psychopathology is then considered "in terms of dysfunction of various kinds and degrees in particular systems" (p. 4).

The increase in the status and visibility of neuroscience has significantly altered the landscape of psychology, and has stimulated a discussion concerning the present and future relations between the disciplines of psychology and neuroscience (Decety & Cacioppo, 2010). One prediction is that "harder" areas of neuroscience (i.e., the areas focusing primarily on cellular and molecular aspects) will split from psychology, which would then primarily be left as a social science of behavior and experience (Kagan, 2006). Arguably, the signs of such a split are already visible in the way that graduate training programs in many psychology departments separate the more cellular and molecular areas of neuroscience not only from other traditional areas of specialization such as cognitive, developmental, or social psychology (Spear, 2007), but also from the more psychologically oriented area of cognitive neuroscience.

The relations between psychology and neuroscience have also been the subject of a good deal of attention in the philosophy of mind, in which views can be broadly characterized as lying at or between two extreme positions. One position espouses the status of psychology as an autonomous discipline, with little or no meaningful connection to neuroscience (Cummins, 1983; Fodor, 1974, 1997). This view has encountered many difficulties, some of which will be considered in this chapter. The opposing position is that psychological constructs will ultimately be reduced to and replaced by descriptions of neurobiological processes (e.g., Bickle, 2003; Churchland, 1981, 2013). In turn, this reductionist view has also found little support from neuroscientists, psychologists and philosophers. Neuroscience and psychology address different subject matter, which precludes reduction (Chemero, 2007), but which also leaves open difficult questions about the relations between the disciplines.

So, how to proceed? The opposing scenarios of "brainless" autonomy and "only-brain" elimination do not appear to present palatable options for the future of psychological or developmental science. Between the extremes, a moderate position invokes a conceptualization of psychology and neuroscience as separate but complementary levels of analysis (e.g., Miller & Keller, 2000). From this perspective, addressing questions on each level has more explanatory power than dealing with one level alone. However, one central premise of this chapter is that as a field, psychology has failed to give sufficient consideration to how to approach the concept of *different levels of analysis* as well as the relations among such levels. One argument is that these issues are not well understood within the psychological literature because the trajectory of this discipline over the past decades has prevented the emergence of a more integrative view (Marshall, 2009). One aim of this chapter is to show how more integrative accounts are coming to the fore, with new perspectives in developmental science adding an indispensable dimension (Greenberg & Partridge, 2010; Marshall, 2013).

OVERVIEW

This chapter takes a wide-angle look at developmental features of the relation between psychology and neuroscience, and is not meant to provide a basic description of brain development (see instead Nelson, de Haan, & Thomas, 2006; Paus, 2009; Stiles, Brown, Haist, & Jernigan, Chapter 2, this *Handbook*, Volume 2; Zelazo & Lee, 2010). The chapter begins with a broad introduction to the concept of neuroscience as a different level of analysis, initially working from an account of how classical cognitivism resulted in a neglect of neuroscience in psychology, and how the growing field of cognitive neuroscience has attempted to address this omission. The emergence of developmental cognitive neuroscience is then considered, with a focus on central questions of plasticity and how early experience relates to the development of brain and behavior. Current theoretical perspectives in developmental cognitive neuroscience are also outlined, including the neuroconstructivist approach.

One feature of neuroconstructivism is an appreciation of the embodied nature of development, which is considered here to be an essential part of any theory of developmental cognitive neuroscience. Indeed, a key argument outlined in the second part of the chapter is that embodiment has the potential to reframe the ways in which neuroscience data are viewed and analyzed in relation to other kinds of data. This potential can be realized through a reconceptualization of what cognitive scientists have termed the *level of implementation*. However, key developmental features of this reconceptualization are currently underspecified, and in the final part of the chapter it is suggested that a relational developmental systems perspective provides a way forward. The implications of this approach for forging a new biologically inspired direction for developmental science are profound, and are discussed in more detail toward the end of the chapter.

NEUROSCIENCE AND LEVELS OF ANALYSIS

Conceptualizing the relations between psychology and neuroscience remains the subject of extensive debate and discussion (Miller, 2010). The question at the heart of this debate is what kind of explanation can be provided by neuroscience data. This question is the starting point for the discussion here, with an initial focus on the concept of neuroscience data as occupying one of several levels of analysis. This focus reflects a current trend in certain areas of psychology to emphasize the utility of studying a phenomenon across multiple levels of analysis, an emphasis that is particularly strong in certain areas of developmental science (see, e.g., Cicchetti, 2008). Within developmental work, this emphasis has roots in theory-predicated research in classic comparative psychology studies involving levels of integration in behavioral development (Schneirla, 1957, 1959; Tobach & Greenberg, 1984; Tobach & Schneirla, 1968).

The position that neuroscience data occupy one of several levels of analysis is a common one across psychology more broadly. For example, in an influential discussion of the emerging subdiscipline of social-cognitive neuroscience, Ochsner and Lieberman (2001) proposed three such levels of analysis: A motivational level, a cognitive level, and a "neural level, which is concerned with the brain mechanisms that instantiate cognitive-level processes" (p. 717). Similar distinctions are common, and are usually accompanied by an emphasis on the deeper understanding that results from studying phenomena at different levels (e.g., Ozonoff, Pennington, & Solomon, 2006). From such a perspective, the study of different levels and their interactions is considered to be a productive and worthwhile enterprise (Cacioppo, 2002; Machamer & Sytsma, 2007).

Although the notion of multiple levels appears at first sight to present a potentially integrative picture, what is specifically meant by different levels of analysis—and how to conceptualize the relations among levels—is often left unsaid. This remains problematic, because issues about levels and the relations among them are at the heart of fundamental questions about the enterprise of explanation across the entire field of psychology. However, addressing these questions has a long history of difficulties, and the vexing nature of many of the associated issues is well known. As framed by Dennett (2000), "it has been widely recognized that many of the false starts in cognitive science have been due to failures to find the proper level of analysis for the topic. The bold claim might be defended that all the really tough problems . . . reside in the murky and embattled zones where the relations between these levels must be clarified" (pp. xi–xii).

Developmental science does, in fact, have a history of tackling the difficult issues concerning the integration of different levels—as seen, for example, in the work of developmentally oriented comparative psychologists working in the mid-20th century (see, e.g., Aronson, Tobach, Rosenblatt, & Lehrman, 1972). However, the emerging discipline of cognitive science also taking shape over that time period did not reflect this move toward integration, but instead it encouraged separation. As discussed by Floridi (2008), the notion of separate levels of analysis became popular among cognitive scientists in the 1970s, in part through an increase in attention to computational methods. Early supporters of levels-based approaches were Dennett (1971), Simon (1969), and Wimsatt (1976), although perhaps the best-known framework came via the theorizing of the vision scientist David Marr (1982). Despite the relative neglect of neuroscience in his own work, Marr's three-level approach has provided a useful conceptual framework for a number of past and present discussions concerning the relations between psychological constructs and neuroscience (e.g., Clark, 2000; Gold & Stoljar, 1999; Kitcher, 1988; Mitchell, 2006; Poeppel, 2012; van Eck, de Jong, & Schouten, 2006).

Specifically, Marr's account concerns "the three levels at which any machine carrying out an information processing task must be understood" (Marr, 1982, p. 25). In brief, these three levels are:

1. A *computational* level that refers to a general analysis of the requirements of the task and the formulation of an overall strategy toward fulfilling those requirements.
2. A level of *representation and algorithm* consisting of the description of a series of mechanical steps that would solve the problems outlined at the first level, including the specification of the representational format to be used.
3. A level of *implementation* that consists of a description of the physical hardware needed to carry out the sequence of steps that was specified at the second level.

Although he was primarily concerned with problems in visual perception, the information processing emphasis in Marr's account is consistent with how cognitive psychology was approached at the time that he was writing—with mental processes being framed primarily in computational terms. As an example, in line with this emphasis Marr illustrated how his three-level framework could be applied to an everyday machine—a cash register. At the first computational level, the question is a broad one: What is the general nature of the task or problem at hand? In the example of the cash register, the computational problem refers to addition—what a cash register needs to do. However, at this level nothing is said about how to *do* addition. This is the question at the second level of representation and algorithm, which can also be considered a level of *mechanism*.

For the example of the cash register, an account at the second level should provide an answer to the question of *how* addition is done. In Marr's account, a description at this level would specify what kind of representation might be used, given the problem stated at the first level. For the cash register, one might adopt Arabic numerals as the representational format. One would then specify the rules or procedures that would be applied to these representations, such as adding the least significant digits first and carrying if the sum exceeds 9. At the third level of implementation, the question concerns how the symbols and processes specified at the second level might be physically implemented. Implementation then becomes a problem of engineering a machine in which the chosen mechanism could be instantiated. In the example of the cash register, this could be done as binary coded decimal numbers in the electrical states of digital logic circuitry, or it could be done on a notched metal wheel (McClamrock, 1995).

Although the machine example of Marr may seem out of place in a contemporary discussion of developmental science, emphasizing the similarities between mind and machine has been a dominant theme in psychology over the past 50 years. The *mechanistic* focus of the level of representation and algorithm closely aligns with a key objective of cognitive science, which is quite literally to try to understand *how* the mind works. In this sense, most of the work in cognitive psychology has taken place at what corresponds to Marr's second level of representation and algorithm—the level of problem solving in terms of what symbols are needed for a solution, and the rules under which those symbols can be manipulated. Indeed, the premise of mainstream cognitive psychology for decades was that the real work was in solving problems at the algorithmic level, with the physical means that might be used to instantiate the solution to the problem being viewed as "mere implementation" (see Smolensky, 1988, p. 7). This lopsided approach was a key aspect of the *cognitivist framework* that underwrote one interpretation of the so-called cognitive revolution in psychology (Miller, 2003; see Bruner, 1990, and text below for an alternative interpretation). Although developmental aspects remained on the sidelines, it is worth further exploring the implications of these broader issues about cognitivism here, because they are closely related to the primary questions concerning levels—and the relations among them—that are central to this chapter.

Cognitivism and the Neglect of Neuroscience

Although the *neopositivism* of the early 20th century aimed to purge psychology of its metaphysical overtones (Overton, 2006), the original objective of the cognitive revolution was to return the study of mental life and meaning to the field of psychology after decades of behaviorism. According to Bruner's (1990) interpretation, the foundational emphasis of the cognitive revolution was "to discover and to describe formally the meanings that human beings created out of their encounters with the world, and then to propose hypotheses about what meaning-making processes were implicated" (p. 2). However, the cognitivist understanding of the nature of mind that emerged from the cognitive revolution did not reflect this emphasis. Instead, the predominant conceptualization of the mind became influenced by the idea that cognition consists of formal computational reasoning processes acting on the syntactic, but not the semantic, aspects of symbolic representations (Fodor, 1975).

The adoption of the cognitivist framework within psychology was also associated with an alignment with the emerging discipline of artificial intelligence, which further contributed to the dominance of an information processing view of the mind. From this perspective, cognitive operations could be seen as manipulations of subpersonal representations to which meaning had been preassigned (see Allen & Bickhard, 2013, for a critique of this position). One rationale for the growth of this view was the sentiment that if computers could be used to model the ways that representations are manipulated, mental processes could be made more transparent (Newell, Shaw, & Simon, 1958). This rationale was an important aspect of the turn toward computational approaches because it provided one way of moving beyond the behaviorist paradigm that had dominated psychology for the preceding decades. However, it has been argued in various places that the move toward the cognitivist view of the mind was fundamentally a wrong turn in that it prevented the emergence of more integrative accounts (e.g., see Rowlands, 2010; Smythe, 1992; Thompson, 2007). In the context of the current project, a related argument is that the turn toward cognitivism encouraged a neglect of neuroscience among cognitive psychologists (see Edelman, 1992).

In encouraging a computational view of the mind, the cognitivist approach put an unduly strong emphasis on the level of representation and algorithm (i.e., Marr's second level), with little or no regard for how these information processing mechanisms might be realized in living systems. As such, perhaps it is not surprising that mainstream cognitive psychology became disconnected from the study of neuroscience: If mental processes could be modeled using symbol-manipulating algorithms implemented on a computer, the actual makeup of the human brain was not particularly relevant. Indeed, Marr's own theorizing put an emphasis on the relation between the computational and the representational/algorithmic levels. The origins of this emphasis lie in the background assumption that the optimum level of explanation involves translating task requirements into an algorithmic solution using an appropriate representational format. If this assumption is accepted, the actual hardware that could be used to manipulate the representations and to implement the algorithmic solution can be seen as less important than the method by which the problem was solved. Within the philosophy of mind, this emphasis on Marr's algorithmic level remained a dominant force in cognitive psychology in the decades following the cognitive revolution. As such, this approach became the conventional way that psychological explanations are understood—as functional explanations that are distinct (and separable) from other kinds of explanation (such as neuroscientific explanation, see Piccinini & Craver, 2011).

At the time of his writing in the late 1970s, the neglect of the implementational level in Marr's own work was partly a response to the sheer complexity of understanding the physiology of the visual system, which was his specific area of study. However, in other circles a similar outlook was further propelled by a particular philosophical perspective—in vogue at the time—that further discouraged a serious consideration of the implementational level. This discouragement concerning the value of neuroscience was based on the argument of *multiple realization*: That the same problem could potentially be solved using processes that were implemented on different *hardware*, be it a human brain, a machine, or even an extraterrestrial being with a physiological makeup completely different to any biological system on earth (Fodor, 1975). The invocation of this argument buttressed the isolation of the computational mind in the cognitivist approach, and placed a further barrier to the integration of psychology and neuroscience (see also Putnam, 1975; Pylyshyn, 1984).

From the perspective that is developed over the course of this chapter, the failure to maintain a focus on the necessary constitutive character of all of Marr's levels represents a distinct problem. Given this fundamental shortcoming of the cognitivist emphasis, more integrative approaches are needed that would incorporate all three of the levels in a unitary framework. However, formulating specific relations between levels has been a notoriously difficult endeavor. Much work in the philosophy of science has attempted to map how interlevel relations could be conceptualized, although as noted by Houng (2012), the concept of level "has been used in philosophical communities in a vague and confusing way" (p. 324).

One attempt to sidestep some of this confusion comes from the suggestion that Marr's levels are *levels of realization* (for discussion see Craver, 2005, 2007). From this viewpoint, the computational level is realized by the algorithmic level, which is realized by the implementational level. Levels of realization can, therefore, be understood as different ways of looking at the same thing, with no level having particular explanatory priority. This may appear at first to be an attractive option because it seems to avoid problematic issues of *reductionism*, either in the traditional sense that one level can be derived (and thus reduced to) another level, or in a more contemporary view that lower level processes might have a stronger explanatory privilege (for discussion see Piccinini & Craver, 2011). Indeed, Miller (2010) has argued that the neutral approach of levels of realization is preferable to one of causal reductionism (see also Miller & Keller, 2000). However, the concept of levels of realization may also give the misleading impression that the different levels of analysis can be considered in relative isolation: One could pay lip service to the importance of levels, while, in fact, neglecting a serious consideration of the relations among them (Marshall, 2009).

Given these difficulties, how can a more integrative account of the development of body, brain, and mind be formulated? The two intertwined central premises of this chapter are that a *relational developmental systems* framework (see Overton, Chapter 2, this *Handbook*, this volume), in which the relational ties among levels can be articulated within the context of *embodiment,* can provide a way forward. To move toward an elaboration of this premise, the field of cognitive neuroscience is first considered, because it has been a testing ground for many of the key questions involving the relations among levels.

The Emergence of Cognitive Neuroscience

The past 30 years have seen advances in neuroscience methods that have driven the emergence of the discipline of cognitive neuroscience (Kosslyn & Koenig, 1992; Posner & DiGirolamo, 2000; Posner & Raichle, 1994). Building on an established tradition of brain research in neuropsychology, newer neuroimaging technologies such as functional magnetic resonance imaging (fMRI) joined existing methods such as electroencephalography (EEG) to allow cognitive neuroscientists to probe brain function in ways that simply had not been possible before (see de Haan, Chapter 18, this *Handbook*, this volume). Furthermore, cognitive neuroscience potentially allows these methodological advances to be used to address questions about implementation alongside questions of mechanism. In other words, the promise of cognitive neuroscience has been that explanations framed at Marr's first two levels can potentially be connected with explanations at the third level of implementation.

Although some have argued otherwise (e.g., Bennett & Hacker, 2003), most cognitive neuroscientists do not view their approach as a reductionistic one nor as a replacement for psychological concepts. Instead, they intend the use of functional neuroimaging and related techniques as a means of decomposing cognitive processes into component activities in much the same way that earlier cognitive scientists used chronometric behavioral measures such as reaction time (Posner, 1978). Related to this aim, the principal goals of cognitive neuroscience have been summarized by Bechtel (2002) as follows: "that an explanation of a cognitive performance involves both decomposing an overall task into component information processing activities and determining what brain area performs each" (p. 49, see also Bechtel, 2008). Each of these two aspects will be considered separately here.

The use of neuroimaging data to investigate the cognitive processes involved in task performance relies on what has been called a strategy of *forward inference* (Henson, 2006). In its most basic form, this method is meant to indicate whether carrying out two related tasks might involve similar cognitive processes. If regional or temporal differences in brain activation are observed during the performance of two seemingly related tasks, the hypothesis that the tasks utilize identical cognitive processes can be rejected. In this approach, neuroscience data can help distinguish between competing psychological hypotheses that were formulated using behavioral data (Schall, 2004). When used in this manner, neuroscience data do not have a privileged status, but instead represent another dependent variable for testing competing hypotheses about unseen mental processes. In this sense, the use of forward inference is consistent with the suggestion that cognitive theories should be the starting point for the application of neuroscience data (Cooper & Shallice, 2010; Hatfield, 2000), although it has also been suggested that this relation operates in the opposite fashion (i.e., from data to theory, see Forstmann, Wagenmakers, Eichele, Brown, & Serences, 2011).

Inferences about which brain regions are associated with the cognitive functions involved in the performance of a task (Bechtel, 2002, 2008) are often made through a different strategy, called *reverse inference* (Poldrack, 2006). Poeppel (2012) refers to this endeavor as *making maps*, with activation of a specific brain region during performance of a task being taken as indicative of the engagement of a particular cognitive process. However, such inferences about the activation of a specific cognitive process have to be made on the basis of evidence from prior studies linking this cognitive process to this particular pattern of brain activation. As noted by Poldrack (2006), this sequence involves the logical fallacy of affirming the consequent, and as such is not particularly helpful (see also Levin & Aharon, 2011). However, it has been suggested that the understanding of relations between activation of certain brain regions and cognitive functions can be strengthened in a number of ways. These include employing neuropsychological data involving transient deactivation or the effects of chronic damage to specific brain regions, and the use of Bayesian inference and meta-analytic approaches that draw on large numbers of datasets and which include parametric manipulations of the supposed cognitive process (see Decety & Cacioppo, 2010; Zacks, 2008).

Although cognitive neuroscience has maintained a high profile, some scientists working within the discipline have voiced concern that the original objective of informing the study of cognitive processes has been pushed aside by a flurry of technological advances. Cooper and Shallice (2010) argue that much of contemporary neuroscience neglects what they see as Marr's most critical level—the information-processing level of representation or algorithm—and that if cognitive neuroscience focuses too much on neuroscience, the cognitive aspect is at risk. Similarly, Poeppel (2012) cautions that the trend toward finer and finer localization methods can only do so much:

> [While] the spatial organization of information-processing systems can be a useful, and even necessary, intermediate

> step in explaining a system ... even fantastic localization of function, incorporating the newest techniques ... does not constitute an explanation. The cartographic imperative does not suffice. It is the mechanistic understanding of the function that we seek, and that is not going to be tractable by localization of function and spatial topographic mapping alone. (p. 38)

In emphasizing the continuing value of Marr's levels as "distinct but tightly yoked levels of description," Poeppel (2012) suggests that although cognitive neuroscientists have been preoccupied with making *maps*, questions about making *mappings* between the structure and units of cognitive psychology and those of the neurosciences have been neglected (see also Poldrack, 2010). Cooper and Shallice (2010) further argue that these kinds of problems lend support to critiques of localization studies in cognitive neuroscience (e.g., Coltheart, 2006, 2013; Hardcastle, 2007; Harley, 2004), and that the response of cognitive neuroscientists to such critiques have been insufficient to adequately counter them.

From the perspective of the current chapter, one suggestion that strongly points toward a break in this impasse comes from the need to consider *developmental* aspects of the mappings problem. Indeed, Poeppel (2012) emphasizes that developmental data—in the context of theory building—can play a key role in providing answers to many of the fundamental problems in cognitive neuroscience. However, the mainstream discussions that have occurred among cognitive neuroscientists about the utility of neuroimaging data in cognitive psychology have not generally recognized a fundamentally important role for development (see, e.g., Shimamura, 2010). This lack of recognition is illustrated by the fact that a recent textbook on cognitive neuroscience by two prominent neuropsychologists (Shallice & Cooper, 2011) contains virtually no mention of developmental processes.

Developmental Cognitive Neuroscience

Despite the adult-centric nature of mainstream cognitive neuroscience, developmental features of neuropsychology have had advocates who have consistently emphasized that studying only the adult state places fundamental limits on the understanding of brain and cognition (e.g., Karmiloff-Smith, 1998, 2013). Building on this advocacy, a subfield explicitly called *developmental cognitive neuroscience* (DCN) has emerged, with the appearance of a handbook (Nelson & Luciana, 2001, 2008), an eponymous journal (Blakemore, Dahl, Frith, & Pine, 2011) and a textbook (Johnson, 2011a).

According to Johnson (2011a), DCN is concerned with the origin of the organized biological structure of the brain and how this structure comes to play its key role in mental life. Relevant background emphases include the notion that "biological structure emerges through complex and variable interactions between genes and their environments" (p. 2) and that "there is no simple sense in which information either exclusively in the genes or in the environment can specify the end product" (p. 5). At a certain level, DCN is therefore a *systems* approach, with implicit connections to the notion of *probabilistic*—rather than predetermined—*epigenesis*, as put forward by the developmental systems theorist Gilbert Gottlieb (1970, 1998; see also Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume). In turn, these connections link further back, to the influence of a lineage of comparative perspectives on the development and integration of behavior (Schneirla, 1959).

In emphasizing "complex *self-organizing* interactive processes" (Johnson, 2011a, p. 225, italics added), the DCN approach is broadly aligned with a *constructivist* approach to the development of human knowledge. One attempt to further expound a constructivist manifesto for DCN comes from the work of Mareschal et al. (2007), who give three reasons why they are committed to considering neural processes in the study of cognitive development:

1. Ontogeny is understood as involving "the construction of increasingly complex levels of biological organization, including the brain and the cognitive processes it supports" (p. 7). Within this context, Mareschal et al. (2007) also argue that higher-level cognitive functions are established through organizational processes operating at lower levels (e.g., cellular interactions).
2. They argue that developmental neuroscience data can be helpful in understanding the origins of developmental disorders and, hence has important clinical implications.
3. They maintain that considerations of brain structure and function place important constraints on theories of cognitive development such that "a proper consideration of brain mechanisms is likely to result in a more adequate model of cognition in general and cognitive development in particular" (p. 8). More specifically, Mareschal et al. (2007) argue that explanations of what they term *representational change* should be consistent across the cognitive and neural levels of explanation.

One other emphasis of DCN has been on the utility of computational modeling in the study of cognitive development (see also Marcovitch & Zelazo, 2012). Indeed, the approach of Mareschal et al. (2007) is essentially an information-processing account, with a key role for the manipulation or transformation of representations by computational mechanisms. At first sight, this emphasis might suggest a continuation of traditional *connectionist* approaches to development such as that of Elman, Bates, Johnson, and Karmiloff-Smith (1996). However, Mareschal et al. (2007) suggest that connectionism has tended to view the child as a passive experiencer without an active or agentive role in his or her own learning. In contrast, they propose that their flavor of developmental theory—*neuroconstructivism*—allows for a stronger role for activity and bodily context in brain and cognitive development.

In line with this emphasis, Mareschal et al. (2007) define a representation as "an information state within the brain of the organism that contributes to adaptive behavior within a given environment" (p. 4). In this view, a consideration of neuroscience means that "representational states must be expressed through patterns of neural activity that reflect (to some extent) states in the world" and that "these representations may interact with, exploit, be constrained and enhanced by physical components outside the brain" (p. 5). This assumption is further reflected in the emphasis of neuroconstructivism on *partial representations*, a term that encompasses both the idea that information is not "stored" in one particular brain region and also that internal representations cannot be central, detailed copies of the world but instead allow the organism to utilize aspects of its environment to accomplish salient goals. The emergence of representations is, therefore, constrained by context dependence, which in turn operates through general processes of cooperation and competition between components and a temporal ordering of the emergence of functional units. From the neuroconstructivist perspective, the context dependence of partial representations stands in contrast to the more limited cognitivist notion of symbolic, acontextual representations (although Lickliter, 2008, raises the question of whether neuroconstructivism can really account for the problem of meaning).

Neuroconstructivism stands as an example of an approach that has taken a computational or information-processing perspective while at the same time engaging with the literature from developmental neuroscience. It is worth noting that the application of computational models remains a theme in other recent high-profile theoretical work on early cognitive development, although the specific connections to neuroscience are less clear. One example comes from prominent developmental approaches involving probabilistic models (Tenenbaum, Kemp, Griffiths, & Goodman, 2011). In employing hierarchical Bayesian multilevel models to model cognitive development, Tenenbaum et al. (2011) note that they "target a view between the computational and algorithmic levels: cognition as approximately optimal inference in probabilistic models defined over a learner's subjective and dynamically growing mental representations of the world's structure, rather than some objective and fixed world statistics" (p. 1284).

Probabilistic approaches such as that of Tenenbaum et al. (2011) have become highly visible in the literature on cognitive development, although key issues remain. Related questions arise about developmental proposals of a *rational unconscious* (Gopnik & Wellman, 2012) and the *rational constructivist* account (Xu & Kushnir, 2013), both of which are firmly grounded in probabilistic models. Echoing the issues faced by theories of cognitive development involving perceptual primitives (e.g., Mandler, 2004), these questions include how and whether the implicit representations of probabilistic approaches connect with experience at the level of the person or with symbolic representations at higher levels of consciousness (Müller & Overton, 1998). Another question about the emerging computational, probabilistic models of cognitive development concerns the nature of their connections with neuroscience, which as noted by Tenenbaum et al. (2011) remains a key challenge for future analyses. In investigations with adults, one line of research has attempted to reconcile features of brain function with probabilistic mechanisms (Friston, 2012), although developmental implications of these linkages have not yet been well explored.

Elaborating the scope and implications of Bayesian approaches has become a very active area of research in cognitive science (see Clark, 2013). However, from the perspective of this chapter, a further problematic omission concerns the role of the active, agentive organism in relation to processes of thought and reasoning. In the Bayesian account, the brain processes information, but on the embodied account that is developed in this chapter, information processing as well as meaning making cannot be fully encapsulated in the brain, but rather they are a function of the actions of the fully embodied organism. Thus, the organism as active agent in this embodied model both acts, which constitutes a prediction, and modifies its actions, which operates to reduce an error of prediction. This is closely akin to the Piagetian notion of the organism's assimilatory action, which predicts, and accommodatory action, which modifies the assimilatory structure, hence reducing the error of prediction. Although elements of this framework are visible in some contemporary probabilistic accounts (Friston, Mattout, & Kilner, 2011), a constructivist embodied developmental perspective might significantly inform such accounts.

Brain Development: Networks and Plasticity

Part of the emerging field of DCN is aimed at understanding the ontogeny of the brain, with a particular focus on the development of the cortex. Although it has a consistent basic structure, the mammalian cortical sheet is not uniform; rather it is characterized by areas that differ in terms of their cellular organization and their connectivity to other parts of the brain (Mountcastle, 1998). Key questions about cortical development include how the laminar (layered) structure of the human neocortex arises as well as how the cortical sheet becomes differentiated into cytoarchitecturally and functionally distinct areas (see Stiles et al., Chapter 2, this *Handbook*, Volume 2). Concerning the first issue, early work in developmental neuropsychology suggested that the development of the laminar structure of the cortex as well as the initial differentiation of cortical neurons do not appear to depend on sensory input to be established (Rakic, 1988). Johnson (2011a) suggests that one view of these processes would be to see them as occurring through processes of *intrinsic* cellular and molecular interactions, but not as the unfolding of a genetically predetermined plan. In line with this emphasis, Stiles and Jernigan (2010) note that "nothing in neural development appears to be predetermined" (p. 345), with all aspects of brain development involving an intricate temporal and spatial web of events entailing the coactions of the genome, the epigenome (Meaney, 2010), and cellular environments.

How the various major regions of the cortex develop and differentiate has been the focus of a great deal of research in developmental biology, some of which is outlined by Stiles et al. (Chapter 2, this *Handbook*, Volume 2). Although primarily the domain of developmental biologists, questions in this area have also been of particular interest to developmental cognitive neuroscientists because they present an ideal opportunity to explore the coactions of genes, cellular environments, and neural activity in the ontogeny of the human brain (Stiles, 2009). One starting point for these questions comes from a consideration of constraints on cortical organization. A comparative examination of brains across mammalian species suggests commonalities in the specialization of major regions of the cortex, such as the presence and relative locations of primary sensory areas (Krubitzer & Kaas, 2005). Indeed, primary cortical areas involved in somatosensation (area S1), vision (V1), and audition (A1) and that are defined by a topographic representation of sensory organs have been identified in all mammalian species examined thus far. Although these areas are positioned similarly across species, their relative size is extremely variable depending on ecological niche (e.g., bats have a particularly large amount of primary auditory cortex). Although this suggests some evolutionary constraints (see also Finlay, 2005), it is also clear that there is a great deal of plasticity during cortical development, in large part due to a key role for activity-dependent processes. As detailed by Karlen, Hunt, and Krubitzer (2010), there is an abundance of data from developing mammals indicating that activity in peripheral sensory receptors plays an important role in influencing the functionality, internal organization, size, and connectivity of cortical fields.

Johnson (2011b) presents two contrasting possibilities for how the apparent functional specialization of major cortical regions arises (see also Mallamaci, 2011). One is that the function of each area of cortex mainly results from intrinsic cellular and molecular factors, such that a biologically specified protomap is generated in the absence of sensory or neural activity. This model of development is sometimes termed the *mosaic* model of development as exemplified by the roundworm *C. Elegans*, which has various cell lineages that develop independently of each other. If such a deterministic model was applied to cortical development, the expression of particular genes in specific regions would allow new functions to emerge, with a resultant mapping between brain regions and particular cognitive functions, and specific abilities coming online as cortical areas mature.

The second possibility for the origin of cortical regions is much less deterministic than the mosaic model. According to this alternative, functionally different areas of cortex arise from a relatively equipotential sheet of protocortex that differentiates based on patterns of neural activity and sensory input. With respect to evidence for either model, the data suggest a middle viewpoint, such that graded patterns of gene expression create large-scale regions, which are then shaped by finer-grained interactions involving genes, epigenetic factors, cellular coactions, and thalamic input. For instance, the early development of cortical patterning is shaped by the coaction of differential gradients in various signaling molecules that lead to the initial differentiation of large-scale regions of the cortex (Sansom & Livesey, 2009). This initial patterning process in cortical development results in areas with properties best suited to certain broad functions (e.g., motor, somatosensory, visual). The specific functional characteristics of these regions then differentiate through activity-dependent processes, with the functions of these regions becoming more integrated over development (Krubitzer & Kaas, 2005).

This process of differentiation and integration is fundamental to Johnson's (2000) *interactive specialization* (IS) model of brain development in which cognitive functions are the product of emergent coactions among different brain regions. According to this view, changes in task performance are subserved through the developmental combination of cortical networks having different computational capacities. Although the result of this combination may give the appearance of specific brain areas as being specialized for processing specific kinds of stimuli, it hides a significantly more complex picture. This developmentally oriented realization provides an important rejoinder to much of contemporary cognitive neuroscience in adults (see Poeppel, 2012), and it has been strengthened by observations that a given brain region or neuroanatomical structure is often activated across multiple tasks and cognitive domains (Anderson, Kinnison, & Pessoa, 2013). As noted by Anderson, Richardson, and Chemero (2012), such findings also bring into question the related assumption in cognitive psychology that the mind can carved up into distinct, separable cognitive domains. Similarly profound notions have also been raised in the context of affective science, where problems with delineating discrete emotions and associated brain circuits have been noted (Lindquist & Barrett, 2012).

Within cognitive neuroscience, a shift away from the localization of cognitive functions in the brain has led to an emphasis on the complexities of brain networks (Sporns, 2011, 2014). As scientists working in this area, Bressler and Menon (2010) state:

> Much of our current knowledge of cognitive brain function has come from the modular paradigm, in which brain areas are postulated to act as independent processors for specific complex cognitive functions. Accumulating evidence suggests that this paradigm has serious limitations and might in fact, be misleading. Even the functions of primary sensory areas of the cerebral cortex, once thought to be pinnacles of modularity, are being redefined by recent evidence of cross-modal interactions. A new paradigm is emerging in cognitive neuroscience that moves beyond the simplistic mapping of cognitive constructs onto individual brain areas and emphasizes instead the conjoint function of brain areas working together as large-scale networks. (p. 277)

In many ways, the importance of brain networks as a *new paradigm* reveals the real promise of DCN, which is that developmental data can add an indispensable component to understanding the integrated functioning of these networks (Dekker & Karmiloff-Smith, 2011). Although much of the study of brain networks has focused on the adult brain, developmental considerations are clearly extremely important, and how networks emerge in the developing brain is currently the focus of increasing attention (Byrge, Sporns, & Smith, 2014; Collin & van den Heuvel, 2013; Hagmann, Grant, & Fair, 2012; Hwang, Hallquist, & Luna, 2013; Power, Fair, Schlaggar, & Petersen, 2010). In a related context, Johnson (2011b) has suggested that the IS framework is a useful way of viewing brain networks in the context of the development of behavior and cognition. According to this view, large-scale patterns of brain organization emerge through the activity of interregional interactions, and developmental processes involve changes in connectivity between brain regions, with network-level changes impacting the development of cortical areas on a smaller scale. Specific evidence for the IS model comes from a variety of findings about brain activity becoming more focal with increasing experience with particular kinds of stimuli (Johnson, 2011b).

This emphasis on the shaping of cortical networks through experience also implies a degree of *plasticity* in cortical tissue, such that a brain region could potentially develop different functions based on the coaction of cortical tissue and input rather than the location of the brain region per se. Relevant studies in this area have examined the sequelae of transplanting or rewiring certain cortical areas (usually primary sensory areas) in early development. In one well-known example, Sur and colleagues induced rewiring in juvenile ferret brains so that visual input was projected to typically auditory regions of the cortex (see Sur & Leamey, 2001). The relative immaturity of visual connections at birth in the ferret meant that the auditory nerve could be stopped from entering the thalamus, after which the optic nerve innervated both visual and auditory cortex. The result of this rewiring was *cross-modal plasticity*, as shown by the development—in what would typically be part of auditory cortex—of a pattern of organization and responsivity that usually characterizes neurons in the visual cortex. Sur's work is an example of what Hurley and Noë (2003) termed *cortical deference*, such that the function of cortical tissue can be shaped according to the type of input (e.g., the modality) received. This deference may be particularly strong in early life, but it should be noted that cross-modal pathways play an important role in the adult brain (Calvert, 2001). Although some of these pathways may be apparent in naturalistic activities and tasks, others can be "uncovered" in adults through experimental manipulations of the availability and patterning of information across different modalities (Merabet et al., 2007).

The findings above from the developmental neuroscience literature highlight the significance of neural activity in the differentiation of major cortical regions. A dependence on activity has also been demonstrated *within* cortical regions, as evidenced by classic animal work examining plasticity in emerging cortical maps of somatosensory space. One example comes from research in rodents on the development of whisker barrel fields, which receive input from individual whiskers and which form a cortical map of sensory space. If one whisker is removed in early development, the corresponding barrel field does not emerge, and neighboring fields will take over the space (Loos & Woolsey, 1973). Although this again suggests a role for early sensory experience, evidence has shown that within somatosensory cortex, the potential for reorganization also remains present across the life span. One well-known example of later-occurring reorganization comes from an examination of adult macaque monkeys following severing of afferent connections along the pathway from spinal cord to primary somatosensory cortex (Pons et al., 1991). This work demonstrated that areas of somatosensory cortex corresponding to a particular limb can begin to process input from adjacent cortical areas (e.g., corresponding to the face) following deafferentation of that limb.

In humans, research on phantom limbs has also demonstrated the plasticity of somatosensory cortex, and it has illuminated additional complexities related to changes in qualitative experience following the loss of limb function. Sensations of a missing limb sometimes remain even when the relevant area of somatosensory cortex has been innervated by neurons from adjacent areas (e.g., the face area). In such cases, stroking of the face can result in the experience of the phantom limb also being touched (Ramachandran & Rogers-Ramachandran, 2000). Hurley and Noë (2003) suggest that this finding is an instance of *cortical dominance* in which qualitative aspects of the prior characteristics of a cortical area are retained after the rewiring of cortical connections. Developmental data have added a fascinating layer of complexity to this area through investigations of aplasic individuals who were born without a particular limb (or without multiple limbs). There is evidence that at least some aplasics experience phantom limb sensations (see, e.g., Brugger et al., 2000), which has provided support for conjectures concerning the origin and development of what could be termed the *body schema* (Gallagher & Meltzoff, 1996). This construct refers to sensorimotor representations of the body that guide actions, or what Gallagher (2005) terms a "system of sensory-motor capacities that functions without awareness or the necessity of perceptual monitoring" (p. 24). As such, the body schema is distinct from the concept of the *body image* that refers to more conceptual, consciously accessible aspects of bodily awareness (for discussion, see de Vignemont, 2010).

Early Experience and Brain Development

As outlined above, one central question in early brain development concerns the balance of constraints on cortical development and a role for activity-dependent plasticity. With the field of DCN, this question relates to attempts at delineating the ways in which *experience* is a factor in the development of brain and behavior. For example, Johnson (2011a) distinguishes between three ways of considering the role of experience:

1. *Innate* (i.e., biological) factors refer to interactions that occur *within* the organism at the level of the internal cellular environment and that are relatively insensitive to the external environment.
2. *Primal* factors refer to interactions between the organism and aspects of the environment that are species-typical (i.e., reliably present) such as the presence of patterned light or gravity.
3. *Learning* refers to life-span interactions between the organism and unique aspects of its environment.

As noted later in this chapter, any discussion of the role of experience requires the recognition of *experience* as a wider concept that represents the coaction of the action of the organism and the action of the environment (e.g., environmental stimulation). In some contexts the focus will be on the organismic activity, while in others it will be on the external environment (Overton, 2010). In the following discussion the focus is on the action of the external environment.

One area of developmental science where related questions about early experience have been the focus of much discussion concerns the effect of early adversity on brain development. As part of this wider debate, recent decades have seen sustained interest in the relation of early adverse rearing experiences and later psychological outcomes, with a recent focus on whether the impact of such early experiences is mediated by changes in the development of particular neural structures or brain networks.

In the mid-20th century, the dominant view of early experience was skewed toward the primacy of early adversity in having long-lasting and often irreversible effects (for reviews see Brim & Kagan, 1980; Kagan, 1998). However, consistent with wider changes across psychology, the 1970s saw a move toward less deterministic approaches in the study of early experience and its impact on behavioral development. Viewpoints emerged that emphasized change and plasticity of behavior across the life span, in part based on more dialectical models of human development (Riegel, 1976; Sameroff, 1975; see also Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume) as well as descriptions of individual recovery from early adverse conditions once those conditions had been remediated (e.g., Clarke & Clarke, 1976).

This questioning of persistent effects of early experience was modified in the 1980s and 1990s by increasing evidence relating early adversity to later psychopathology (for review, see Rutter, 1999). In contrast to earlier deterministic approaches, this body of work in the emerging discipline of developmental psychopathology showed an increasing awareness of the heterogeneity of the effects of early adverse experience, both within and between individuals (Cicchetti, 1990; Sroufe & Rutter, 1984). The work of life-span developmental psychologists also contributed to this awareness, particularly concerning the importance of intraindividual change (Baltes, Lindenberger, & Staudinger, 2006).

The past two decades have also seen increasing interest in the role of neuroscience data in studying the relations between early adversity and later outcomes (Cicchetti & Curtis, 2006; Cummings & Valentino, Chapter 15, this *Handbook*, this volume; Gunnar, 2003; Hostinar & Gunnar, 2013; Mirescu, Peters, & Gould, 2004; Nelson, 2000; Pollak, 2005). The origins of this interest are partly founded in work on the neural changes accompanying manipulations of early experience in various mammalian species (e.g., Rosenzweig & Bennett, 1996) including maternal separation (e.g., Levine, 2001; Polan & Hofer, 1999) and the effects of natural variation in maternal behavior (e.g., Meaney, 2001). This comparative literature has been particularly influential in shaping current research and theory on early experience and neuroscience in humans, particularly in the realm of social and emotional development. One illustration is the work of Greenough, Black, and Wallace (1987), whose constructs of experience-expectant and experience-dependent processes are based in the comparative literature and are closely related to contemporary discussions of early experience and brain development. Indeed, the levels of primal factors and learning outlined by Johnson (2011a) are quite similar to these two constructs.

Bearing a close resemblance to the concept of critical periods, experience-expectant models posit that appropriate stimulation within a specific period is required for species-typical development to proceed (Greenough et al., 1987). The expected experience is usually characterized as having features with survival value that would be common to all individuals in that species. For example, the brain “expects” to be exposed to patterned light, without which the visual system will not develop normally. Thus, the typical consideration of experience-expectant programming is that development is likely to be permanently and adversely affected when exposure during a critical period is outside the typical range of environmental variation, with subsequent exposure to typical environments having no effect. As with critical period models, individual differences in outcome are not expected or considered, because all individuals would be equally affected by the adverse experience.

Much of the work on experience-expectant models has been conducted with animal models, with effects resembling critical periods being documented for certain aspects of behavioral development in various species, including birdsong in oscine songbirds (e.g., Nottebohm, 2005) and auditory localization in the barn owl (e.g., Knudsen & Knudsen, 1990). Such investigations have often involved examination of the neurobiological systems involved, as in the classic work on critical periods for the development of ocular dominance columns in mammalian visual cortex by Wiesel and Hubel (1965). This work also showed that in contrast to partial deprivation that provided aberrant sensory input, behavioral and anatomical changes resulting from complete deprivation (i.e., the complete absence of any stimulation) were more readily modified by the later restoration of typical sensory input. This finding supports the expectancy aspect of experience-expectant plasticity, and suggests that if no relevant input is present, the offset of critical periods may be extended in time (see Hensch, 2004; Knudsen, 2005). This latter effect was originally demonstrated by Moltz and Stettner (1961) who in line with Schneirla (1959) rejected the simplistic notion of fixed, age-based critical periods.

In contrast to the focus on critical periods that is connected to the construct of experience-expectant processes, experience-dependent processes optimize “individual adaptation to specific and possibly unique aspects of the individual organism’s environment” (Black & Greenough, 1986, p. 14). For example, the brain does not “expect” the child to develop a specific vocabulary, which is dependent on observational experiences. Experience-dependent processes place an emphasis on continued plasticity and individual differences. Instead of stressing the need for particular experiences to be present in a specific time frame, experience-dependent processes involve sequential dependencies such that mastering one skill is dependent on the previous learning of other skills. In this sense, a focus on experience-dependent processes emphasizes the capacity for adaptation across the life span.

In addition to the constructs of experience-expectant and experience-dependent plasticity, a third construct that combines elements of both constructs has become increasingly visible in the literature on the biology of early experience (Marshall & Kenney, 2009). Founded in studies of the impact of the prenatal and early postnatal environment on later health outcomes (Barker, 1994), the concept of experience-adaptive plasticity has been proposed as another way in which early experience could exert persistent effects on brain and behavioral function (Rutter, 2002).

Models of experience-adaptive plasticity are closely related to the constructs of developmental programming or developmental plasticity, which emphasize individual adaptation to environmental signals present in early phases of development (Bateson, 2007). According to one prominent account of developmental plasticity, such signals influence the characteristics of various regulatory systems in the developing organism, with related implications for health and disease across the life span. This hypothesis has been explored quite extensively with regard to prenatal development (Coall, Callan, Dickins, & Chisholm, Chapter 3, this *Handbook*, Volume 3), particularly in terms of the consequences of fetal undernutrition. For instance, citing an association between low birth weight in term infants and a range of increased health risks throughout life, Barker (1994) proposed that the nutritional environment experienced by the fetus influences the homeostatic set points of various physiological systems. He further proposed that the prenatal environment may, under certain conditions, be mismatched with the postnatal environment such that these systems (which were established prenatally) cannot adjust. For example, consider an individual who experienced undernourishment in utero but then is exposed to a significant change in the nutritional environment (e.g., a large increase in caloric intake) postnatally. According to the developmental plasticity model, the programmed metabolic systems may be unable to adjust to this change, with an increased likelihood of later adverse health outcomes such as diabetes or cardiovascular disease (Barker, 1999).

Although the original focus of the developmental plasticity work was on the lasting effect of early prenatal nutritional deficiency, there is continued interest in the potential influence of other factors, such as prenatal maternal anxiety, on the development of brain systems related to stress regulation (e.g., Talge, Neal, & Glover, 2007; Weinstock, 2008). Related comparative work has focused on the lasting effects of the early postnatal caregiving environment in relation to the development and activity of the hypothalamic-pituitary-adrenal (HPA) axis (e.g., Meaney, Szyf, & Seckl, 2007; Seckl & Meaney, 2004). One line of studies in this area has shown that the pups of rat mothers who attend to them less tend to have deficits in various learning tasks in later development (Fenoglio et al., 2005; Liu, Diorio, Day, Francis, & Meaney, 2000). One posited physiological process linking the early experience of rat pups and later outcomes is the epigenetic modification of regulatory genes involved in the stress response (Cameron et al., 2008; Champagne & Curley, 2009; Meaney & Szyf, 2005). These effects have been framed as a form of experience-adaptive plasticity, with deficits in the early caregiving environment acting as a signal triggering epigenetic upregulation of the stress response system in the offspring (Weaver et al., 2004).

The relation between early experience and epigenetic regulation of the stress response has been a focal point of interest in discussions of early adversity and brain development, with particular interest in whether the rodent work can be translated to the human context (Kaffman & Meaney, 2007; Roth & Sweatt, 2011). Related human work has suggested that variation in factors such as maternal mood during pregnancy and the experience of abuse during childhood is associated with epigenetic alterations in the regulatory region of a glucocorticoid receptor gene associated with stress reactivity (McGowan et al., 2009; Oberlander et al., 2008). Further notable findings from humans suggest that epigenetic modifications accumulate over the lifetime (Fraga et al., 2005) and also that differences in DNA methylation are apparent in monozygotic twins at birth, most likely as a function of differences in the intrauterine environment experienced by each individual twin (Gordon et al., 2012). Such findings have contributed to a high level of sustained interest in the potential of epigenetics to inform the study of early experience and brain development. However, practical options for examining the epigenome in relation to human brain function are still limited (Champagne & Curley, 2009) although recent work in developmental psychopathology has suggested the utility of assessing epigenetic markers in blood samples (Wang et al., 2012).

In contrast to the highly controlled nature of the comparative work, testing hypotheses related to the role of early adverse experience in the development of brain function in humans presents a variety of methodological and conceptual problems (Repetti, Taylor, & Saxbe, 2007). One such obstacle, concerning inferences about the persistent impact of early adverse experience, is that outcomes for children living in environments high in psychosocial risk could be due to the cumulative effects of adversity, rather than any special effects of early experience per se (Schaffer, 2000). Early adverse experiences during infancy often tend to be followed by adverse experiences during childhood, such that the effects of the early experience cannot be teased apart from the cumulative effects of experience over the entire time span. A related but often overlooked problem is that it is also difficult to show that a particular experience has greater effects on later development when it occurs earlier in life as opposed to at a later age. In this respect it is challenging to definitively show that the early environment has specific effects, rather than exposures that occur for a similar duration but which begin later (Ames & Chisholm, 2001; Bruer, 2002).

There have been various attempts to overcome these issues in developmental studies on early psychosocial risk (Fox, Levitt, & Nelson, 2010; Fox & Rutter, 2010; Gunnar, 2003). One strategy has been to examine situations in which a large discontinuity in a child's environment arises, such as adoption or entry into long-term foster care, following early experience in an adverse environment (O'Connor, 2003). In the case of children coming from severely deprived backgrounds, such a life change provides an opportunity to examine whether early adverse experience has persisting effects once the caregiving environment improves. A growing number of related studies have examined the development of formerly institutionalized children who were either placed into family care through international adoption (Hellerstedt et al., 2008; Loman, Wiik, Frenn, Pollak, & Gunnar, 2009) or who entered into foster care within their home country (Nelson et al., 2007). Through documenting the relations between early adverse experience and the development of brain and behavior (Nelson, Fox, & Zeanah, 2014), studies in this area are also relevant to wider questions of early intervention and social policy (Bakermans-Kranenburg et al., 2011; Groark & McCall, 2011; Gunnar, Bruce, & Grotevant, 2000; Millum & Emanuel, 2007).

Although neuroscience data are assuming an important place in the study of early adverse experience, many questions remain about how best to frame the role of such data (Marshall & Kenney, 2009). One such question concerns the translational gap between comparative and human work (Gottlieb & Lickliter, 2004). As mentioned above, this gap arises in part through the multifaceted nature of early adversity in studies of human development (Boyce, Sokolowski, & Robinson, 2012). A further concern arises from the fact that as psychological agents, humans construct and reflect on their own experiences in a way that other animals may not. A related issue concerns a growing literature in biological psychiatry concerning the impact of early stress on brain functioning (e.g., Anda et al., 2006; Bremner & Vermetten, 2001; Kaufman, Plotsky, Nemeroff, & Charney, 2000). Although such work has become a significant force in the study of early experience, it could also be argued that it downplays fundamental questions about agency and plasticity in human development (Lerner, 2002; Lewis, 1997; Lillard & Erisir, 2011; Nelson, 2011).

One further key issue in the study of early experience concerns the construct of experience itself. As mentioned earlier, much of the literature concerning early experience and brain development tends to take a particular view of experience as a distinct external influence on the developing brain (e.g., Perry & Pollard, 1998). This partly reflects the historical focus of neuroscience on a reactive view of brain activity as mainly reflecting responses to external stimuli (for discussion see Abrahamsen & Bechtel, 2012). However, in their framing of experience-expectant plasticity in the context of human development, Greenough et al. (1987) note that "we suspect that some types of 'expected' experience may rely largely on the infant to produce them" (p. 545). Such a suspicion is well-founded and is illustrated by classic work showing the necessity of self-produced activity for typical development (Held & Hein, 1963), with this work being later extended to humans by Abravanel (1968) and Birch and Lefford (1963).

A deeper consideration of the active role of the organism works against a further tendency that is prevalent in work on early experience, which is to pit the individual and their internal properties against an external environment. As is emphasized later, this split or dichotomous approach is not supported by integrative approaches in developmental science, particularly the relational developmental systems perspective (Overton, 2013, Chapter 2, this *Handbook*, this volume). This perspective has implications for reframing the study of early experience and brain development through its emphasis on experience as embodied action (Overton, 2006). In this reframing, the conventional view of interaction between the individual organism and its environment would be replaced with the notion of reciprocal bidirectional coactions (←→) across all levels of analysis (Gottlieb, 2007). With this in mind, the focus of this chapter now turns to embodiment as a way of moving beyond the split notion of individual and environment and other problematic dichotomies that have historically impeded the emergence of a truly integrative developmental science. This endeavor entails a coherent account of the development of body, brain, and mind as a differentiated and unified system, operating within a broader sociocultural system.

EMBODIMENT AND THE INTEGRATION OF LEVELS

The constructs of embodiment and embodied cognition have become the focus of interest and debate across psychology and cognitive science (Foglia & Wilson, 2013; Menary, 2010; Shapiro, 2011). Part of this interest comes from studies showing how cognitive processing and decision making can be influenced by bodily states, although as detailed below, this is only one aspect of what embodiment can entail (Overton, 2008; Stapleton, 2013; Wilson & Golonka, 2013). At a more foundational level, embodiment is fundamentally a rejection of the isolated, computational mind of cognitivism (Edelman, 1992). By locating, in a constitutive fashion (Rowlands, 2010), the brain in the body of an active organism, embodiment threatens the traditional distinctions between perception, cognition, and action that are essential to the cognitivist account. Although they have deeper roots (see Beer, 2008), embodied approaches have gained a good deal of momentum in recent years (e.g., Barsalou, 2008; Clark, 1998; Damasio, 1994; Gibbs, 2006; Glenberg, 1997; Overton, Müller, & Newman, 2008; Rowlands, 2010; Semin & Smith, 2008; Thompson, 2007; Varela, Thompson, & Rosch, 1991; Wallace, Ross, Davies, & Anderson, 2007; Wheeler, 2005; Wilson, 2002).

Developmental features of embodiment are being increasingly considered (Lerner & Benson, 2013a, 2013b; Overton, Chapter 2, this *Handbook*, this volume; Overton et al., 2008), and an important component of this chapter concerns the exposition of those features as part of a move toward a more integrative developmental science that entails a coordination among psychological, developmental, and neuroscience concepts. Other discussions on embodied cognition and development appear to suggest that a role for embodiment may be particularly (or primarily) apparent in the study of infancy—echoing aspects of Piaget's theorizing about the sensorimotor stage of development (e.g., Daum, Sommerville, & Prinz, 2009). The premise of this argument is that as symbolic thought emerges, mental life becomes more "disembodied" or less dependent on aspects of bodily action. This premise is reflected in an emphasis on studies of physical and motor development in infancy as providing evidence for the importance of an embodied approach (Needham & Libertus, 2011). While this emphasis may serve an illustrative purpose (although see Longo, 2009), throughout this chapter the term *embodiment* refers to a much broader view. As Overton (2008) points out.

> Embodiment references not merely physical structures, but the body as a form of lived experience, actively engaged in and with the world of sociocultural and physical objects. The body as form references a biological [including a neural] standpoint, the body as lived experience actively engaged references a phenomenological or psychological person standpoint, and the body actively engaged in and with the world points to a contextual social, cultural, and environmental standpoint. (p. 3)

The Scope of Embodied Cognition

Within cognitive science there has been vigorous debate concerning the meaning and implications of an embodied approach to the study of cognition. In a useful summary, Kiverstein (2012) distinguishes between three current views: what he labels *body-conservatism*, *body-functionalism*, and *body-enactivism*. Although issues of development and neuroscience remain in the background, delineating the differences between these views is helpful for understanding the wider issues at stake in the area of embodied cognition.

For the *body-conservative*, the scope of embodiment is necessarily limited, because the body can only contribute to cognition by providing inputs to the brain and as the apparatus through which motor commands (from the brain) are executed. In many ways, such a position does not go far beyond the traditional cognitivist model in the sense that although it places the brain in a body, this brain is still a central processor and a clear divide between perception, action, and cognition is maintained. This divide is anathema to the *body-functionalist*, who sees embodied cognition as mounting a strong challenge to the cognitivist approach. For the body-functionalist, the body itself is understood "as playing a role in implementing the computational machinery that underpins our cognitive capacities" (Kiverstein, 2012, p. 740), with the proviso that this "computational machinery" does not need to be exclusively located in the brain but can be distributed across a wider brain-body-environment system. As suggested by this description, the account of cognition for the body-functionalist is still fundamentally a computational one; therein lies the contrast with the more radical position of *body-enactivism*, whose proponents tend to eschew a role for computational approaches in the study of mental life. The distinction between these two latter positions is an important one, and it is worth expanding on here in order to avoid potential confusion.

In defining the notion of computation as advocated by the body-functionalist, Kiverstein (2012) notes that: "Sometimes computation can be done through the recruitment and bodily manipulation of external artifacts; other times it can be done entirely within the head. This is a decision the brain makes on the fly, temporarily constructing short-lived coalitions of neural, bodily, and cultural artifacts when this is the most appropriate strategy for accomplishing a cognitive task" (p. 742). As noted by Silberstein and Chemero (2012), one early example of such a "wide" computational explanation came from Rumelhart and McClelland (1986) who discussed the act of solving math problems on a chalkboard: This act was seen as involving a cognitive system that went beyond the brain to include the chalkboard itself as well as the act of writing on the board. One contemporary advocate of wide computationalism is Clark (2008) who also put forward the thesis of the *extended mind* (Clark & Chalmers, 1998), which provides a prominent example of the body-functionalist perspective. According to Clark, cognition inherently involves computational processes, but the computational work of cognition is not always carried out solely in the head. Instead, this work can be spread across the wider brain-body-environment system through the recruitment of external objects and artifacts (see also Anderson, 2003; Hutchins, 1995; McClamrock, 1995; Rowlands, 2010; Rupert, 2010).

Although not as radical as enactive accounts of embodiment (see below), the views of the body-functionalist still present a distinct challenge to traditional notions of mental life and brain function. Indeed, the concept of the extended mind has not gone unchallenged within cognitive science, with reactions ranging from mild criticism about emphasis to complete rejection of the central premise. Along the lines of the former, Sterelny (2010) notes that the original view of the extended mind as put forward by Clark and Chalmers (1998) may understate the importance of broader cultural and environmental scaffolds for cognitive competence by emphasizing what he calls "highly trusted, individualized and entrenched, single-user resources" (p. 480). According to Sterelny, the extended mind construct occupies one corner of a much larger space in which "the most critical, mind-and-brain-shaping environmental supports for cognition are those cumulatively built, collectively provided tools for thinking" (p. 479). For the purposes of this chapter, this perspective allows a potentially important entry point for embodiment to be considered from a combination of cultural and developmental standpoints, which also remains an important area for future work.

A stronger challenge to the notion of wide computationalism comes from those who believe that cognitive processes are confined to the head (e.g., Adams & Aizawa, 2010; Fodor, 2009). On this reading, the challenge for embodied cognition is to show that processes going on outside the brain can be genuinely *constitutive* parts of cognition, rather than being inputs and outputs for the central processing taking place in the head. Fodor (2009) objects to wide computationalism on the basis of the argument that only internal mental states can have *underived*, intentional content—the so-called "mark of the mental"—that distinguishes them from any of Clark's examples, which according to Fodor can be seen as *derived* content. Although acknowledging that there is a slippery slope between underived and derived content, Fodor (2009) does not accept that the externalism of wide computationalism follows from the existence of this slope: In his view, internal representation will always be necessary to bridge "the gap between mind and world."

Although the criticisms of Fodor come from a cognitivist perspective that depends on a wholesale rejection of embodied cognition, a further challenge to the body-functionalist account has come from within the embodiment literature itself. This challenge comes from *body-enactivism* (or what is usually known as simply *enactivism* or *enaction*), which is the third view of embodiment outlined by Kiverstein (2012). Compared with body-functionalism, enactivism takes a more radical stance, which begins with the perceived inadequacy of any kind of computational account to provide a context of meaning for an organism. From the enactivist perspective, the body itself is a source of meaning, and this meaning can be experienced without a reliance on either traditional notions of internal representation or the more externalist (but still computational) leanings of body-functionalists such as Clark.

Meaning and Representation

As noted earlier, the problem of *making meaning* is one that has plagued computational approaches to mental life, and it is this precisely this problem that enactivists seek to solve. In framing cognition as a disembodied process occurring on an isolated computational device, cognitivism precluded any real consideration of meaning or meaning-making (Bruner, 1990). This omission echoes the central problem with 20th-century neopositivism, which required the meaning of a statement to depend on verification, even though any statement must already have some meaning in order to consider verifying it (Smythe, 1992). Cognitivism suffers from a similarly fundamental issue in the form of the *symbol grounding problem* (Harnad, 1990).

The symbol grounding problem refers to the issue of explaining how representational items come to have psychological meaning: As such, the formal properties of representations cannot be sufficient for their semantic properties. This problem is at the heart of arguments that were initially voiced by critics of the cognitivist focus of early work in artificial intelligence (Dreyfus, 1972; Searle, 1980). According to these critics, the disembodied nature of symbol-crunching computational approaches could not adequately address the question of how these symbols can be meaningful for the device on which their manipulation is being carried out. Early expectations for progress in artificial intelligence through a cognitivist framework were, therefore, misplaced because of the fundamental problem faced by an isolated computational system in "needing to impose a meaning on a meaningless Given" (Dreyfus, 2006, p. 45).

The enactive perspective attempts to solve the symbol grounding problem in a particular way. For many contemporary observers, enactivism became crystallized through the publication of *The Embodied Mind* by Varela, Thompson, and Rosch (1991). These authors drew on an eclectic mix of philosophy, biology, and psychology to propose a paradigm shift from the computational account of mind that had dominated cognitive science for the previous decades. One important influence on this way of thinking about embodiment came from phenomenology, particularly the work of Merleau-Ponty (1962), who drew on the notion that the body is not merely an object among other objects, but is instead the phenomenal body or "the situation from which our world and experience flows" (Johnson, 2008, p. 164). As such, the enactive approach frames the biological nature of what could be called *sensemaking*, such that the individual brings forth or enacts the world in which it exists, and sustains its identity as a self-organizing system (Thompson, 2007). This idea relates closely to the notion of *autopoiesis* as put forward by Maturana and Varela (1980) who framed living systems as being self-creating and self-organizing in a fundamentally different way to nonliving systems. From this perspective, living systems are not created or maintained according to externally imposed influences that assign meaning. Instead, living systems "construct themselves by generating the very boundary conditions necessary for the creation and maintenance of their self-organization" (Witherington, 2011, p. 79). From the enactive perspective, this stipulation not only allows living systems to be studied from the empirical viewpoint of self-creation, self-organization, and self-regulation, but it also enables the consideration of questions of agency, individuality, identity, and the construction of meaning.

At the center of the enactive approach is the recognition of the organism as an active agent that is tightly interconnected with its environment, such that the actions of the individual modify its relation to the environment, which in turn influences subsequent actions (←→). For enactivists, this concept of the *action feedback loop* is the basis of a dynamic system in which the boundaries between individual agent and environment cannot be definitively determined (Stewart, Gapenne, & Di Paolo, 2010). This assumption brings with it some strong suggestions. Advocates of what Chemero (2009) has termed *radical embodied cognitive science* propose that the dynamic coupling of organism and environment has two important implications for understanding cognition (see also Hutto & Myin, 2012). First, in contrast to the more constrained computational thesis of Clark and other body-functionalists, the radical tenets of enactivism necessitate that cognitive processes are distributed across the dynamic system that results from the nonlinear coupling of individual and environment. Second, according to these theorists, the formulation of the wider cognitive system as a dynamic system pushes against the need to invoke the concept of representation as an explanatory vehicle. As framed by Silberstein and Chemero (2012):

> Non-linearly coupled animal-environment systems are taken to form just one unified system. This removes the pressure to

> treat one portion of the system as representing other portions of the system—at least for many cognitive acts. That is, if the animal-environment system is just one system, the animal portion of the system need not represent the environment portion of the system to maintain its connection with it. There is no separation between animal and environment that must be bridged by representations. So extended cognition invites anti-representationalism. Of course, extended cognition does not entail anti-representationalism and many extended cognitive scientists are also representationalists. Nonetheless, anti-representationalism is made plausible by the non-linear connections between animal and environment one sees in extended cognitive systems. (p. 40)

For proponents of enactivism, it is these "nonlinear connections" that preclude a clear distinction between the organism and the environment, and which together constitute a wider system in a more fundamental sense than in the body-functionalism of Clark. In line with these suggestions, a good deal of empirical work from the enactivist perspective draws on *dynamical systems theory* (see Witherington, Chapter 3, this *Handbook*, this volume), which has its origins in the study of chaos and complexity from a mathematical perspective (see Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume) and which is increasingly visible in developmental science (Hollenstein, 2011; Molenaar, Lerner, & Newell, 2014). To proponents of enactivism, the attraction of dynamical systems methods partly comes from their ability to model the coupling of an agent's behavior over time with the changing state of the environment. Accounting for the coupling of organism and environment is inherent in the methodology of the state space and phase space models that have been the typical ways in which dynamical systems approaches have been applied (Partridge, 2011; see also Molenaar and Nesselroade, Chapter 17, this *Handbook*, this volume; Witherington, Chapter 3, this *Handbook*, this volume).

One key facet of dynamical systems models is that they do not rely on the manipulation of symbols or the need to invoke the concept of representation. Given this emphasis, it is perhaps no surprise that Chemero (2009) connects antirepresentationalism in radical embodied cognitive science to the work of Gibson (1979). Indeed, there are linkages between the Gibsonian perspective and certain threads of the enactivist perspective, such that the sensorimotor abilities of the organism are seen as the coupling between its nervous system and its ecological niche, or its network of available affordances, which are in turn altered by the activity of the organism. However, despite this association, it would not be accurate to equate an embodied approach with a Gibsonian perspective or with one particular flavor of dynamic systems models. As Witherington (2011; see also Witherington & Heying, 2013) argues, a complete understanding of self-organization entails seeing process (function) and organization (structure) as being complementary and indissociable. As further noted by Witherington (2011), this pushes against the Gibsonian notion of preexisting environmental structure that is apparent in certain flavors of dynamic systems theory, for instance that of Thelen and Smith (1994). According to Witherington and Margett (2011), enactivism could be more productively aligned with Piagetian constructivism, in that "meaning must be actively constructed and does not inhere in the world. . . . the world becomes meaningful . . . only in the context of an organism actively structuring it—assimilating it—and in turn actively accommodating to it" (p. 287). This sentiment would be endorsed by those dynamical systems practitioners who see constructivism as being fundamentally consistent with systems approaches to development (van Geert, 2012). As such, constructivism appears to be appropriate as a potentially productive emphasis for the application of embodiment to developmental science.

The Embodied Brain

Although there are clearly different strands of embodiment, to a greater or lesser extent they all challenge the notion that cognition can be neatly packaged into a level of information processing—or the level of mechanism in the framework of Marr (1982). As noted by Clark (2000), embodied cognition blurs the lines between Marr's levels, such that "our notions of what top-level task needs to be performed, and what kinds of algorithms are adequate to perform it, are deeply informed by reflection of details of bodily implementation, current needs, and action-taking potential" (p. 96). Embodiment is, therefore, particularly relevant to integrating neuroscience into the study of psychology, as a counter to the neglect of the brain that was a consequence of the information-processing interpretation of the cognitive revolution (see also van Dijk, Kerkhofs, van Rooij, & Haselager, 2008). Although cognitive neuroscience added a consideration of how cognitive processes might be implemented in the brain, embodied cognition can be seen as reframing the level of implementation beyond the brain, which then precludes the notion of a clear distinction between levels. As such, embodiment puts pressure on a tidy separation of levels, and understanding the relatedness or interconnections among levels becomes paramount.

As discussed by Marshall (2009), one of the key implications of embodiment for conceptualizing the relations among levels of analysis stems from its rejection of the assumption of a linear perception-cognition-action that is at the heart of the cognitivist framework. Relevant evidence from neuroscience comes from a growing body of work demonstrating that neural processing can be altered by varying the context in which stimuli are presented (Engel, 2010; Freeman, 2000). Contextual or top-down effects have long been discussed in psychology (e.g., in terms of expectancy effects) but are the importance of these effects for studying brain function can be clearly seen across the field of cognitive neuroscience. For instance, it has been found that parietal and premotor activity depends on action context (Graziano & Gross, 1998). In a related vein, there is a growing emphasis in cognitive neuroscience on the fundamental role of attention in modulating the activity of brain circuits involving in early sensory processing (Engel, Fries, & Singer, 2001; Reynolds & Chelazzi, 2004). This modulation even seems to apply in primary visual cortex (V1), which had previously been thought of being invulnerable to contextual influences (Kok, Jehee, & de Lange, 2012).

The sensitivity of early cortical processing to contextual factors provides further evidence against the cognitivist emphasis on the modular divisions between perception, cognition, and action. Evidence for this sensitivity is further buttressed by neuroanatomical findings that the visual system involves highly complex bidirectional pathways involving extensive back-projections from deep inside the brain to early sensory-processing centers (Felleman & van Essen, 1991). These back-projections in the visual system play a key role in attention to relevant events, as the person moves his/her eyes, head, and body to better characterize things in its environment that have been captured by low-level perceptual processes (Clark, 1998).

Considerations of attentional and contextual influences as well as of neuroanatomy lead to a very different model of the brain than would be suggested by the linear perception-cognition-action sequence described by classical cognitivism. In an embodied model of brain function, perception and action are naturally linked through the interconnectivity of the brain. Edelman (e.g., Edelman, 1992; Edelman & Tononi, 2000) has proposed that all brain networks have the dual properties of reentry (with complex bidirectional connections between outputs and inputs) and degeneracy (a lack of specialization of any individual neural pathway). The contrast between this account of brain function and the classical cognitivist account is related to alternative perspectives on the directional flow of causality. One perspective—associated with both stimulus-response psychology and cognitivism—understands causality as unidirectional, flowing from input to output. The second perspective—associated with embodiment—understands causality as relationally bidirectional (←→) and as entailing positive and negative feedback loops (Overton, 2013).

As an example, Engel (2010) describes an approach to the relations among context and patterns of brain activity that is particularly informed by considerations of embodiment. This approach emphasizes the dependency of neural activity on contextual factors, and the role of neural activity as supporting the organism's capacity for structuring situational contexts in a prescriptive manner. This emphasis leads to a novel view of the role of neuroscience data in the context of perception and action. Engel uses the term *directives* to refer to states of the wider cognitive system in its entirety, rather than the narrower focus that is associated with the concept of *representation*. From this perspective, objects in the environment are not understood as simply the represented targets of actions: Instead, environmental objects are part of the broader directive, or the state of the wider cognitive system. Importantly, neuroscience data can be readily accommodated in this framework, as patterns of neural activity can be understood as measurable traces that "support and partially implement directives as their functional roles" (Engel, 2010, p. 230).

The action-oriented nature of directives means that patterns of brain activity are closely tied with attention to relevant features of the environment, with a view to acting. Engel (2010) further suggested the value of developing a view of attention as a bias in sensory processing that is introduced by the selection of particular directives in the context of current or imminent action (see also Engel, Maye, Kurthen, & König, 2013). This turn toward action in cognitive neuroscience is a promising development, and one that has begun to be explored in more detail (Cisek & Kalaska, 2010). It should be further noted that such an action-oriented emphasis does not simply refer to action in the sense of overt movement or motor control, but is instead connected with the broader, constructivist notion of action in the sense of Piagetian operative intelligence.

Within Engel's model, the neural aspects of directives are highly complex, involving cell populations distributed across numerous brain regions that coact in a dynamic fashion. In the context of neural synchrony and binding, Engel further notes that "temporally coordinated signals from other regions can have a strong impact on assembly formation in sensory regions by modulating the local neural dynamics in a top-down manner" (Engel, 2010, p. 232). Attention then plays a key role in this modulation, with attentional and sensory processes being closely linked (Engel et al., 2001). Indeed, the neural signature of attention may be understood as increased activation of cortical networks related to the processing of task-relevant sensory information (Jones et al., 2010). Relevant studies with humans support the idea that attention modulates neural synchrony in the auditory, visual, and tactile system (Bauer, Oostenveld, Peeters, & Fries, 2006).

Embodiment and Social-Cognitive Neuroscience

As Overton (2008) points out, the unified study of embodiment entails at least three interwoven perspectives—the biological, the cognitive, and the sociocultural. Although much of the discussion above has focused on the cognitive perspective, the wide scope of embodiment clearly has repercussions for the study of the involvement of brain and body in social processes. This relates to what has become known as *social neuroscience* (Cacioppo et al., 2002) and the associated subdiscipline of *social-cognitive neuroscience* (Ochsner & Lieberman, 2001), which have become the focus of much research in recent years, including growing interest from developmental scientists (Marshall & Fox, 2006; Zelazo et al., 2010). Although a significant portion of this work has not directly explored the issues discussed above concerning embodiment, the literature is seeing a growing emphasis on embodied themes such as the *socially situated nervous system* (Coey, Varlet, & Richardson, 2012) or the *interactive brain* (Di Paolo & De Jaegher, 2012). From an enactivist perspective, Gallagher, Hutto, Slaby, and Cole (2013) argue that

> The explanatory unit of social interaction is not the brain . . . but a dynamic relation between organisms, which include brains, but also their own structural features that enable specific perception-action loops involving social and physical environments, which in turn affect statistical regularities that shape the structure of the nervous system. (p. 422)

Related work has included a call for the strengthening of a *second-person neuroscience* (Schilbach et al., 2013), although specifically how to proceed in this direction has been debated, with disagreements reflecting the various perspectives on embodiment and representation that were outlined above. In addition, Lewis and Stack (2013) note that the recent prescriptions by Schilbach et al. (2013) lack a thoroughly developmental perspective (for further discussion see also Moore & Paulus, 2013). However, this increasing focus on a neuroscience of social interaction promises to be an important area for developmental neuroscientists to explore in the coming years.

One area that has attracted a great deal of attention from those interested in the intersection of social interaction, neuroscience and embodiment relates to the discovery of *mirror neurons* in the ventral premotor cortex (F5) of macaque monkeys (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Monitoring their activity using single-cell methods, it was shown that mirror neurons fired not only when the animal executed an action on an object (e.g., grasping a food item), but also when the monkey was observing the same action being carried out by another individual. Individual mirror neurons have not been shown to exist in the human brain; this may be, in part, because single-cell recording is not possible in healthy individuals (for a study in a patient population, see Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010). However, a good deal of evidence has accumulated to support the notion of an overlap in the activation of certain brain systems between the production of action and the perception of others' actions (e.g., Hari & Kujala, 2009), with developmental considerations also being a key focus of interest (Decety & Sommerville, 2003; Marshall & Meltzoff, 2011, 2014).

In adults, evidence for overlaps in brain activation patterns between action observation and execution derives from a variety of neuroimaging techniques including functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), and electroencephalography (EEG), and the transient disruption of cortical tissue via transcranial magnetic stimulation (TMS). The basic contention from this work of an overlap in patterns of cortical activation between action perception and action production is fairly well established (Wilson & Knoblich, 2005). However, much debate has centered on the inferences that can be made about the function of this overlap (Gallese, Gernsbacher, Heyes, Hickok, & Iacoboni, 2011). Some have argued that it reflects the activity of a putative mirror neuron system (MNS) in humans, and that this activity plays an important role in the understanding of others' actions (Rizzolatti & Sinigaglia, 2010). On the opposite side of the debate, it has been argued that evidence for involvement of mirror neurons in action understanding is weak and that theoretical speculations have gone beyond the extant data (Hickok, 2009).

Among those who believe that mirror neurons may play some (direct or indirect) role in action understanding, the debate has concerned how and whether accounts involving mirror neurons can explain the attribution of mental states, which has traditionally been what theories of social cognition are aimed at explaining. As reviewed by Michael (2011), there are various models of MNS function, including the *direct matching* account of Gallese (2007), the *action reconstruction* approach of Csibra (2007) and the related account of Jacob (2008), the *interactionist* view of Gallagher (2007), and the *predictive* account of Kilner (e.g., Kilner, Friston, & Frith, 2007b). As an illustration of divergent views on the relation of mirror neurons to embodiment, the accounts of Gallese and Kilner are briefly outlined here.

Gallese (2007) views mirror neurons as contributing to a form of action understanding characterized by a form of prelinguistic, pretheoretical content originating in the relations between the organism and the world of objects that it inhabits. According to Rizzolatti and Sinigaglia (2010), this kind of attribution constitutes a form of action understanding, but not a mentalistic understanding as such. They suggest that "this understanding is completely devoid of any reflexive, conceptual, and/or linguistic mediation as it is based exclusively on the vocabulary of acts and the motor knowledge on which our capacity to act depends" (p. 125). As noted by a number of critics, a key challenge to this account is its ability (or inability) to handle the more conventional notion of intentionality (de Bruin & Kästner, 2012). According to other critics, the activation of mirror neurons during action observation could at best signal to the observer that the other person is acting purposefully, but cannot shed light on what the actor's intention is (Borg, 2007; Jacob, 2008). In turn, advocates of a role for mirror neurons in action understanding agree that mirror neurons cannot capture reasons, beliefs, desires, and intentions but still argue that a putative MNS could play a role in intentional attribution (Sinigaglia, 2008). However, according to others who generally favor a minimal, unconventional approach to social cognition, mirror neurons cannot be involved in action understanding, although a role in a nonmentalistic intersubjectivity may be granted (Hutto, 2013).

A contrasting view of mirror neuron system function comes from Kilner (e.g., Kilner et al., 2007b). In this account, motor system activity during action observation is part of the activation of a wider system that generates a prediction of the sensory consequences of the action that would be most likely to complete the inferred goal of the action. As noted by Friston, Mattout, and Kilner (2011), certain other accounts of a role for mirror neurons in action observation have emphasized a combination of forward and inverse models (e.g., Keysers & Perrett, 2004). In such accounts, mirror neurons are a product of associations between carrying out (including watching, hearing, and feeling) one's own actions and their sensory consequences, with these associations being established in the brain through a forward model. Via an inverse model, the observation of others' actions (i.e., sensory input from action observation) then activates the corresponding motor representations that had previously been paired with those actions through Hebbian processes. The activation of this inverse model can then be used to recognize the action and/or infer the goal of the actor (Keysers, Kaas, & Gazzola, 2010).

An associative account of mirror neuron function has also been espoused by Heyes (2010) who combined related ideas about forward and inverse models into a developmental model of *associative sequence learning*. However, the purely associationist accounts of Heyes (2010) and Keysers and Perrett (2004) differ from Kilner's account in which there are no inverse models that directly link sensory information about observed actions with the observer's motor representations. Instead, a different kind of mapping is accomplished through the suppression of *prediction error*. Building on the free energy principle outlined by Friston (2005), Kilner, Friston, and Frith (2007a, 2007b) have suggested that mirror neurons "emerge naturally in any agent that acts on its environment to avoid surprising events" (Friston et al., 2011). What takes this model beyond an associationist account is that it "depends on self-organizing, reciprocal exchange of signals among hierarchical levels of the brain's generative model" (Friston et al., 2011, p. 157). This account also has implications for theories of motor control, such that the need for an explicit motor control signal is removed—instead, movement is controlled by predictions (Adams, Shipp, & Friston, 2012).

The contrast between the viewpoints of Gallese and Kilner was presented here as an illustration of two of the various positions that have been advanced as explanatory frameworks for the functioning of a putative MNS in the human brain. The coming years will doubtless see continued exchanges and new ideas. Although much of the theoretical writings to date have only considered research with adults, there is increasing interest in developmental aspects. However, it is arguably the case that initial speculations about MNS development (Del Giudice, Manera, & Keysers, 2009; Gallese, Rochat, Cossu, &

Sinigaglia, 2009; Kilner & Blakemore, 2007; Lepage & Théoret, 2007) outstripped the available empirical evidence. Although more extant data are now available, many questions still remain about the existence and nature of neural overlaps between action perception and action production in early human development (Marshall & Meltzoff, 2011, 2014). These questions are wide ranging and include the need to go beyond simple associationist theories to recognize the more specialized nature of connections between action perception and action production (Boyer, Longo, & Bertenthal, 2012). Given that these connections likely originate very early in life, one key challenge for developmental neuroscientists has been to develop relevant techniques and protocols for use with infants. Because methods such as fMRI and TMS are precluded for use with these populations due to practical and ethical constraints, empirical research in this area has focused on the use of EEG methods, which are more amenable to use with infants and young children (see De Haan, Chapter 18, this *Handbook*, this volume).

Recent developmental research has focused interest on the *mu rhythm* in the infant EEG, which occurs in the alpha frequency range at central electrode sites overlying sensorimotor cortex. Mu rhythm desynchronization. (evidenced by a reduction in amplitude) is thought to reflect increased cortical activation through a decrease in synchrony in the underlying neuronal population (Pfurtscheller, 2003). Regional similarities in mu rhythm desynchronization have been used to infer an overlap in patterns of cortical activity during infants' execution of actions and their observation of similar actions (Marshall, Young, & Meltzoff, 2011; Southgate, Johnson, Osborne, & Csibra, 2009). Further work has begun to show the complexities of the mu rhythm response during action observation in relation to infants' action experience (Marshall, Saby, & Meltzoff, 2013; Saby, Marshall, & Meltzoff, 2012).

Of particular interest here are the theoretical challenges that arise from interpreting the data from EEG studies involving infants' observation and execution of actions. Although some of this infant EEG research has attempted to directly connect with the concept of mirror neurons and the associated debate about action understanding in adults (Nyström, Ljunghammar, Rosander, & von Hofsten, 2011), others working in this area have adopted different perspectives in order to address related developmental questions. For instance, Marshall and Meltzoff (2011) explore a series of issues related to how an extant behavioral literature—specifically on infant imitation—can inform the findings from developmental cognitive neuroscience (see also Marshall & Meltzoff, 2014; Saby, Meltzoff, & Marshall, 2013). These challenging issues relate to wider questions of placing findings from developmental neuroscience in the context of an existing knowledge base on social cognitive development (Meltzoff, Williamson, & Marshall, 2013).

In summary, the field of mirror neuron research stands as a particularly interesting example of the complexities of combining embodiment, development, and neuroscience. The relevance of this work for embodiment comes from the fact that by their definition, mirror neurons have been seen as a neural instantiation of linkages between perception and action, which are a key aspect of theories of embodiment. However, as can be seen from the discussion above, accounts of mirror neuron function have emphasized very different functional roles for these linkages, from the non-representational resonance of Gallese's account through to the radical Bayesian account of Kilner. Given the ongoing interest in questions related to the role of a putative neural mirroring system in human social cognition, the coming years will likely continue to see further elaboration of theories in this area—and it is hoped that developmental work will come to take center stage in this respect (Marshall & Meltzoff, 2014).

EMBODIMENT WITHIN A RELATIONAL DEVELOPMENTAL SYSTEMS PERSPECTIVE

Returning to the question of different levels of analysis, considerations of embodiment clearly complicate the convenient but simplistic notion from cognitivism that questions about neural functioning can be consigned to an inconsequential level of implementation. Yet although many would acknowledge that neuroscience should be integrated with psychology, how to conceptualize the role of neuroscience data continues to present a challenge. So how should the deep challenges of integration be met? Although the construct of embodiment (as outlined earlier) suggests one avenue, embodiment and related constructs such as that of the developmental system operate within the assumptions of a broader set of principles. In the following sections, these are discussed and elaborated as they participate in forming the integrative approach of *relational developmental systems*, which has been proposed as a scientific paradigm within which formulations of the interrelations among brain, body, and mind can be advanced (Overton, 2013, Chapter 2, this *Handbook*, this volume). The relational developmental systems approach is based on the integration of two metatheoretical streams: *Developmental systems* and *relationism*. What is broadly meant by each of these terms is now discussed, and the value of their integration is then emphasized as an important step toward a thoroughly integrative, developmental science that includes all levels of the organism's functioning—from the genetic through the neuroscientific to the psychological and sociocultural (see also Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume).

TOWARD AN INTEGRATIVE DEVELOPMENTAL SCIENCE

It is arguably the case that the emergence of a truly integrative, biologically informed developmental science of brain, body, and mind has been hampered by the inherent limitations of what Goldhaber (2012) labeled *the classic debate* concerning nature and nurture, which was manifested in various ways throughout the 20th century. This debate has deeper origins, but a rough sketch of the beginnings of its contemporary form—at least in North American psychology—serves to inform why more integrative views of biology, neuroscience, and mind have historically struggled to gain a foothold in mainstream developmental science. In terms of the project at hand, understanding the inherent limitations of the classic nature-nurture debate is relevant to building a developmental science that is fruitfully informed by biology more generally and neuroscience more specifically—and at the same time avoids the mistake of isolating neuroscience data on a "biological" or "nature" side of a false dichotomy.

Accounts of the origin of the contemporary nature-nurture or nativist-empiricist debate often begin with Francis Galton (Logan & Johnston, 2007). The influence of Galton and his associates such as Pearson and Fisher on early American nativism in the 20th century has been well documented. Combined with the translation of Binet's intelligence test, this influence set the stage for the political and social ramifications of eugenics. However, moving against this tide were empiricist voices such as the psychobiologist Zing-Yang Kuo (1939), who went on to be influential in the emergence of the developmental systems approach (see Honeycutt, 2011). It is notable that early attacks on nativism also came from embryologists such as Kuo and also Carmichael (1925), foreshadowing the influence of developmental biology on the emergence of more organismic, developmental systems perspectives.

From the start, the classic nature-nurture debate was characterized by split notions of additivity (Overton, 2006). The divide between biological and environmental explanations of behavior became particularly apparent in the 1930s through the advent of kinship studies and adoptive designs as well as intervention and deprivation studies. Across such studies, the same data could lead to quite different conclusions, depending on whether its interpretation was focused on consistency (as in the nativist emphasis on rank order correlations) or change (as in the empiricist focus on change on group means). Although these exchanges were inherently limited by the opposition of nature against nurture, sporadic critiques and calls for more sophisticated developmental approaches were made. Anastasi (1958) suggested that the wrong questions were being asked about behavioral development: Instead of asking "Which" type of factor was more important, or "How much" development was due to one factor versus another, Anastasi argued that the correct question to ask was simply "How?" That is, how do biological factors and how do environmental factors contribute to behavior and the development of behavior? At the time of her writing, Anastasi's call for a more nuanced, integrative consideration of process was, in fact, already being answered as part of the transatlantic exchanges involving Lehrman and Lorenz (see Lerner, 2002). Indeed, Lehrman's (1953) construal of experience in broad terms—following that of Schneirla (1949)—and the denial of the causal import of deprivation studies—laid the foundations for the establishment of a *general systems* view of development (Overton, 1973).

Despite the attempts of Anastasi and others to destroy the false dichotomy of nature versus nurture, the contentious debate continued. In the late 20th century, however, the influence of nativist population behavior geneticists began to be confronted by developmental psychobiologists who argued against the idea that behavior can be split into additive genetic and environmental factors (for discussion, see Partridge, 2011). In the typical behavior genetic approach, kinship studies, including those entailing the construction of heritability indices (see Bateson, Chapter 6, this *Handbook*, this volume; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume, for critiques) are employed to avoid questions of process (Turkheimer, 2000), and developmental explanations are reduced to dividing the supposedly additive sources of between-group variation (gene, environment, and G $\times$ E additive interactions) across age (Scarr, 1992). For developmental psychobiologists, such as Gottlieb (1970, 1992, 2007), who took a developmental systems perspective, however, the issue of process is central. Thus, the questions asked as well as the methods employed by nativist behavior genetics are of a very different nature than those of the developmental systems or relational developmental systems approach (Overton, 2013).[1] From the relational developmental systems perspective, the central questions are not primarily about individual differences assessed through the division of additive variation across individuals. The questions for relational developmental systems investigators instead focus on process, and concern "intraindividual changes and interindividual differences in intraindividual changes across the life span" (Lerner & Benson, 2013a, p. 2).

Developmental psychobiologists such as Gottlieb rejected the metatheoretical assumptions of behavior geneticists and by extension, the additive methods that they employ (Overton, 2003). These objections have been outlined by various authors, including Griffiths and Tabery (2008, 2013) who highlight the fundamental and intractable differences in the assumptions of each approach (see also Bateson, Chapter 6, this *Handbook*, this volume; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume). For developmental systems theorists, *interaction*—or more specifically *interpenetration* or *coaction*—characterizes all aspects of the developmental system. The fact that behavior genetics finds only statistical interaction effects of small magnitude is viewed as an artifact of methodology—because for the developmental psychobiologist (or relational developmental systems theorist), there can be no such thing as a main effect. The robust nature of the developmental system may produce what looks through the lens of the behavior geneticist's methods to be main effects, but such notions are meaningless to the developmental psychobiologist. For the latter, interaction effects cannot be understood through group means, and the behavior of the system can often best be understood by driving parameters outside of the normal range, which is primarily the domain of animal studies. These stipulations have been a constant source of frustration to behavior geneticists (Turkheimer, 2000).

One important source of evidence supporting a relational developmental systems perspective and strongly opposing a simplistic, split, or maturational (i.e., biologically determined) view of development comes from classic embryological work carried out in the early- to mid-20th century. This work was characterized by an organismic perspective, founded in the holistic notion that parts of a system can only be understood through their relation to the whole system, and that the behavior of a system cannot be predicted from—or reduced to—the simple aggregation of its parts (Pepper, 1942). Together with the earlier influence of von Baer (1828), the embryological research of Kuo (1939), Spemann (1938), Waddington (1957), and Weiss (1939) emphasized the hierarchical nature of development and showed how complex forms develop from simpler ones through the principles of differentiation and integration. As is argued below, much of the work in modern developmental biology has echoed and expanded on these themes, and provides strong evidence against more deterministic accounts. Two reasons for focusing on these biological influences here are that they can inform the study of brain development (and thus the development of brain-behavior relations; see Stiles, 2008) and that in many ways they relate to the current call for networks (i.e., systems) approaches in cognitive neuroscience (Sporns, 2011, 2014).

Organicism in embryology was a strong influence on parts of developmental psychology in the 20th century (Cairns & Cairns, 2006), with the *orthogenetic principle* of Werner (1948) and Piaget's (1977) concept of the *equilibration* process being partly based on evidence from the study of embryological development. More recently, Gottlieb's theory of *probabilistic epigenesis* emerged from this same organismic background (Gottlieb, 1992, 1998, 2007). As detailed elsewhere (e.g., Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume), probabilistic epigenesis is a central feature of the leading approach that formed the backbone of developmental psychobiology in the late 20th century. Probabilistic epigenesis is fundamentally an organismic, holistic principle that emphasizes the interconnected relational nature of the parts of the developmental system. From this perspective, conceptualizing these interconnections goes beyond simple notions of interaction to encompass a wider view of reciprocal, bidirectional, coacting, interpenetrating (←→) processes (Overton, 2013, Chapter 2, this *Handbook*, this volume).

As discussed by Gilbert and Sarkar (2000), the organismic framework within embryology did not go undisputed, despite its intrinsic appeal. One challenge for early moves toward organicism in embryology came from the allure of vitalism, which posited a mysterious, unknowable force

[1] As noted later in this chapter, *developmental systems* was extended to *relational developmental systems* (Lerner & Overton, 2008). As a consequence, in the following text, the term *relational developmental systems* is used whenever a distinction does not apply.

as the cause of developmental change. Hans Driesch, one of the pioneers of embryology in the late 1800s, rejected organicism and became a strong promoter of vitalism (Driesch, 1914). Despite such setbacks, in the principal challenge to organicism in the longer term did not come from vitalism but instead from genetic determinism, or the assumption that the genome is the fundamental causal agent in the development of a phenotype. In its stronger form, genetic determinism is the modern form of preformationism, in which the morphology and capacities of the organism are explained through their latent representation in the genes. From this perspective, development as a relational process is rendered irrelevant by the dominance of maturational (i.e., biologically determined), mechanistic patterns of gene activity.

Relational Developmental Systems

As noted earlier, the initial momentum toward an integrative account of the development of body, brain, and mind emerged from what could broadly be called developmental psychobiology. Since the early 1990s, related accounts have become increasingly prominent under the rubric of *developmental systems theory* (Johnston, 2010). In the context of developmental psychology, a foundational use of this term comes from the book of the same title by Ford and Lerner (1992), with this line of theorizing being more recently extended to *relational developmental systems* (Lerner, 2006; Lerner & Benson, 2013a, 2013b; Overton, 2006, 2010, 2013, Chapter 2, this *Handbook*, this volume; Overton & Lerner, 2012). The construct of the developmental system was also highlighted somewhat independently and in a different context by two philosophers of biology, Griffiths and Gray (1994). Each of these sets of authors drew on the work of Gottlieb and other theorists (e.g., Lehrman, 1970; Oyama, 1985) who had previously emphasized the importance of a systems perspective in the study of developmental process.

From a relational developmental systems perspective, the *explanandum*—what is to be explained—is, as stated above, how the individual organism becomes, and the *explanans*—the explanation—is the entire relational developmental system itself, which includes all biological and environmental resources available to the individual organism. This emphasis on the wider relational developmental system reflects what has been called the parity thesis, such that any one aspect of the system cannot be elevated in terms of its causal role (see Shea, 2011). On this view, parts of the relational developmental system can only derive their meaning from the context of the entire system (holism), and the explanatory power of one developmental resource cannot be elevated over another. The parity thesis relates to another fundamental tenet of the relational developmental systems approach, which is the rejection of a privileged role for genes (Bateson, Chapter 6, this *Handbook*, this volume; Ford & Lerner, 1992; Griffiths & Knight, 1998; Keller, 2010; Lickliter & Honeycutt, 2003, Chapter 5, this *Handbook*, this volume; Oyama, Griffiths, & Gray, 2001; Robert, 2004, 2008). Although relational developmental systems theorists acknowledge that genetic material is a necessary condition for cellular function, they emphasize that genes are not "unmoved movers" because they only become causally relevant through their involvement in the entire relational developmental system.

One related lesson from work in modern developmental biology is that specific genes do not solely determine major characteristics of bodily form such as segments, eyes, or wings. The same can be said for all bodily structures, including the brain (Stiles, 2008), and this principle extends to the development of more abstract characteristics such as symmetry or polarity (e.g., of hands, limbs, or eyes). These characteristics are not predetermined as an end result of gene expression, but instead arise through the organized activity of the relational developmental system (Minelli, 2009). Genes can be identified that are *involved in* the development of any bodily structure or characteristic, and changes to these genes—in specific temporal and spatial contexts—can impede or divert the typical course of development. However, the morphology of the brain and body clearly arises not through a highly specified genetic plan but through the reciprocal coaction of component parts of the developmental system.

Such findings from developmental biology have provided important insights into development as an epigenetic process that proceeds through reciprocal and dynamic coactions among coding and noncoding DNA, transcription and translation factors, the cytoplasm, and the intra- and intercellular environments more generally. From this perspective, the action and function of a gene depends on contextual factors, including temporal and spatial coactions with other genes and gene products. Related to these fundamental points, there have been important changes in the definitions of what constitutes a gene and the genome (Keller, 2011), and a reframing of the role of environmental influences on gene expression (Greenberg & Partridge, 2010; Slavich & Cole, 2013). Stiles (2009) notes the relevance of these issues for developmental psychology, particularly for its historical preoccupation with delineating the relative influence of inherited versus environmental influences. Indeed, the view from developmental biology more generally presents a vastly different picture than is suggested by the shopworn received formulations of the nature-nurture debate. The processes involved in the development of the nervous system provide a distinct rejoinder to simple claims of innateness (i.e., biological determinism—for discussion, see Stiles et al., Chapter 2, this *Handbook*, Volume 2). Instead, modern developmental biology has supported the organismic perspective of the early embryologists, whose perspective went on to influence the emergence of developmental psychobiology and developmental systems approaches.

The Relational Framework

One reason for an extended discussion of the relational developmental systems perspective comes from its rejection of simple notions of causation, a point which forces us to think closely about the relational ties among body, brain, and mind more generally. A related rejection is at the heart of the *relational* worldview (Overton, 2013, currently termed *Process-Relational* worldview; see Overton, Chapter 2, this *Handbook*, this volume), which has further implications for the questions about levels that are central to the current project. A worldview constitutes a metatheoretical framework "that both describes and prescribes what is meaningful and meaningless, acceptable and unacceptable, central and peripheral, as theory . . . and method . . . in a scientific discipline" (Overton, 2007, p. 154). Overton (2006, 2013) has written extensively on the contrast between a Cartesian-Split-Mechanistic worldview that imposes a split between levels, and a relational worldview that emphasizes their interdependence.

A central goal of this chapter is to promote the notion that adopting a relational framework can assist in addressing the questions about levels that currently constrain the creation of integrative approaches to the development of body, brain, and mind. To outline such an integration beyond that already accomplished in the discussion of embodiment, one potentially helpful approach is to note the similarities (and differences) between contemporary levels-based approaches and the explanatory framework proposed more than 2,300 years ago by Aristotle. In terms of its value for an integration of psychology and neuroscience, this approach not only allows us to frame current approaches to levels in historical context, but it also enables us to move beyond the separation of levels that is apparent in contemporary levels-based theories. In short, beginning with the multiple modes of explanation first put forward by Aristotle and placing those modes in a relational framework allows us to place the lessons learned about the embodied nature of neural processes into a broader, developmentally oriented paradigm in which the integration of different levels can be achieved.

In brief, Aristotle proposed that an explanation of a given phenomenon entailed the coordination of a set of four *aitia*, or what have become more commonly known as the *four causes*. Although Aristotle's four causes (efficient, material, formal, and final) are not frequently explicitly mentioned in contemporary psychological science (see, however, Blachowicz, 2012; Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume; Overton, 2006, Chapter 2, this *Handbook*, this volume; Sokol, Hammond, Kuebli, & Sweetman, Chapter 8, this *Handbook*, this volume; Witherington, 2011, Chapter 3, this *Handbook*, this volume), they can be seen as foundational to many current approaches to different levels of analysis (Overton, 1991). Indeed, there are similarities between Aristotle's framework and the three levels of Marr (1982) that were discussed in some detail earlier in this chapter. To better understand the relevance of the four causes to contemporary theorizing about levels, a brief description of each is necessary. It should be noted that not all of the four causes map onto contemporary notions of causality, and as such it may be helpful to think of them as *explanatory factors* rather than causes per se (Caston, 2006).

1. *Formal* causes refer to *the way something is*—its form, structure, or organization.
2. *Efficient* causes refer to the forces or factors that move the object.
3. *Material* causes refer to what substances make the object.
4. *Final* causes are the end, goal, telos, or purpose of the object.

In modern usage, efficient and material factors are generally understood as mapping onto traditional explanatory causes, whereas formal and final factors can be seen as explanations related to the pattern, form, or organization of the object of interest (Overton, 2010, Chapter 2, this *Handbook*, this volume).

The efficient cause is perhaps the most intuitive of Aristotle's *aitia*, because it is closest to everyday notions of cause and effect. Efficient causes refer to observable factors or forces that effect change, are distinct from the object being acted on, and have a causal action that precedes the effect or outcome. Material causes are also observable factors, referring to the substance of which something is made. In contemporary formulations of levels of analysis, the material cause may correspond to the level of neurobiology (or to Marr's level of implementation); although as is discussed later, this mapping is not quite as straightforward as it might initially appear.

Formal and final pattern explanations are more abstract than efficient or material causes, but are no less essential for understanding. They are reasons or principles that provide intelligibility to the object and its evolution and, hence, intelligibility for the other types of explanation. Formal and final explanations are therefore necessary complements to efficient and material causes. In particular, the central importance of the formal and final explanation comes from their providing a structure or pattern through which the other kinds of explanation can be understood. As such, the formal explanation is central to any kind of systems explanation, such as the body-brain-environment system that is the foundation of the embodied approach. Furthermore, the final explanation is central to any kind of relational developmental system.

As noted by Aristotle, the four explanatory factors cannot be considered in isolation but must be seen as being inextricably interwoven in a relational sense. In this respect, the Aristotelian framework exemplifies a pluralist notion of cause, in which "no one perspective constitutes the gold standard of understanding: only when brought together as four unique vantage points . . . will the phenomenon be open to complete understanding" (Witherington, 2011, p. 73). It is this reciprocal relation that underlies discussions of *circular* and *downward* causality (Witherington, 2011; Chapter 3, this *Handbook*, this volume). Each new level of organization constitutes a dynamic system that contextualizes earlier levels and forms the base for later levels within which efficient and material causes operate (Overton, 2010). Of central importance here is the observation that although one can say the organization (form) and direction (final) of a system comes into being through efficient and material causes, these mechanical causes themselves presuppose an organization and direction.

Through its emphasis on the interconnected or relational nature of different kinds of explanations, Aristotle's framework appears to be particularly relevant to tackling the challenges related to the questions about development, neuroscience and levels that are at the heart of this chapter. So how might Aristotle's four causes be applied to look more closely at what is meant by different levels of analysis in developmental science, particularly with regard to questions about neuroscience? One signpost comes from the work of Overton (1991) who places the formal and final factors at a *competence* level, in contrast to a level of mechanisms or *procedures*, The latter can reflect Aristotelian efficient causes, when these causes are understood as relationally bidirectional and, hence, processes. The material cause is less prominent in Overton's framework, but can be viewed as a level of *hardware* that is similar to the implementational level of Marr (1982). Taken together, the levels of competence, procedures, and hardware are somewhat analogous to the computational, algorithmic, and implementational levels of Marr. However, what sets the framework of competence, procedures, and hardware apart concerns the relational interdependence of the levels and the central place of *development* for understanding this interdependence. These considerations can be sharply contrasted with the independence of the levels in the theorizing of Marr—whose work also mentioned very little, if anything, about developmental considerations.

The framework of competence and procedures originated in dual-systems approaches to the development of reasoning (Overton, 1991). There is some heterogeneity in how different theorists conceptualize dual systems, but in general the basic distinction is between an abstract, reflective, rule-based, propositional system for cognitive processing (closely related to the construct of competence) and a contextualized, associative system (i.e., the procedural level). Developmental aspects of this model have been discussed in some detail by Ricco and Overton (2011), who proposed that the procedural system can be seen as an early established, highly efficient but inflexible system, which operates in the context of a later developing, more flexible competence system. Ricco and Overton (2011) also discussed the similarity between the competence-procedures framework and other dual-systems approaches to the study of cognition such as those from Kahneman (2011), Stanovich (2009), and Tversky and Kahneman (1974) although none of these authors include much consideration of developmental factors.

In the theorizing of Overton (1991), the construct of *competence* reflects top-down design features of the system being explained, or the structure or organization that drives the activity of the system (i.e., the competence system like all self-creating, self-organizing systems is spontaneously active). One basic assumption is that this form of explanation—sometimes termed *pattern explanation*—is formulated at a level that provides a meaning context for a different but complementary level of mechanisms (i.e., the procedural level, which may also be considered to be *processes*). In turn, the mechanisms or processes serve to bring the formal level or the pattern explanation into being. This allows arrival at a relational frame of understanding in which both causal and pattern explanations are legitimized in scientific explanation, and the dialectic between them is appreciated and understood as fundamental to the scientific enterprise (Overton, 2006).

Although certain theoretical perspectives have included a key role for pattern explanations in the conceptualization of developmental process (e.g., most systems models, as well as Piagetian theory) much of contemporary developmental science has until recently tended to focus on mechanistic explanation to the exclusion of structural explanations. The background to this asymmetry is complex (see Overton, 2006, Chapter 2, this *Handbook*, this volume) and may be partly a consequence of the abstract quality of pattern explanations, which can lead to conceptual and empirical confusion. As discussed by Witherington (2011), such confusion is reflected in attempts to minimize or dismiss the importance of structural explanation, under the assumption that higher level forms have no causal powers, instead being inert epiphenomena arising from the activity of lower-level processes. A different but equally mistaken path is the reification of formal and final causes as entities that directly exert causal influence in the same way as efficient causes. Both of these conceptual confusions reflect a neglect of the fundamentally different but interconnected (i.e., relational) roles that formal and final causes play as explanatory factors (Witherington, 2011).

Even if the explanatory necessity of Aristotle's formal and final explanations is recognized, giving precedence to efficient causes still appears to be an easier option than a full consideration of both types of explanation. As noted by Wimsatt (2007), "we tend to be suspicious when we are called on to explain phenomena by going up a level" and that the dominance of reductionist methodology "implies a kind of explanatory priority, that things not explicable at a given level are to be referred to the next lowest level" (p. 216). However, the competence level cannot be ignored in the forlorn hope that structural explanation will become unnecessary if enough mechanisms or processes are described. Adopting such a position would present a conundrum that stretches far back in the history of philosophical and scientific thought, which is that every efficient cause cannot be caused by another efficient cause. Avoiding such pitfalls requires the understanding that mechanisms or processes at the procedural level must be organized in some way, and that in and of themselves, these processes or mechanisms have no context. It is this issue that brings the focus to competence as a different level of analysis, which as formal explanation becomes the *system* of a systems approach.

Neural Mechanisms[2] and the Mereological Fallacy

Given the preceding discussion, the question becomes how best to place neuroscience data in a relational framework. Neuroscience data make little sense in isolation and, as such, a level of hardware or implementation cannot meaningfully exist without relational ties to other levels. Sidelining a role for neuroscientific explanation (as in cognitivism) is clearly short-sighted, but on the other hand, integration presents a difficult challenge. Toward this goal, conceptualizing the relational ties between levels—and honing approaches to target cross-level questions—is of utmost importance for a successful integration of body, brain, and mind in developmental science. As noted earlier, the approach of framing neuroscience as occupying a causally neutral level of realization avoids having to specifically address the problem of the relation among levels (Miller & Keller, 2000). Although superficially reassuring, this approach is problematic and ultimately unsatisfactory. As an alternative, it may be tempting instead to try to accommodate neuroscience in two-level frameworks (e.g., of competence and procedures), without introducing an additional level of implementation or hardware. Such attempts relate to the usage of the term *neural mechanisms*, which reflects the identification of neuroscience data with the procedural level of mechanisms. However, through a relational lens, a level of mechanism, which in relational terms would be called *processes* (see Overton, Chapter 2, this *Handbook*, this volume) still requires a separate but interconnected level of organization (i.e., competence, or a systems level), and in this sense the isolated invocation of the concept of "neural mechanisms" remains limited in its explanatory power.

This issue relates to a larger problem in developmental science more generally, which is a tendency to highlight the explanatory role of mechanisms or processes in the absence of a consideration of what was described above as a competence level. One prime example concerns the

[2]See Overton, Chapter 2, this *Handbook*, this volume, for an extended argument that within any systems approach the term *mechanism* should be discarded and replaced by the term *process*.

use of looking time measures (which reflect subpersonal processes) to make inferences about social cognition in infants, prior to the manifestation of more flexible abilities in early childhood. Apperly and Butterfill (2009) discuss the potential utility that a dual-systems approach can play in resolving the related debate on infant social cognition. In a similar vein, Rakoczy (2012) noted that a full consideration of both systems (i.e., competence and procedures) is necessary for a full understanding of the development of theory of mind, and that any account that fails to do this is necessarily limited in its scope of explanation. Rakoczy further cautions that to confuse the two levels commits a "mereological fallacy" in which subpersonal processes—as properties of parts of a system—are equated with or substituted for personal-level properties of the whole system. Indeed, this very argument was originally raised by Bennett and Hacker (2003) in the context of neuroscience, such that an accumulation of neural mechanisms could not stand in as a full explanation of the properties of the individual.

ON THE DEVELOPMENT OF THE RELATIONAL SYSTEM

Returning to the competence-procedures framework (Overton, 1991), a consideration of the relational ties between levels naturally brings developmental considerations to the foreground (Overton & Dick, 2007). Competence as pattern can only be realized through the *developmental* course of reciprocal, bidirectional (←→) causes, with the procedural level of mechanisms (processes) only becoming coherent in the context of the pattern itself. This stipulation brings an awareness of the necessity of developmental science for relating different types of explanation. In short, *the puzzle of how levels are related to each other can only be solved in the context of developmental processes*.

From a broader perspective, it can be seen that when developmental considerations are added to an exploration of the relational ties between different levels, various fundamental questions emerge that lie at the heart of developmental science. How can new (novel) structures arise that are qualitatively different from the sum of their parts? How can activity at one level of explanation account for change at another (qualitatively different) level? How can the result of "doing more of the same" not simply be "more of the same"? It is worth noting that related puzzles underlie some of the most fundamental questions about the wider discipline of psychology itself, and it is worth briefly appreciating the scope of this problem. Although outside the primary focus of this chapter, understanding the relational ties of competence and procedures has distinct connections to the philosophical problems of intentionality, consciousness, free will, and agency. The shared question running through these problems fundamentally involves the relation between levels of mechanism (process) and meaning. Splitting and isolating these levels leads directly to the classic brain-mind or mind-body problem, which becomes an irresolvable mystery when viewed through the traditional lens of analytic philosophy and an associated Cartesian-Split-Mechanistic framework. By moving away from this paradigm, the transformative integration provided by a relational developmental systems approach offers a solution that is based on the fundamental premise that levels of mechanism/process and meaning cannot be split off and pitted against each other, but must be viewed as an indissociable complementarity.

Recalling again Aristotle's explanatory scheme, the level of competence (i.e., of formal cause) can be considered to be what something *is* (i.e., its meaning) in the abstract sense of a pattern or system (e.g., the visual system, the auditory system, the nervous system, or the system of consciousness). Simultaneously, competence is a *dynamic pattern* entailing both form (organization) and function (activity) as an indissociable relation. If the level of procedures or mechanisms (processes) is understood as the active means through which each new competence level comes into being, while simultaneously the competence level serves as a functional context for organizing the procedural level, it can be understood how the two levels of operate in a complementary fashion. From this viewpoint, the relation between competence (system, meaning) and procedures (mechanism-process)—as a dynamic tension in living systems—becomes the base of a truly developmental, constructivist perspective. Witherington (2011) operationalizes this tension as *circular causation* that recognizes both the emergence of form through process as well as the constraining, *downward* influence of form on process. The potentially transformative power of this fundamentally relational notion has been discussed by Overton (2006, 2010, 2013, Chapter 2, this *Handbook*, this volume), who has proposed that it can move us beyond the narrow confines of the nature-nurture debate and other dichotomies (e.g., brain versus mind) that currently constrain the wider discipline of psychological science.

A joint emphasis on development and circular causation leads to a concluding point and a future direction: The integration of the concept of the developmental system with the relational worldview has led to an understanding of the developing organism as "co-acting, co-developing processes functioning according to the reciprocal causality entailed by complex positive and negative feedback loops" (Overton & Lerner, 2012, p. 375). As such, the framework of relational developmental systems has been offered as a paradigm for the future of developmental science (Lerner, 2006; Lerner & Benson, 2013a, 2013b; Lerner & Overton, 2008; Overton, 2006, 2010, 2013; Overton, Chapter 2, this *Handbook*, this volume). As a paradigm, relational developmental systems recognizes the dynamic complexity of developmental processes and exposes the inadequacy of split approaches, which emphasize simple interaction and the elevation of one level of analysis over another. Living organisms are, therefore, understood as dynamic, adaptive, nonlinear, self-organizing, and self-regulating systems (Lerner, 2006; Lerner & Overton, 2008; Overton, 2006, 2010, Chapter 2, this *Handbook*, this volume). From this perspective, the notion of a system provides a formal explanation, with the directional features of adaptation and self-organization constituting a final pattern explanation (Overton, 2010). By further focusing on the reentrant quality of the connections among levels, relational developmental systems has at its foundation the concept of *development* writ large. In a complex system where the parts (or levels) are connected in an interpenetrating or coacting way, development is not simply about time per se, but instead concerns transformation and emergence (Overton, 2006). It is only through an awareness of this notion of reciprocal causality that an understanding can be reached of how the relational (and inherently developmental) ties between levels can provide a solid foundation for the study of brain, body, and mind.

CONCLUSION

The overall message of this chapter is that developmental science is at a key crossroads at the intersection of psychology, biology, and neuroscience. This location presents an opportunity to pursue an integration that can move beyond the dead ends that have been historically imposed by the Cartesian-Split-Mechanistic approach. One key feature of this integration entails embodiment, which integrates body, brain, mind, and social-cultural context. Sporns (2011) notes that one particular tenet of embodiment—the dynamic linkages of brain and body—may at first glance appear trivial. However, he reflects that the deeper implications of these linkages lie

> at the heart of what it means to be an autonomous organism. The essence of autonomy is self-determination—the actions of an organism within a physical and social environment continually perturb the rich web of dynamic interactions that make up brain and mind. (p. 324)

In line with the emphasis on embodiment in this chapter, Sporns (2011) further suggests that it is only through a networks (i.e., systems) approach that self-determination can be studied (see also Sporns, 2014). He further notes that the term *networks* does not solely refer to connections within the brain, citing the proposal by Ashby (1960) that coordination between parts of the brain need not take place via "some anatomically or histologically demonstrable tract or fibers" but can also take place as a result of the organism's own activity and through the effect that activity has on further neural activity. As emphasized throughout the current chapter, these considerations necessitate that neuroscience data can only be understood in the context of a wider developmental system that includes—but goes beyond—the brain itself (see also Byrge et al., 2014).

Looking ahead, this wider notion of networks does not negate the importance of the recent high-profile initiatives having the stated goal of mapping the patterns of connectivity within the human brain. These large-scale initiatives include the ongoing structural mapping of the human connectome, which has already generated a great deal of raw data (van Essen et al., 2013), as well as a proposal to map functional connectivity (The White House Office of the Press Secretary, 2013). The view developed in this chapter suggests that the interpretation of the vast amounts of data from these projects can only be meaningfully analyzed in the context of a relational approach. In addition, although it may appear to greatly add to the demands of what are already enormous challenges, developmental data are essential to understanding brain connectivity (Collin & van den Heuvel, 2013).

In discussing the need for complex systems approaches for understanding brain function, Sporns (2011) places the flurry of research on mapping brain connectivity in the context of another large-scale biological initiative—the Human Genome Project. He notes the initial but ultimately misplaced hope from some biologists that the data derived from the sequencing of the genome would reveal a complete understanding of human life. But although these hopes were dashed (for many of the reasons outlined in this chapter), Sporns notes that the genome project stimulated an awareness among biologists of the need for systems approaches in the study of how phenotypes arise. A similar opportunity is present for informing the understanding of brain function in terms of what can be gained by the recent large-scale brain mapping initiatives.

Finally, recent years have seen increasing emphasis on the inclusion of biological measures in developmental science. Although much of this research is carried out with concern for the theoretical issues involved, it is critically important that this turn toward the biological does not bring with it a limited view of neuroscience data as having elevated explanatory power than other kinds of data. As Overton (2010) has noted, to consider genes, neurons, or brain changes "to be sets of additive causes that drive development is to miss the point that these are all resources that the developmental system uses to grow" (p. 7). In this sense, work claiming to delineate "neural mechanisms" cannot be conducted in theoretical isolation from the concerns about embodiment and relational developmental systems as discussed in this chapter. In the context of this project, related considerations concern problems that can arise if brain processes are understood as mechanistically determined and changes in brain processes as the result of a split-off biological "maturation." Broadly, the argument presented in this chapter is that in order to forge a viable developmental science that includes the body, brain, mind, and the sociocultural world one must go beyond any idea of the brain as an isolated information processing device. The brain functions in the body of an active agent embedded within a wider developmental system and wider sociocultural context. This conclusion is by no means in opposition to an important role for neuroscience in the future of developmental science: Instead, it brings forth the hope of meaningful multilevel investigations that can move us toward integration rather than separation.

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CHAPTER 8

The Development of Agency

BRYAN W. SOKOL, STUART I. HAMMOND, JANET KUEBLI, and LEAH SWEETMAN

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The term *agency* refers to a person's autonomous control over his or her actions—but also much more than this, including a sense of what individuals can accomplish themselves and responsibility or ownership over one's actions. Common day-to-day intuitions suggest that notions of agency cut across a wide range of human experiences. References to agents and agencies abound in everyday language—from chemical agents to travel agents, from cleaning agents to government agents. What do these various uses of agency all mean, or even have in common? The present discussion of the development of human agency attempts to answer this question, as well as other questions and puzzles surrounding conceptions of agency. As it happens, there are no easy answers or solutions. Still, as a preview of where we hope to end up, the commonalities or continuities we see across various forms of agency—that is, chemical agents, travel agents, and government agents—whether they operate at the molecular level or at the macro, sociopolitical level, is that agents "get things done." That is, agents *act*, and by acting, they serve catalyzing and navigational functions in networks of relations, sometimes involving atomic particles, sometimes people, and sometimes nations.

Despite the importance that agency should hold in psychology, as the science of behavior, scholarly discussions of agency in the mainstream are relatively few and far between (for some notable exceptions, see Bandura, 1989, 2001, 2006; Brandtstädter 1998, 2006; Kuczynski & Parkin, 2007; Little, 2002; Martin, Sugarman, & Hickinbottom, 2010; Mascolo & Fischer, 2010, Chapter 4, this *Handbook*, this volume; McAdams, 2013). As a way to enrich these discussions and bring them closer to the mainstream, we must turn to everyday experience to clarify key features of our present account linking agency and action. We must also turn to other literatures outside of psychology, including philosophy and sociology, which have explored issues of agency. In philosophy, questions of agency have arisen in both metaphysics, with the issue of causality, and in moral philosophy, particularly with the problem of free will. In sociology, agency is typically contrasted with social structure, defining actions that originate in individuals against those that are rooted in societal impositions and constraints. From these diverse threads, our response to the initial question of "what do all these references to agency mean?" seems quite broad. It is so broad, in fact, that the inclination to comment on continuities across different forms of agency raises the additional question of whether there is anything distinctive or special about *human* agency. That is, on some accounts (e.g., Bidell & Fischer, 1994; Brandtstädter, 1998), the activities of any self-organizing system, human or not, constitute agency. But, as Witherington (2011) has cautioned, self-organizing activity "should not be confused with the deliberative, reflective agency associated with higher-order, emergent forms of psychological functioning like consciousness" (p. 81). Consciousness, and similarly robust forms of deliberative agency, connote a form of self-determination and control seen more typically in the psychological constitution of human beings (see Lewis, Chapter 11, this *Handbook*, this volume, on consciousness and agency). But even with this useful distinction between self-organizing agency and deliberative, reflective agency, the expressions of agency unique to human beings are quite varied. Agency can involve basic choices, such as an infant choosing where to cast her attention (e.g., Russell, 1996), or sophisticated narrative constructions of defining one's identity and marking the appropriation of particular normative values and principles (e.g., Blasi, 2005; McAdams, 2013; Sokol, Müller, & Chandler, 2013; C. Taylor, 1989).

Although the theoretical framework offered in our review is more of a sketch than a fully formed account, our premise is that *human agency is unique* insofar as persons develop a sense of self-awareness, or reflexivity, and personal meaning-making that is integrated with self-control abilities over the life span. Altogether—reflexivity, meaning-making, and control—give rise to a sense of personal agency and self-authorship that does not exist, or emerge, within other relational networks and social structures. The embeddedness of human agents in these structures and networks constrains, extends, and leads to new expressions of agency (Ratner, 2000). Reflexive agency itself develops within, and because of, these networks. Although agency is typically contrasted with some sort of limitation or restriction in the physical or social environment, here we turn to physical and social contexts less to describe the limits of agency and more to explain the *constitutive*, and thus, *developmental dimensions* of agency. In doing so, we adopt a relational view of agency (Furth, 1981; Macmurray, 1957; Overton, 2013) and work to move beyond the common *splits* or dichotomies (Overton, 2006, Chapter 2, this *Handbook*, this volume) in the literature, such as the *structure-agency* debate that has dominated sociology (e.g., Archer, 2000, 2003; Emirbayer & Mische, 1998; Giddens, 1984, 1991) or the *agency-communion* contrast seen in certain quarters of personality psychology (e.g., Bakan, 1966; Frimer & Walker, 2009; Paulus & Trapnell, 2008; Wiggins, 1991).

In this chapter, several important relational aspects of human agency, particularly those embedded in family, school, and community networks, are described as supporting the development of agency and self-determination in young people (Gestsdóttir & Lerner, 2008; Lerner, 2004; Lerner, Dowling, & Anderson, 2003; Mistry & Dutta, Chapter 10, this *Handbook*, this volume). These *social* structures go hand-in-hand with *psychological* structures constituting the emergence and development of human agency. The complicated work of defining agency, therefore, must capture its varied forms and expressions, extending from basic self-organization activities to richer psychological and cultural instantiations of self-authorship and shared meanings. Accordingly, the definition proposed in this chapter has three parts:

1. ***Biophysical agency*** constitutes the activities of a self-organizing system to regulate and sustain itself.
2. ***Psychosocial agency*** constitutes the deliberate, intentional acts of a self-aware system to determine a course of actions and construct meaning from them.
3. ***Sociocultural agency*** constitutes the dynamic patterns of shared values and norms of cultural systems, both past and present, to extend and limit (i.e., empower and constrain) individual and collective actions.

Before unpacking the different layers in this definition of agency, a more elaborate conceptual analysis and theoretical overview is needed to clarify the place that agency has had in the psychological literature. Given that this chapter is oriented toward developmental scientists, most of the emphasis is on making sense of the second part of the definition, or *psychosocial agency*.

OVERVIEW

Rather than being a coherent body of research, accounts of agency tend to be unsystematized and dispersed across scholarly literatures, in part reflecting disciplinary boundaries (Borstelmann, 1983), but also reflecting the lack of a common framework to tie various discussions together. In our view, psychology, particularly developmental science, will prove to be the nexus point and organizing structure to better unify these disparate accounts. Indeed, like other agency theorists, we see a crucial role in the constructivist roots of Piagetian and Vygotskian theory for investigating the dimensions of agency (e.g., Archer, 2000; C. Taylor, 1985).

Although psychological research has the potential to contribute to a coherent theory of agency, it can also contribute to important applications of the role that human agency has for social change. Or, to borrow from Giddens (1984), human agency is not simply about being able to act, but about being able to "'make a difference' to a pre-existing state of affairs or course of events" (p. 14). Understanding the nature of our own agency, as well as current limits in this understanding, can help us develop further the capacity for action in ourselves and in others, with relevance to social and moral development, as well as broader social movements. In this discussion we look to bolster treatments of the *capabilities approach* found in the work of philosophers and economic theorists such as Nussbaum (2011) and Sen (1992, 1999). This approach argues for *freedom* as the basis of development both at personal and societal levels, in much the same way that the developmental scientist, Lerner (2004), has described *liberty* as being at the heart of positive youth development and civil society. Educational institutions, in particular, hold a special place in promoting such freedom and liberty.

We begin our account, however, with an exploration of the roots of agency in physical causality and biological self-regulation. This section deals briefly with the work of Aristotle, before turning to conceptions of biological regulation that originate in embryology of the 19th century and its relation to evolutionary and developmental biology. At their core, the various conceptions of agency that are discussed throughout this chapter all require that an agent be *self-determining*. Although at a day-to-day level it may seem obvious that human beings can make volitional decisions, even merely choosing to look at one thing rather than another, self-determination has proven to be a major philosophical question in a universe that is, at least according to some materialist views, wholly determined and caused by external forces rather than internal choices and decisions. The question becomes especially relevant to psychology in considering what organisms are considered to be agentic, and at what point in the human life span agency is recognized.

From this starting point, we turn to questions of defining the opposite end of the spectrum: a fully developed form of moral agency. Before the emergence of self-determination in biological theory, philosophers faced the question of how to understand human freedom in a mechanistic worldview that seemed to be constricting the very possibility. The influential solution of Kant (1785/1959) was to carve out a separate realm for human autonomy. Kant's solution has shaped a great deal of modern thought on moral agency and expectations for the role of moral emotions, a sense of duty, and other important considerations. At the same time, his solution placed its own limitations on our understanding of agency that have set the stage for subsequent moral philosophy, as well as C. Taylor's (1985) writings on reflexivity—of the agent as self-interpreter and evaluator, able to reorganize in important ways an understanding of one's self and the world.

Next we explore the place of the agent in the social world, one filled with other agents and with social structures and institutions. In the sociological literature, the concept of *social structure* has often been set against individual agency. When we want to make something happen, what helps to achieve our goals, and what holds us back? The usual answer would be that the "*I*" makes things happen—with *my* ideas and *my* willpower, set against the constraints of society (e.g., laws and regulations) and the limits of my body. In a common way of thinking about the problem of freedom, with echoes in the philosophical literature, modern society and culture, and especially technology, bind us. And yet society and technology, as well as biology, are also what enables us to act and think.

After summarizing the backdrop of modern agency, we then turn to psychological and developmental questions. Some seminal thinkers, particularly Jean Piaget (Piaget, 1932/1965; 1936/1963; see also Russell, 1996) and Lev Vygotsky (Vygotsky, 1978, 1986; see also Valsiner, 1998), have adopted perspectives that reserve an important place for agency. Although this chapter does not offer a detailed account of either, we share the same constructivist impulses that these theorists have been shown to hold in common (see Bidell, 1988; Chapman, 1991; Tudge & Winterhoff, 1998). Broadly speaking, both the Piagetian and Vygotskian traditions begin with action and the active organism as fundamental to all development. Across the course of development, conscious reflection (Piaget & Inhelder, 1982; Piaget, 1977) and social communication (Vygotsky, 1986) increasingly play a role in the reorganization of action and in promoting the growth of agency (Piaget, 1974/1976a; Piaget, 1932/1965). After establishing this general outline, we turn to surveying several areas of developmental science that help clarify the nature of human agency and its origins.

Finally, we examine several practical implications of agency. Although the concept of agency has a clear kinship to psychological questions involving self-regulation and self-determination, it also shares important connections to questions of human freedom, social responsibility, and community or civic engagement (e.g., Lerner, 2004). Ratner (2000) has argued, “If agency has a social character that depends upon social relations, it is not intrinsically creative, fulfilling, or empowering. It only becomes so by creating social relations that will promote these characteristics” (p. 426). Accordingly, we argue that psychosocial agency is self-sustaining only insofar as people create and invest in the social and cultural structures that are necessary features of human agency. For human agency to flourish, development at the sociocultural level must foster participation, public debate, and democratic practices that empower individuals and create the conditions for social transformation (Alkire & Deneulin, 2009).

PHILOSOPHY OF THE ACTIVE ORGANISM

Agency is grounded in activity. But more than that, agency is grounded in self-directed activity. Although this type of activity is ubiquitous in our daily lives, its existence has been hotly disputed in both classical philosophical thinking and modern-day psychological theorizing. As we summarize later, the history of the idea of agency reveals a split between conceptions of a “physical” world, whether atom or brain, where activity is caused by outside forces, and a “mental” (and/or moral) world, where free will reigns (see Overton, 2006, 2013, Chapter 2, this *Handbook*, this volume). Agency is generally absent in the first view and ubiquitous, but impotent and removed, in the second.

Our goal is to rise above this debate and make self-directed activity the site of the emergence of agency. In our view, the psychological and philosophical work of *action theorists* such as Piaget and Vygotsky, and pragmatists such as John Dewey, who situate the growth and development of knowledge in the active organism, represent the best way forward in understanding agency. This means that developmental science has a particularly important voice in addressing issues of agency.

Why Agency Is Neglected

Given the many routine assumptions and everyday expectations that people hold regarding their own agentive abilities—formulating plans, making decisions, and committing to particular courses of action, to name just a few—one might expect to discover a wealth of information and research on human agency in psychology. This is not the case. As Sokol and Huerta (2010) have described, “talk of human agency in psychological circles . . . is the cocktail party equivalent of talking about religion or politics” (p. 46). Discussions of agency are relatively rare, and often strained, in the mainstream of psychology (for similar claims regarding agency’s neglect, see Frie, 2008; Little, 2002; Sugarman, 2007). Psychology’s neglect or even active aversion of agency appears to originate in its Cartesian foundations, which places a heavier emphasis on epistemic questions over problems of action (Martin & Sugarman, 1999; Overton, 2013, Chapter 2, this *Handbook*, this volume; Overton & Ennis, 2006). These issues are further compounded by narrow conceptions of causality drawn from the natural sciences, which restricts determinism to external causes and disavows self-organization (Bunge, 1959/1979). As Little (2002) has observed, the “dueling worldviews” that lie behind psychological theorizing form a central stumbling block in the exploration of agency. There is an overarching tendency to rely on a reductionist view of causes originating in singular structures, even while paying increasing lip-service to interactivism and relationalism (see also Bunge, 2000; Overton, 2013, Chapter 2, this *Handbook*, this volume; Overton & Ennis, 2006).

For much of modern psychology, just as for Descartes, the central problem has been to explain thought and its relation to the world, especially to *other minds* in the world. Problems of action have not been a central question in psychological research, and the relation between action and choice has not been extensively elaborated in the psychological literature. The central psychological problem has not been “how do I get this done?” but “how do I know what he or she is thinking?” As a result, the problem of agency, (i.e., the problem of acting in the world and interacting with others), has been subsidiary to the problem of other minds. We argue there needs to be a shift from the view of isolated Cartesian minds to one of action (see also Brandtstädter, 2006; Carpendale & Lewis, 2004; Heckhausen, 1999; Hobson, 2004; Mascolo & Fischer, 2010; Chapter 4, this *Handbook*, this volume; Overton, 2006, Chapter 2, this *Handbook*, this volume). In doing so, we join other theorists that, in the words of John Macmurray (1957), claim: "we should substitute the 'I do' for the 'I think' as our starting-point and center of reference and do our thinking from the standpoint of action" (p. 84). As Furth (1981) remarked, we must all come to recognize just how inescapable, even if only tacitly present, agentive questions are in many strands of research, particularly in developmental science.

We also acknowledge that accommodating agency into current psychological theories and frameworks is challenging. Our overriding argument is not that psychology has rejected the notion of choice, but rather the frameworks that have formed the operating context for theories, methods, and research in psychology make understanding agency difficult. When action—or behavior, as many psychologists default to saying—is explored, it is often from the perspective of an externally imposed determinism. The behaviorisms of Watson (1924) and Skinner (1974) are often held up as key examples of this deterministic view of causality. In most areas of psychology, action is not an inherent feature of living organisms, rather it is an outcome determined by forces outside the individual, such as environmental stimuli, or originating outside the individual's life history, such as in evolutionary or neuropsychological factors (e.g., Belsky, 2012; Bjorklund & Pellegrini, 2002; Ellis & Bjorklund, 2012; Greene & Haidt, 2002). The position adopted in this chapter, however, is that agency is epigenetic and relational in nature (e.g., Elder-Vass, 2010; Overton, Chapter 2, this *Handbook*, this volume; Turiel, Chapter 13, this *Handbook*, this volume; Witherington, Chapter 3, this *Handbook*, this volume). Agency cannot be found in the isolated motor neuron, the isolated social norm, or the isolated individual. Rather, in following a path of epigenesis, agency is a *constitutive* property of persons, or biological beings embedded in social relationships (Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume; Martin & Sugarman, 1999; Mistry & Dutta, Chapter 10, this *Handbook*, this volume). Because agency is an embodied phenomenon (Overton, 2008, Chapter 2, this *Handbook*, this volume), it is a mistake to say that biological systems alone contain or define agency, just as it is a mistake to say human agentive capacities are granted solely through social regulation and cultural norms.

Levels of Reality and Causality

As the introduction suggested, the study of agency, whether human or otherwise, draws on different levels of functioning ranging from physical processes to sociopolitical structures. In our analysis of agency, three functional levels in particular—the biophysical, the psychosocial, and the sociocultural—coact and coconstruct human agency. The argument is that human agency is a psychosocial reality constructed from both "higher" sociocultural and "lower" biophysical constituents, while remaining irreducible to either.

Although it is common to distinguish different levels of functioning in any complex phenomenon (e.g., Marr's 1982 influential account of visual systems, or Dennett's 1987 well-known approach to characterizing mental life), much of contemporary science is dominated by reductionist tendencies to reveal more fundamental, or foundational, forms of reality by which to explain events and behavior (for discussion and critique of this tendency see Overton, 2013, Chapter 2, this *Handbook*, this volume). The direction such reduction takes—that is, whether explanations move "upward" to privilege sociocultural constructs or "downward" to prioritize biophysical constructs—often depends on where in the spectrum of the different social and natural sciences the investigation is first launched. Not surprisingly, social and natural scientists tend to select diverging analytic strategies. A baseball game, for instance, might be analyzed and described by a sociologist or anthropologist from a sociocultural level of cooperation and competition among groups of people. By contrast, the game might look very different to the physicist or physiologist who articulates a biophysical level of analysis involving the mechanical movements and muscle control that guide throwing, catching, and hitting a ball. Reducing the reality of the game, however, to either one of these descriptive levels captures only a partial explanation of what is happening when people play baseball or any other sport. Indeed *neither* the biophysical *nor* the sociocultural perspectives or stances offered in this case are sufficient. Socially constructed rules are just as real, and causally relevant, as muscle movements when it comes to baseball (for a similar argument regarding sociocultural practices and baseball, see Martin et al., 2010, p. 31).

In fact, games as different as baseball and chess can readily be seen as operating at multiple levels of reality at the same time. Neither the cultural conventions and social rules that stipulate how to play nor the biophysical mechanics embodied by a game's participants tell the whole story. Analysis at any one of these levels entails acknowledging the realities of the others, and ultimately, realizing the complex causal web involved in most human activities.

The same argument can be made for human agency. That is, it is possible to describe human agency solely in biophysical terms (e.g., Bargh & Chartrand, 1999) or solely in sociocultural terms (e.g., Ratner, 2000). Descriptions of this sort, however, tend to be reductionistic: they explain *away* human agency as a kind of ancillary or epiphenomenon (e.g., Wegner, 2003) with no substance and merit of its own, nor as a real causal force in human affairs. We take a different approach to agency. By acknowledging both the biophysical and the sociocultural as constitutive parts of human agency, we mean to promote a nonreductionistic account of agency that treats biophysical, psychosocial, and sociocultural levels as realities in their own right (see also Martin et al., 2010). These constitutive parts of human agency operate in a relational context and are not simply different descriptive "stances" that propose competing alternative analytic strategies. Agency, in various forms, is found at each of these levels and has real consequences for organized relational systems, particularly for humans.

The nested characteristics of these levels—the biophysical is nested in the psychosocial, which in turn is embedded in the sociocultural—has important implications for the kinds of causal relations that operate between the levels. Given the reductionist impulses just described, one might assume that because the origins of the biophysical level appear to temporally precede the other two this level must cause, or determine, what happens at the others. This assumption could be characterized as *biophysical determinism*. Conversely, because this nesting scheme also means that the sociocultural level broadly encompasses the biophysical and psychosocial, one might assume, on the other hand, that sociocultural phenomena are the root cause of these other levels. This assumption could be described as *sociocultural determinism*.

Neither of these two assumptions allows for a viable account of human agency. Nevertheless, although biophysical and sociocultural determinism run counter to the relational position for which we advocate, we must still make room for some kind of upward and downward causation between levels (see Witherington, 2011, Chapter 3, this *Handbook*, this volume). The way to prevent one or the other—upward or downward causes—from dominating an explanatory account of human agency, and thus leading to a form of determinism, is to imagine other ways of conceptualizing what *cause* means. Specifically, we must recognize that antecedent-consequent causal relations, or what some call *efficient causality*, provides only one of several ways of understanding causation (Bunge, 1959/2009; Marshall, Chapter 7, this *Handbook*, this volume; Overton, Chapter 2, this *Handbook*, this volume; Witherington, 2011, Chapter 3, this *Handbook*, this volume).

Biophysical Agency: The Disappearance and Reappearance of Self-Determination

Although our everyday intuitions about why and how people act make room for purpose and intentionality in describing causal relations, contemporary science has tended to view causality much more narrowly. Self-determination is often forced into an efficient causal account according to which one object or thing makes contact with another and propels it in some way. "Scientific orthodoxy," as Witherington (2011) has remarked, "carries with it a monistic view of all causation as temporal exchanges of energy from an antecedent to a consequent—in other words, as cause-effect relations" (p. 72). With few exceptions (e.g., Deci & Ryan, 1985; Marshall, Chapter 7, this *Handbook*, this volume; Overton, 2006, Chapter 2, this *Handbook*, this volume; Ryan & Deci, 2000), this view of causality has tended to dominate psychology. Historically, this has not always been the case. Conceptions of causality have shifted from a richer, though earlier classical account of causal explanation, to a less nuanced and far more restricted account that arose during the period of the Enlightenment.

The classical view is exemplified by Aristotle's four modes of causality: (1) *efficient causation*, which relates to our current understanding of causality through the application of external force; (2) *material causation*, the contribution of the materials in question; (3) *formal causation*, the contribution of the structure; and (4) *final causation*, the contribution of the goal or endpoint of events. Aristotle famously used the example of a sculptor to illustrate how these four modes of causality operate together. In the process of making a statue, the sculptor applies the strokes of the chisel (efficient causation), relies on the hardness of the marble (material causation), recalls the shape of the horse (formal causation), and has the goal of producing a thing of beauty (final causation). These four modes of causation were codeterminants of any process, and although efficient causation is the only to have persisted in much of neopositivistic contemporary scientific thought, the others have modern analogues as well (Overton, Chapter 2, this *Handbook*, this volume). For example, formal causation has echoes in the idea that DNA contains a *blueprint* for a phenotype—an idea we now know to be overly simplistic and misleading (see, e.g., Bateson, Chapter 6, this *Handbook*, this volume; Meaney, 2010; Misteli, 2013; Slavich & Cole, 2013). Similarly, material causation is often characterized in terms of items made of metal, plastic, or wood, whether baseball bats, canoes, or earrings. Each material has different respective properties that contribute to whether they break or bend, or are easy to lift, and so on.

Although we now know that final causes may be understood as regulative principles or principles of intelligibility providing *reasons* for the nature and functioning of the object or event under consideration (Overton, Chapter 2, this *Handbook*, this volume), what became especially controversial in philosophical and emerging scientific thought following the classical period was the role of final causation. In medieval religious thought, Aristotle's modes of causation were eventually assimilated into Christian theology and philosophy, particularly by St. Thomas Aquinas (1947). Final causation was attributed to the divine creator, the prime being, the unmoved mover, ultimate source of efficient causes, but not subject to efficient causation. As religious thought came under critical scrutiny during the Enlightenment, the question of final causation, where causes have some end or purpose, became especially unsettling and difficult to align with notions of a beneficent God. What was the final cause of the 1755 Lisbon Earthquake, which killed tens of thousands of Christian believers? This version of final cause was removed from other modes of causation and relegated to a more mysterious, transcendental sphere of existence, although aspects would persist in subsequent moral philosophy, as is discussed in the next section.

Gradually, with the emergence of the Cartesian-Split-Mechanistic worldview, efficient causation came to dominate Enlightenment thinking about causality, with other modes of causation, particularly final causes, deemed unscientific because they were not directly observable (Bunge, 1959/1979). Causality came to be restricted to the determination of an event by its antecedent: Event A causes Event B. This causality, which has been termed *Newtonian mechanical causality* (see Overton, Chapter 2, this *Handbook*, this volume; Prosch, 1964), is strongly connected to popular and philosophical conceptions of modern physical sciences. Causality is conceptualized as external to the object under consideration, with the implication that nothing is self-caused, most importantly, not human action. Agency is problematic for this mode of causation, because in acting deliberately, the agent seems to stand outside the efficient causal sequence.

The whittling away of different causal forms reached an extreme in the philosophy of David Hume (1888/1978), who posited that if causation is merely the succession of externally determined events, why is the notion of causation required at all? Hume's skeptical response was to relegate causality to an illusory mental and epistemological phenomenon, rather than a real property of the world. For our purposes, it is sufficient to note that both the doctrine of efficient causation and Hume's possibility of no causation at all exclude the possibility of agency. However, Hume's relegation of causality from an ontological category of things in the world to an epistemological category in the heads of the perceiver did have important implications for Kant's view of agency, discussed in the next section.

In the 18th and 19th centuries, along with improved microscopes, a very different interpretation of causation began to emerge within biological science. Experimental work demonstrated that embryos could be perturbed by external causes, and yet would go on to develop as typical organisms. This finding suggested that some sort of structuring feature was built into living beings (De Robertis, 2009; Gottlieb, 2002). Embryonic development showed that efficient causal events could be regulated by organisms themselves—as if reverting to a *formal* cause. Although these findings sometimes led to references to mystical vital forces, a more scientific account also emerged that saw life as *self-organizing* (Mahner & Bunge, 1997). This view was acknowledged and developed by some of the early pragmatist philosophers, such Charles Peirce, William James, and John Dewey, who attempted to infuse goals and choices into psychology (e.g., Dewey, 1896; Dewey & Tufts, 1908).

For complex reasons, this developmental story (see Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume) was overlooked in the so-called evolutionary *modern synthesis*, which joined neo-Darwinism and Mendel's genetics. Such simplistic causal thinking still can be located in some scientific quarters, particularly in anachronistic claims that genes *cause* behavior (see e.g., Dawkins, 1976; Tooby & Cosmides, 1990, 1992). Although modern biology has largely escaped misleading forms of causal thinking—creating, instead, room for complex causality and organismic self-regulation (Robert, 2004)—the doctrine of efficient cause is also still evident in many philosophies of science, persisting despite theoretical problems and evidence to the contrary.

Importantly, the biological view of self-organization provides a place for agency by highlighting how organisms are self-determining (Skewes & Hooker, 2009). External events form part of the causal system, but the organism as a self-creating, self-organizing system reopens the door for formal and final explanations. Self-organization itself provides a low-level starting point for the problem of agency (Bickhard, 2009; Witherington, 2014). Organisms are spontaneously active systems. To illustrate, Bickhard (2009) describes a bacterium on a sugar gradient as the basis for agency, as knowledge-in-action. If the bacterium fails to move up a sugar gradient, it eventually dies. But it may also incorrectly detect a sugar gradient in a toxic material, leading to death. This creates a place for evaluation, even if merely through monitoring one's own body. Intelligence-in-action emerges in the ability to monitor the world, making assessments, and fixing errors (Clark, 2013). Writ large, agency at this biophysical level also becomes a crucial dimension of evolutionary processes (Gissis & Jablonka, 2011; Gould, 2002; Jablonka & Lamb, 2005; Keller, 2010).

Psychosocial Agency: Self-Legislation and Self-Interpretation

Although modern biology has resuscitated the notion of self-determination, for the better part of the Enlightenment determination was seemingly restricted to external events. A tension was born during this period, and to some extent, has plagued philosophy ever since natural science emerged as a dominant way of knowing: *How can free will exist in a supposedly determined world* (e.g., Dennett, 2003)? The narrowing of causality to efficient causation, and then to a mere psychological category in the work of Hume, became the spark for Immanuel Kant's struggle with agency. Kant is the best known of a number of philosophers who grappled with the consequences of the Enlightenment for human freedom (di Giovanni, 2005). Kant (1785/1959) took restricted causation as his starting point and asked, as Schneewind (1992) put it, "Can we both take ourselves to be free and believe theoretically in a deterministic universe?" (p. 329).

Kant followed Hume to some extent by agreeing that causation, at least in the world we perceive, is a category of thought. His solution—of which a full account is too complex to detail in this chapter—was to place choice and freedom outside the world of experience. The world that we experience, the *phenomenal* world, as Hume noted, was one of mere coincidence and succession of events. But the *noumenal* world, the world as it truly is, or the *thing-in-itself*, as Kant put it, was quite different. With morality and free will outside of experience, these were thereby outside the deterministic laws of the physical world. However, humans had some contact with this noumenal world—otherwise, how else could there be a sense of freedom?

For better or for worse, Kant established his conception of agency by cleaving reality in two, creating two metaphysics: one of empirical science and one of morality. Although morality can have *heteronomous* aspects (i.e., laws originating from outside the individual), true morality relies on autonomous judgments (Reath, 2006; Schneewind, 1992; Turiel, Chapter 13, this *Handbook*, this volume). This creates several possibilities, but also several problems. Kant's views divorced the problem of agency from real life and arguably established unrealistic demands for achieving autonomy (Métayer, 2001; Slote, 1992). According to Kant, any and all influences on human decisions, such as feelings, family considerations, friendships, and so on, are considered heteronomous influences and external to agency. Agency, for Kant at least, is very limited to performing duties that meet some kind of rule (Reath, 2006). Critics have questioned where these rules originate and how are they are applied. Nevertheless, Kant's work returned agency to the foreground of philosophical discussion. Kant restored the notion of an agent that had to interpret and evaluate situations to decide what must be done.

The Kantian agent has duties in the world, the ability to choose, and to determine a course of actions. Still further, the Kantian moral project added another critical psychological dimension to agency: *reflexivity*. When C. Taylor (1985) argued that "[h]uman beings are self-interpreting animals" (p. 45), he was attempting, like Kant, to capture a psychological view of persons as reflexive beings. Still, Taylor's notion of agency, following Heidegger (1962), was also social-relational insofar as individuals were part of a preexisting social world (Martin & Sugarman, 1999, p. 17). Social circumstances may constrain agency, but because individuals have developed interpretive abilities, these circumstances also provide meaning-making opportunities, even when experiences are beyond individuals' control. This does not necessarily mean that agency is entirely epistemological. Certainly, reflexive forms of interpretation provide humans with the capacity to regulate and reevaluate their choices (C. Taylor, 1985; see also Bandura, 2006). But insofar as self-reflection is an action of persons embedded in social contexts and in relationships with others, it resists Cartesian (and Kantian) implications of being a disembodied form of consciousness (Martin & Sugarman, 1999). Although such social-contextual considerations were not very salient in Kant's thinking, they became particularly important in the work of his successor, Hegel (1770–1831).

Sociocultural Agency: Hegel and Sociological Thought

Hegel (1807/1977; see also Guyer, 1993) took the Kantian view of self-determination and put it back in the world. The Hegelian dialectic seeks to reconcile seeming splits, including those that Kant introduced between the realm of physics and the realm of freedom (Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume; Overton, 2006, Chapter 2, this *Handbook*, this volume; Pippin, 1991). Hegel delineated a worldview in which activity was found at every level of existence. In Hegel's worldview, there was no denying agency; there was transformative activity originating in all the parts of a whole with no external forces per se. Different levels of activities resolved themselves into larger totalities, with distinctive dynamic forms transcending the previous levels, and "reconcil[ing] themselves into a 'higher' synthetic unity" (Bernstein, 1991, p. 294).

For historical reasons, Hegel's system largely focused on nation states as a critical level of activity. As a result, Hegel's influence loomed especially large on subsequent sociocultural accounts of agency. In a sense, the agency of the person, though readily acknowledged in Hegel's worldview, becomes lost in descriptions of higher levels of societal organization and cultural structures. Culture and the march of history, although emerging from the activities of persons, has a life of its own in Hegelian thinking, and when taken to an extreme, the active agent universe seems to override the individual agent.

This interpretation of Hegel's work has prompted questions regarding the extent to which individuals are free to make their own choices when born into societies with preexisting structures and institutions that constrain human agency. The field of sociology attempts to explain how social structures and social norms are transmitted across generations and change over time. The growing consensus among sociologists, emerging out of Archer's and Gidden's seminal work in the 1980s, is that sociological theories confront the "fundamental problem of linking human agency and social structure" (Archer, 1982, p. 455; Elder-Vass, 2010; Giddens, 1984; Ritzer, 1996), and understanding how human beings are both "free and enchained, capable of shaping our own future and yet confronted by towering, seemingly impersonal, constraints" (Archer, 1995, p. 65).

At times in its history, sociology has risked dissolving the agent into a reductionism of what Archer called "downwards conflation" (Archer, 2000, p. 19). People are conceived as determined by their society and culture. That is, the person is conceptualized as indeterminate matter, absorbing the sociocultural conditions from the outside in. A particular challenge for agency theorists is to explain whether personal narratives or life stories, which play a prominent role in the development of human agency, might, in fact, be the outcome of a strict cultural determinism. For example, Western cultures often consider the *self* to be a constant entity, whereas some indigenous cultures treat the self as an unfolding story influenced by events throughout life (Chandler, Lalonde, & Sokol, 2000). Each of these cultural constructions of selfhood has different implications for the agentic regulation of individuals and social relationships that sustain agency (Trommsdorff, 2012).

Despite the evident tendency within sociology to sometimes dissolve the agent into culture, human agency is also an unavoidable part of sociological analysis because social structures, such as rules and laws, although establishing powerful constraints on human action, still need someone to interpret them. They cannot, as Durkheim (1961) acknowledged, "be applied exactly and mechanically in identical ways in each particular circumstance. It is up to the person to see how it applies in a given situation" (p. 23). Although Durkheim is usually thought of as the paragon advocate of social structural determinism, he too clearly recognized the tensions between social structures and personal agency (Sawyer, 2002).

A Constructivist Synthesis: Agency and Piaget

Sociology, like many quadrants of philosophy and the natural sciences, struggles with questions of agency. But here again, with the point raised by Durkheim (1961), the issue of self-interpretation and self-awareness is identified as an important, and perhaps uniquely human, feature of agency. *Reflexive* views of agency, however, also raise important concerns. With the attribution of reflexive abilities to individuals, there is a risk of going too far and creating a psychologically unrealistic view of human agentiveness and self-awareness. In addition, the psychosocial dimensions supporting the emergence of agency implicate systemic, or relational, properties that may become unbalanced, particularly in cases where social conditions privilege or empower some individuals while disempowering and disenfranchising others. Recognition of such unequal social realities adds another layer to the moral considerations related to human agency and development—or what Lerner (2004) has called the constitutive conditions of *thriving*—and suggests there are close ties between social responsibility, or social justice, and agency (Lerner & Overton, 2008). Finally, to the extent that agency is dependent on biological, psychological, social, and cultural forms of living—that is, agency is *embodied* (Overton, 2008, Chapter 2, this *Handbook*, this volume)—it depends on conditions that are themselves fragile. To sustain and promote human agency, prudent use of the forms of life that enable reflexivity and self-awareness in the first place is required. These concerns and connections are described later in the discussion of civic agency and citizenship.

One way to address these issues begins with the recognition that the human organism is already spontaneously active. Both Piaget and Vygotsky, insofar as each were influenced by the work of Baldwin (Valsiner & van der Veer, 2000; Vidal, 1994), represent key proponents of this view of the active organism. Our focus in this section, however, will be exclusively on features of Piaget's theory. Ironically, although Piaget, as one of the founders of modern development science, understood self-determination to be a central characteristic of developing children, subsequent interpretations of his theory have been forced into a causal deterministic framework, in which stages (formal causes) are assumed to be efficient causes of action and behavior (see review in Carpendale, 2000; also, Chapman, 1988). Some aspects of Kohlberg's interpretation of Piaget (for further discussion, see Sokol & Chandler, 2004) provide an example of this causal deterministic framework by casting structures in the individual, rather than the individual's own reasoning, as the cause of moral thought and behavior (Rottschaefer, 1991).

Piaget did not use the term *agency*; instead he favored terms such as *intelligence*, *autoregulation*, and *will*. However, his theory is clear that structures (i.e., systems), whether sociological (Piaget, 1973, 1977) or biological (Piaget, 1974/1976a, 1976b), are insufficient to account for development without the organism's own autonomous regulative activity. The parts of an organism and the food it needs to live can each be present or available, but unless the organism consumes the food, the organismic system will fail. Such activity might seem a long way from what is usually understood as psychology, but, as is argued later, self-determined action is the necessary basis of a psychology that can accommodate agency. This is equally true for society. In his text, *Sociological Studies*, Piaget acknowledged that the "object of sociological knowledge is of vital interest to epistemology, since human knowledge is essentially collective" (Piaget, 1995, p. 30). In fact, "child psychology is a branch of sociology, concerned with the study of the socialization of the individual at the same time as a branch of psychology itself" (p. 36). But for Piaget, merely being present in this collective milieu is insufficient for children to gain knowledge; rather, they must construct knowledge from their actions within the collective. Or, as Piaget (1967) claimed: "I think that human knowledge is essentially active. To know is to assimilate reality into systems of transformations. To know is to transform reality . . . knowing an object does not mean copying it—it means acting upon it" (p. 15).

Initially, the child's knowing is best characterized as a psychology of action, not one of reflection or complex thought. Recognizing the endogenous actions of the organism as a basic form of agency radically restructures the epistemological problems that humans face. Rather than symbolically representing the world, and then acting based on those representations, children act and later in the developmental sequence come to reflect on action (i.e., representation becomes a later developmental achievement). Developmentally, sensorimotor and perceptual action leads to reflection (Müller, Sokol, & Overton, 1998; Piaget & Inhelder, 1982). Reflection increasingly plays a role in reorganizing action, and once reflection (i.e., the symbolic function) emerges, reflective action and sensorimotor action function together to co-constitute each other in a system of relations (Piaget, 1974), which create further opportunities for agentive development. To be clear, agency in its early sensorimotor action-based form is simply the ability to act independently, even if only partially, of external stimuli, or to "alter at will," as Russell (1996) remarked, "one's perceptual inputs—motorically or attentionally" (p. 3). According to Campbell and Bickhard (1986), who characterized Piaget's account as *knowing levels*, the first level is nonreflective, nonlinguistic activity, or *prereflective agency* (Martin & Sugarman, 1999, p. 18).

Piaget understood that the growth of an individual's will—that is, personal agency—was intimately connected to different levels of reflexivity (Sokol et al., 2013). Piaget argued that agency is a psychological process that closely resembles, and even draws on, the process of perspective taking. The will, according to Piaget (1954/1981), involves coordinating and integrating one's desires and personal values, just as perspective taking involves coordinating and integrating multiple points of view. In a short essay titled, *What is involved in a genetic psychology*, C. Taylor (1985) notes ways in which Piaget's views eludes the usual vices of objectivism. Suggestive of Campbell and Bickhard's (1986) knowing levels, Taylor argues that the person can, "contrast a higher, more clairvoyant, more serene motivation, with a base, more self-enclosed and troubled one, which we can see ourselves as potentially growing beyond" (C. Taylor, 1985, p. 67). Indeed, Campbell and Bickhard (1986) argue that the Piagetian approach has "convergences with hermeneutics" (p. 127) like that seen in Taylor's work, particularly regarding the importance of interpretation. In a sense, both the baby and the mature adult operate in one and the same world; and yet just as clearly they do not. The adult can interpret, understand, and organize the world and their actions in very different and symbolically meaningful ways. The sensation of being thrown around can be terrifying, if in a car accident, or fun, if on a rollercoaster (Campos, Dahl, & He, 2010).

Before such interpretive symbolic meaning-making can occur, however, agency is reflected in the sensorimotor ability "*to take up different mental orientations towards . . . objects*" (Russell, 1996, p. 74). This ability involves reflection at a sensorimotor level on a course of action (Müller et al., 1998). This presymbolic and "prelinguistic ground and its constraints are never lost, and can never be fully transcended . . . [i]n this respect the interactive model diverges sharply from those themes in hermeneutics that . . . reduc[e] the person to a local nexus of social relationships" (Campbell & Bickhard, 1986, p. 127). At the same time, "we must neither under- nor over-privilege human agency in our analytical approach" (Archer, 2000, p. 21). Humans are already active—agency is always present in the actions of the child even if operating in a very rudimentary form.

Summary: Why Agency?

Issues of agency run throughout philosophical theory, sometimes acknowledged, sometimes denied. At times, the very concept of agency has been rejected as a form of antiphysicalism or individualism, only to have agentive notions arise again as a necessary condition for explaining and understanding the lived human experience. The possibility of agency requires a broadened view of causation, wherein self-determination is understood as an authentic form of determination. At the same time, agency is not some omnipotent mystical power allowing people to do whatever they choose. Reflection on actions, reinterpretation of situations, and regrets for the past all aid in planning anew for the future, but even then, persons act in a world they do not wholly determine and where their actions bring unexpected and sometimes unintended consequences.

In the next section, we attempt to unpack the psychological agent. This effort runs up against the theoretical struggles described earlier, where psychology, under the historical constraints of a limited conception of causality in the natural sciences, has often attributed human action to neurons or reinforcement schedules, but rarely to the whole person operating in a physical and sociocultural world. Psychology also faces the problem of explaining how a self-determined actor can then go on to reflect on its own actions. Developmental science provides a particularly powerful way of understanding these issues and can outline a way forward.

PSYCHOLOGY AND DEVELOPMENT

The review of the conceptual background of agency demonstrates that issues surrounding agency have long puzzled philosophers. Because agency has often been understood in the framework of a philosophical debate with poles set at all or none, the main conceptual issue has typically been whether humans are wholly free (i.e., have agency) or entirely determined (i.e., do not have agency) in their conduct. With the advent of Enlightenment conceptions of mechanical causation and control, the response to this debate, especially in the natural sciences, tended to minimize human agency as either an illusion or epiphenomenon. Human lives, it seemed, were determined like other physical objects in the universe, even if not in foreseeable ways. By contrast, those trying to preserve human agency were often driven to take untenable ontological positions regarding the nature of the world or the extent of human psychological powers. That is, to be free, humans either participated in some kind of transcendental realm (e.g., were split between a noumenal and phenomenal world) or they possessed rich powers of self-reflection and self-transparency that ran counter to experience, and increasingly, to scientific evidence.

Agency, as a reality, did not fare well against dominant currents of a split Cartesian-Split-Mechanistic worldview (Overton, 2013, Chapter 2, this *Handbook*, this volume). However, especially in the developmental sciences, this Cartesian paradigm has progressively fallen into disrepute and been replaced by a relational perspective, asserting the primacy of activity over passivity, organization over uniformity, and change over stasis (Overton, 2006, Chapter 2, this *Handbook*, this volume). This movement has opened new possibilities for exploring agency, including the exploration of how different forms of agency emerge over time, and how agency exists in social relationships rather than being a process encapsulated in the individual. Following from our relational developmental systems perspective the review of the psychological literature that we undertake in the following section begins by working to undo the long-standing freedom-determinism antinomy inherited from the Cartesian-Split-Mechanistic perspective, and reframing human agency in terms of the origins and sources of psychological functioning that support self-determination. To do this, we begin with a taxonomical system for organizing the various psychological approaches to agency that makes use of a distinction between *internalist*, or individualist, and *externalist* approaches to psychological life (Sugarman & Sokol, 2012). In the end, the relational developmental systems stance we adopt will entail features of both internalism and externalism as we shift our focus to the psychosocial developmental processes that blur the endogenous and exogenous characteristics of human agency.

Internalist Approaches to Agency: Idealism and Materialism as Cartesian Splits

Within the split Cartesian-Split-Mechanistic framework, agency is often characterized as a feature contained solely within or inherent to an individual—that is, as an endogenous feature of persons. This *individualistic*, or *internalist*, characterization of human agency has manifested in two broadly different ways. The first, or *idealist* form, of internalism maintains a dualistic or split view of individual minds as being distinct from the external physical world. According to this view, human agents posses a capacity to reflect upon their immediate circumstances and, through their choices and actions, alter themselves and their life conditions in ways that seems to drive a wedge between human existence and the causal forces that affect the rest of the universe. The second, or *materialist* form, of internalism accords with contemporary attempts to naturalize, and often reduce, individual mental life to more basic, physically determined, properties. On this view, the notion that persons somehow hold a unique ability to control their actions, or assert their personal wills, is minimized or even denied. Both idealist and materialist forms of internalism reflect Cartesian assumptions regarding the nature of mind and matter.

Idealism

At the heart of internal-idealism is the view that human agents, by virtue of psychological structures and processes (e.g., executive processes, metacognition, self-regulation, self-control, self-concept, self-efficacy), are the ultimate causal source of their choices and actions. In many ways, internal-idealism credits human persons with the *prime mover* capacity attributed to divine authority in classical and medieval theological conceptions (R. Taylor, 1958). Because, on this view, a wide gap is seen to separate human agents from other causes in the world, *agent causation* and *event causation* are understood as ontologically distinct (Coole, 2005). Moreover, because the sources of agency are internalized within individuals, this view of agent causation suggests a "well metaphor" (Côté & Levine, 2002, p. 55) according to which individuals draw on internal psychological capacities to align their choices and actions with their inner potential, transcendent being, or other homeostatic processes (e.g., Baumeister, Schmeichel, & Vohs, 2007; Blair & Ursache, 2011; Grouzet, 2013; Hofmann, Schmeichel, & Baddeley, 2012). Internalist appeals to agent causation, at least in this idealist version, often are made on humanistic and phenomenological grounds (e.g., Grouzet, 2013) in view of an everyday understanding of ourselves as persons who plot their own course in life and experience the exercise of their capacities for freedom of choice and action: the sense of personal agency. It is not simply that human agents produce effects by their actions, but also that they experience a sense of personal agency through the self-referential awareness of intentions, actions, and outcomes. In turn, as Bandura (1989, 2006) has studied, self-referential awareness of causal efficacy is understood to act reciprocally as an instrument of agentive development.

Materialism

Although there are some appealing features of the idealist view, its ontological assumptions generally run counter to the materialist trends in contemporary science. This establishes the context for the reactive counterresponse found in materialist versions of internalism. Internal-materialism rejects agency as being unique in the physical world. Internal-materialism, like its idealist counterpart, retains the Cartesian split of the separateness of individual minds, but maintains that psychological agency has little explanatory utility once it has been distilled from the structural and functional properties of causal interactions at the physical level. At root here is the ontological doctrine of *physicalism*: The physical realm is causally complete. All things, including mental phenomena, are constituted by basic physical entities, and the physical and biological sciences provide sufficient conceptual means to represent all extant phenomena, psychological or otherwise (e.g., Churchland, 1986; Kim, 1996). For physicalists, the experience of psychological agency and, for that matter, all mental events can be explained totally by reduction to biophysical terms. Human choice and action are considered the result of neurophysiological mechanisms (i.e., efficient and/or material causes) that are internal to individuals, but operate outside and prior to their awareness and control. Consequently, the self-referential features of agency to which humanists and phenomenologists draw attention are merely epiphenomenal events that simulate what is occurring neurophysiologically. They are little more than a "user illusion" (Nørretranders, 1999) and ultimately play no role in the control of action.

One vein of psychological research takes this materialist position through positing unconscious automatic processes of human thought and action, which operate outside awareness and conscious control (Kihlstrom, 2008). In both cognitive and psychoanalytic theories of automaticity, although individuals may have conscious awareness of their thoughts, they are nevertheless unaware of the processes by which these are evoked. Hasher and Zacks (1979) argue that automatic processes function independently of conscious intentions and, being biologically determined in origin, "should be widely shared and minimally influenced by differences in age, culture, education, early experience, and intelligence" (p. 360). Bargh and Ferguson (2000) and Wegner (2002) also argue that automaticity pervades thought, action, and experience, and that any so-called intentional behavior can be reduced to automatically operating processes unavailable to awareness. Wegner argues further that "we are not intrinsically informed of our own authorship and instead must build it up virtually out of perceptions of the thought and the actions we witness in consciousness" (p. 218). In other words, our personal sense of agency is a fabrication.

Various studies have been interpreted as support for unconscious or preconscious sources of agency. Libet's (1985, 2004) and Walter's (1964) investigations of the timing of conscious volition are prime examples. Each author claims to have discovered a readiness potential prior to subjects' awareness of willing a behavior. Sparked by such findings, other researchers have attempted to show how our sense of agency can be derived from neuronal events that initiate motor responses. Wegner and Wheatley (1999), for instance, have demonstrated that research participants primed with thoughts relevant to an action, in turn, experience a sensation of having initiated that action even when they themselves did not perform it. Also, in a series of studies exploring self-regulatory abilities, Baumeister and colleagues (Baumeister, 2003; Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister et al., 2007; Muraven & Baumeister, 2000; Muraven, Tice, & Baumeister, 1998) have shown that cognitive resources for self-regulation may be depleted from one domain of activity to the next and negatively affect individuals' self-control. The implication of these findings, Bargh (2008) remarks, is just how little of human conduct appears to involve conscious choice and intention.

Externalist Approaches to Agency: Biophysical and Sociocultural Reductionism

Externalism stands as the counterpoint to both forms of internalism, although it too admits variations and similar kinds of splits. At their core, externalist views make clear that purposeful activity is differentiated by agents' particular orientations toward and relationships with worldly objects, locations, and events (Malpas, 1999). That is, the constitution of agency cannot be considered in isolation from the contexts to which it is related and within which it takes place. Attention to context alone, however, is not what leads to split, reductionistic conceptions of agency. Rather, stronger claims about the biophysical or sociocultural *sources* of agency within externalist approaches are responsible for this.

Biophysical Reductionism

Naturalistic, or biophysical, externalism holds that the outward orientations of agents to particular objects, locations, and events are a consequence of the way in which those orientations enable evolutionary adaptations (Burwood, Gilbert, & Lennon, 1999). Agency consists not only in the neurophysiological activity of human brains and bodies, but also is the result of the evolutionary history of *Homo sapiens*, during which agentive capacities have been selected as a means to meet the demands and constraints of the biophysical world. The basis of naturalistic externalism is belief in a universal superordinate evolutionary process that governs the living world and drives the actions and development of all animate beings, including humans (see, e.g., Belsky, 2012; Ellis & Bjorklund, 2012; Ellis, Schlomer, Tilley, & Butler, 2012, as examples). As such, agency is firmly embedded in the natural order. Still, as Bandura (2006) points out, "the creative power of human agency generally is downgraded in evolutionary accounts of human behavior, especially in the more biologically deterministic views propounded in psychological evolutionism" (p. 173). In other words, agency on this view begins to resemble other materialists' claims that any sense of personal agency an individual may have is merely an illusion or form of self-deception. Prominent advocates for naturalistic externalism have included E. O. Wilson (1978), Pinker (1994, 2011), Tooby and Cosmides (1990, 1992), and Dawkins (1976), whose famed notion of the "selfish gene" characterizes humans as "survival machines" whose actions are driven by evolutionary processes that function to ensure successful genetic development.

Sociocultural Reductionism

Sociocultural externalism is similar to its naturalistic counterpart but holds that agency is constituted as an artifact of sociocultural forms and practices, instead of being the result of evolution. From this perspective, sociocultural structures and practices are cast as the causal agents of psychological capacities. Individuals are the locations of intersecting forces by which they are constituted and enabled as actors. Agency and other psychological characteristics are produced and sustained by the structures and functions of social, cultural, political, economic, educational, and other institutional arrangements. These ideologically prescribed structures and practices in which we are embedded from birth regulate, organize, and channel individual activity to conform with varying culturally specific timetables for the appropriation and enactment of social norms, roles, and statuses (e.g., Hogan & Astone, 1986; Neugarten, 1979). As Rose (1998) describes:

> Agency is an effect, a distributed outcome of particular technologies of subjectification that invoke human beings as subjects of a certain type of freedom and supply the norms and techniques by which that freedom is to be recognized, assembled and played out in specific domains. (p. 187)

This understanding of agency resonates, as well, in Bourdieu's (1990) notion of the *habitus*, which emphasizes how human conduct is "coherent without springing from an intention of coherence and a deliberate decision; adjusted to the future without being the product of a project or a plan" (p. 51).

The perspective of sociocultural externalism has a rich history in the social sciences. Although its most contemporary expressions are reflected in the *structure-agency* debates in sociology (e.g., Archer, 2000, 2003; Bourdieu, 1990; Elder-Vass, 2007, 2010; Emirbayer & Mische, 1998; Giddens, 1984, 1991), the roots of sociocultural externalism can be found in Durkheim's (1949/1893) seminal work. In seeking to differentiate sociology as a distinct discipline differing from both biology and psychology, Durkheim asserted the priority of *social facts*. Social facts, Durkheim proposed, consist of material and nonmaterial social structures that regiment thought and action in ways that strongly constrain agency and render psychological explanations superfluous. However, many contemporary sociologists now agree that agency cannot easily be dissolved by structure. Emirbayer and Mische (1998), for instance, claim:

> The concept of agency has become a source of increasing strain and confusion in social thought. . . . At the center of the debate, the term agency itself has maintained an elusive, albeit resonant vagueness; it has all too seldom inspired systematic analysis, despite the long list of terms with which it has been associated: selfhood, motivation, will, purposiveness intentionality, choice, initiative, freedom, and creativity. Moreover, in the struggle to demonstrate the interpenetration of agency and structure, many theorists have failed to distinguish agency as an analytical category in its own right—with distinctive theoretical dimensions and temporally variable social manifestations. The result has been a flat and impoverished conception that, when it escapes the abstract voluntarism of rational choice theory, tends to remain so tightly bound to structure that one loses sight of the different ways in which agency actually shapes social action. (pp. 962–963)

Emirbayer and Mische (1998) argue that the sources of agency cannot reside solely in social structure, but also inevitably are to be located in the psychological capacities of individuals. Agency, as they describe, is incarnated as an internal conversation with dialogical structure that takes its shape from, and within, transpersonal interactions and sociality. However, they also are explicit that, "while transpersonal contexts do both constrain and enable the dialogical process, such contexts cannot themselves serve as the *point of origin* of agentic possibilities, which must reside one level down (so to speak), at the level of self-dynamics" (p. 974; emphasis added).

The Relational Developmental Alternative

Taking our lead from Emirbayer and Mische's (1998) critical remarks about impoverished views of agency, the foregoing overview of internalist and externalist perspectives on the origin and development of agency serves to clarify the challenges inherent to split Cartesian-Split-Mechanistic accounts of the relations between persons and contexts. That is, although various perspectives on agency may pay lip service to the idea that both person and context are necessary pieces in the puzzle of agency, the fact remains in these models that either (a) persons tend to fade into context (i.e., externalism), or (b) context is omitted in favor of endogenous characteristics of individuals (i.e., internalism). The fundamental reason for this is that each account, whether externalist or internalist, ultimately views person and context as two pure forms—bodily sphere and social sphere—that *causally* (efficient, material) interact in an additive fashion to produce what are termed agentive (intentional, purposeful) acts. What is needed is a relational model in which person and context are not merely causally related, but are *co-constitutive*. This model begins from a neutral monism in which idealism and materialism are themselves relational concepts (Overton, 2013, personal communication), and proceeds to understand agency as the relational epigenetic coconstruction of internal-external parts of the whole person.

One implication of a relational developmental systems account of agency is that psychosocial processes and structures extend well beyond the usual boundary conditions of an individual's skin. Accordingly, agency necessarily includes context as constitutive, and not as merely accidental or arbitrary factors influencing the direction of individuals' actions. The sources of agency are shared by individuals and their contexts, and cannot be reduced to one or the other. Or, as Piaget (1932/1965) remarked: "There are no more such things as societies qua beings than there are isolated individuals. There are only relations . . . and the combinations formed by them, always incomplete, cannot be taken as permanent substances" (p. 360). In this regard, the theoretical work of Vygotsky (1978, 1986) also counts as an influential example of relationalism, particularly in the characterization of the *General Genetic Law of Cultural Development*.

> Any function in the child's cultural development appears twice, or on two planes . . . on the social plane, and then on the psychological plane. First it appears between people as an interpsychological category, and then within the child as an intrapsychological category. . . . Social relations, or relations among people, genetically underlie all higher functions and their relationships. (Vygotsky, 1978, p. 57)

Although Vygotsky's emphasis on interpersonal sociocultural processes is sometimes treated as a form of sociocultural determinism, such a view misses how his theoretical contributions also stress the dynamic self-organizing activities of persons (Cole & Wertsch, 1996; Tudge & Winterhoff, 1993; Valsiner, 1993; Valsiner & van der Veer, 2000). The *General Genetic Law of Cultural Development* captures how psychological phenomena, such as agency, are constructed and shared across individuals and social contexts. The fluidity between *inter*- and *intra*-psychological contexts, and the coconstructive processes that allow this movement back and forth, are not only central for Vygotsky and a coconstructive, relational interpretation of his work (see Overton, 2006, especially p. 63), this interpretation of Vygotsky also advances our review of the milestones found in the development of human agency.

Developmental Dimensions of Psychosocial Agency

A growing number of psychologists have begun to address critical features of the psycho-sociocultural constituents of human agency and its development. Programmatic investigations of agency in the developmental literature are still rare, although Sugarman and Sokol (2012) have identified several prominent threads of theory-driven research warranting further attention. These include the works of Bandura (2001, 2006), Martin and colleagues (Martin, 2005, 2006, 2007; Martin & Sokol, 2011; Martin, Sokol, & Elfers, 2008), Russell (1996), and Stetsenko (2002, 2005, 2008; Vianna & Stetsenko, 2006). Each of these investigators targets different features of psychosocial functioning, as well as different points of the developmental course. Recounting these efforts is not the primary goal of this chapter. Instead, we want to identify other strands of research that, although perhaps less systematically organized, nevertheless stand to contribute to key facets of agentive development especially in children and young people. Our main focus will be on psychosocial agency: *the deliberate, intentional choices of a self-aware system to determine a course of actions and construct meaning from them*. But we also describe some of the early precursors—and key developmental building blocks—to reflective forms of psychosocial agency that are evident in the basic sensorimotor and perceptual functioning of infants, as well as in early social interactions. Nascent knowledge of others' intentionality and an early sense of self become evident over the first year of life through infants' social interactions with others (Nelson & Fivush, 2004). Given that babies are born into a community of other agents, human agency is psychologically and socially co-constituted from birth.

Although there is a notable tendency to think of agency as a *capacity* that individuals *possess* to one degree or another, we have argued that viewing agency as a *process*, particularly a *relational* process, stands to be a more promising avenue for future research. In this regard, we have suggested that agency is a distributed phenomenon, not a singular psychological faculty or module. Nor, do we argue that human agency is necessarily consolidated in a single individual. That is, as Frie (2008) has explained, "agency is not a fixed entity that conforms to traditional definitions of free will. It is an active process ... [which] can never be divorced from the contexts in which it exists, yet neither can it be wholly reduced to these contexts" (p. vii). As a multilayered psychosocial process, human agency is never entirely here nor there, all because it is distributed, not only across ontogenetic time, but also across people and their relationships to each other (see Sugarman's 2008 discussion of persons as relational agents). Or again, as Vygotsky has characterized when describing other higher mental functions, human agency manifests *interpsychologically*. Applying this concept to agency prompts us to search for agency in children's earliest interactions with caregivers and in the family, and with increasing age, in a broader circle of relationships with others, such as teachers and peers (see Bronfenbrenner & Morris, 2006; Grolnick & Raftery-Helmer, 2013; Kuczynski & Parkin, 2007).

Importantly, in addition to Vygotsky's relational characterization of psychological functioning, he has also used the notion of *interfunctionality* to describe particular mental processes. He wrote, using memory as an example:

> [W]ith a change in developmental level there occurs a change not so much in the structure of a single function (which, for example, we may call memory) as in the character of those functions with the aid of which remembering takes place; what changes is the interfunctional relations that connect memory with other functions. (Vygotsky, 1978, p. 49)

Consider, for a moment, the implications of replacing the references to *memory* and *remembering* with *agency*. This would suggest that what changes in development are the functions of agency and the ways in which agency is connected with other functions. Luria (1966/1980), who elaborated on Vygotsky's view of interfunctionality, described functional systems as consisting of "a complex dynamic 'constellation' of connections, situated at different levels ... that, in the performance of the adaptive task, may be changed with the task itself remaining unchanged" (p. 22). Agency is a similar sort of constellation, which may manifest in multiple ways through various functions.

A more contemporary interfunctional approach, which also identifies important parts of the psychosocial constellation constituting agency, has been suggested by Nelson and Fivush (2004). They describe the various functions associated with autobiographical memory development through 5 years of age, including basic endogenous or intraindividual aspects, such as early memory capacities in the first year of life and the later emergence of language and representational abilities, along with more exogenous or interindividual aspects that are social and communicative in nature. Our exploration of agency draws on similar functions, from perceptual and sensorimotor, to symbolic and linguistic, to sociomoral. Altogether these processes form the psychosocial backbone around which agency takes shape at various levels, and when missing, may grossly diminish or change the developmental course of agency, leading at times to atypical outcomes (Davidson & Shahar, 2007; Gallagher, 2004). In addition, an important assumption for this account is the degree to which development saturates the multiple layers and aspects of human agency. Time marches on not only for agency, but also for each of the other processes that contribute to agency's development. We therefore assume that the contributions of psychological and social processes that support agency development are in reality not separable, but are co-constitutive of each other and coact together over time.

Sensorimotor and Perceptual Functions

Healthy infants begin life with an impressive array of psychological functions that have their origins even before birth, as part of prenatal biophysical development (see Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume). These functions contribute to the earliest manifestations of prereflective agency. Here we include infants' earliest sensorimotor and perceptual abilities to visually orient, detect, and sustain attention to the dynamic events that their environments afford. Such affordances, as E. J. Gibson (1982) has noted, "are the essence of what we perceive" and already action-oriented as the "things we can eat, or write with, or sit down on, or talk to" (p. 60). That is, affordances are "opportunities for action in the environment of an organism" (Sanders, 1999, p. 129). Perceptual functioning, given the agentive assumptions embedded in the notion of affordances (J. J. Gibson, 1986), has its roots in what can be done or accomplished with a perceptual object, that is, "its functional possibilities and uses" (E. J. Gibson, 1988, p. 24). Accordingly, although we acknowledge the significance of early sensorimotor and perceptual achievements of infants to detect differences between animate and inanimate objects, we do not presuppose any biologically determined conception of self or others as agents. Nor, do we make any claims that agency emerges in some modular sense, as have some other researchers (e.g., Spelke & Kinzler, 2007) who argue for an innate core knowledge system that governs representations of agents and their actions, with innate here meaning "biologically determined" rather than simply "present at birth" (see Bateson, Chapter 6, this *Handbook*, this volume). Rather, we take the view that psychosocial forms of agency first arise from more basic biophysical processes associated with infants' earliest sensorimotor acts, including perceptual acts, such as visual attention to dynamic events in their world, and from this basis, other agentic forms of understanding and behavior are constructed over time. For example, the ability to visually detect action in the environment and to "parse" visual streams occurring in the world may support agency at the beginning of life along with underlying basic sensorimotor capacities to anticipate, and eventually to cognitively represent through symbolization, recurring sequences of external objects. Statistical learning—that is, the ability to anticipate or detect regularities and probabilities with perceptual events—is another psychological function likely to be necessary, though certainly not sufficient, for early forms of agency. Strong evidence for statistical learning has been reported as early as 8 months (Hay & Saffran, 2012; Lany & Saffran, 2013; Saffran, Aslin, & Newport, 1996). Thiessen (2011) has argued still further that statistical learning could constrain development more generally, including "infants' learning of visual patterns" (p. 462) and early sensitivity to goal-directed movement in their visual field.

Woodward's work, in particular, has been central to researchers' understanding of infants' developing conceptions of action, animacy, and intentionality. Woodward and colleagues' research (e.g., Hamlin, Hallinan, & Woodward, 2008; Sommerville, Woodward, & Needham, 2005; Woodward, 1998, 2009), in conjunction with studies from other labs (e.g., Biro & Leslie, 2007; Király, Jovanovic, Prinz, Aschersleben, & Gergely, 2003), indicates that midway during the first year of life infants begin to demonstrate sensitivity to goal-structured actions presented to them in laboratory experiments. For example, Woodward demonstrated that 6-month-olds selectively encoded actions in terms of agent-goal relations (Daum & Gredebäck, 2011; Woodward, 1998) for motions carried out by actors, although not for motions of inanimate objects. By 7 months of age, babies selectively imitate both completed and uncompleted actions of actors on objects (Hamlin et al., 2008; Mahajan & Woodward, 2009), suggesting that they were sensitive to actors' underlying intentions and were not just simply reproducing completed actions on objects that they had witnessed. Nine-month-olds failed to imitate actions presented as performed by an inanimate mechanical device unless they had first witnessed an actor using the device in a goal-directed manner. Additionally, Cannon and Woodward (2012) demonstrated that 11-month-olds also systematically anticipated goal-directed reaches by an actor toward an object. Sommerville et al. (2005) speculated that "[t]his basic ability to construe action with respect to external goals may form the cornerstone for an understanding of goals as abstract entities that guide human action and govern event sequences" (p. B2). Woodward and others (Cannon, Woodward, Gredebäck, von Hofsteen, & Turek, 2012; Sommerville, Hildebrand, & Crane, 2008; Sommerville et al., 2005) have also provided compelling preliminary evidence that suggests that babies' self-produced actions may play an especially important formative role in knowledge about agency via the capacity to attribute goals to others' actions.

Unsettled is the persistent question of whether the seeds of agency are found first in awareness of the world or awareness of the self. In an interfunctional approach such as ours, neither needs to be privileged or given developmental priority. In a related vein, Rochat has argued (2003, 2010, 2011) for an embodied self-awareness from birth that is prereflective or implicit (see also Martin et al., 2008, for a similar view). Embodied accounts (e.g., Overton, Müller, & Newman, 2007), including Rochat's work, challenge traditional views that symbolic capacities and language are essential for self-awareness. Rochat (2011), in particular, has adopted a coemergence perspective through which self-awareness in conjunction with "feeling experience" transform active organisms into "volitional actors" (p. 110). On this view, infants' perceptions of their own bodies, both posturally and "situated in the environment" (Rochat, 2010, p. 738), precede more explicit forms of awareness of the self-as-agent. Self-produced action from birth is argued to yield proprioceptive information that is "self-specifying" (Rochat & Striano, 2000; see also Rochat & Hespos, 1997). Rochat (2010) further argues that this preconceptual self-awareness is fundamentally relational because it is derived from the infants' embodied experiences of *relations* between the implicit early self and the environment, including the social environment. According to Rochat (2010), newborns have "an implicit sense of the body as an identity that is differentiated, organized, and situated in the environment" (p. 738).

He reviews evidence that babies demonstrate awareness of themselves as "an entity that is situated, physically bounded, organized, and an agent in the environment" (p. 738) and that this entity with development becomes "recognized, evaluated, and labeled as an intrinsic part of the concept of 'Me'" (p. 738). Behaviorally, the implicit, embodied ecological sense of newborns, which would correspond to a minimal self-consciousness, is immersed in socially shared and socially mediated interactions, which Rochat (2010) indicates are supported over the developmental course by children's emerging symbolic and linguistic functions, as well as folk psychologies, or theories of mind. We turn to a closer examination of these functions next.

Symbolic and Linguistic Functions

The prereflective forms of agency evidenced in infants' early proprioceptive, perceptual, and, sensorimotor actions manifest in richer and more powerful ways with the emergence of symbolic and linguistic functions. Both Piaget and Vygotsky recognized the significance of symbolic functioning, of which linguistic development is a part, for the reorganization and control of individuals' actions (Chapman, 1991). Symbolization, in effect, drives a wedge between individuals and their environments, ultimately providing a way "to transcend a present situated activity context and create a new one" (Valsiner, 1998, p. 388). Commenting particularly on Vygotsky's conception of agency, Holland and Lachicotte (2007) noted that "without semiotic mediation [i.e., symbolic functioning] people would be buffeted about by the stimuli they happened to encounter as they went about in the world. Instead, semiotic mediation provides the means for humans to control, organize, and resignify their own behavior" (p. 115). Indeed, as young people develop, the possibility of resignifying one's own conduct—past, present, and future—opens new agentive avenues (Martin, 2008). As Modell (2008) has claimed: "Our sense of agency is enhanced not only through physically embodied acts but also through the creation of new meaning" (p. 42). This is one of the main reasons why philosophers, such as Charles Taylor discussed previously, argue for the centrality of self-interpretation in the development of agency.

In addition to the ways that symbolization promotes, as Vygotsky (1978) has said, "emancipation from situational constraints" (p. 99) and, as Piaget (1971/1967) noted, the "bursting of instinct" (pp. 366–367; see also Müller et al., 1998), language becomes a means by which children learn more explicit ways to articulate and reflect on their competencies as purposeful agents. Such learning becomes possible "Because linguistic symbols are both subjective and perspectival, when children learn to use words and linguistic forms in the manner of adults, they understand that the same objects and events are construed variously in relation to different points of view" (Martin, 2008, p. 103). Children's references to themselves provide a particularly interesting case in which early word use appears to promote perspective taking and agentive development (Budwig, 1989).

Personal pronouns—*I, me, mine, you, yours*—are categorized as deictic utterances, in that whereas other words for people typically have stable referents (e.g.*, grandma, Blake, Alice)*, the referents of personal pronouns are always specific to social-relational contexts in which referents change depending on who is uttering them. Deictic terms, therefore, can demarcate different physical perspectives and ownership (biophysical agency), differences in interpretation or views (psychosocial agency), and even demarcations of cultural and group inclusion (sociocultural agency). As noted by Smiley, Chang, and Allhoff (2011), personal pronouns "do not refer to particular people but rather to the roles they occupy in relation to one another in interaction" (p. 77). Thus, the referent of *I* when a child announces proudly to her mother "*I* threw the ball" shifts when the mother tells the child "Now *I* threw it." In effect, children's mastery of the system of personal pronouns demonstrates that they can "encode the range of roles they occupy in interaction—mover, agent, controller, experiencer . . . and the complementary roles of their partners" (Smiley et al., 2011, p. 78).

From birth on, young language learners are routinely exposed to self- and other-referencing pronouns (e.g., *I* versus *you*) in the language directly addressed to them and indirectly when adults converse with others in their company. However, because symbolic functioning is a later arriving developmental accomplishment, so too is their use of personal pronouns. It is not until around 18 months, then, that the linguistic use of personal pronouns emerges, with *I* usually preceding *you* (Smiley et al., 2011; Stipek, Gralinski, & Kopp, 1990). Production of possessive personal pronouns—*my, mine*—occurs only as early as 15 months but usually later (Hay, 2006; Saylor, Ganea, & Vázquez, 2011). Coinciding with these linguistic achievements in personal pronoun use, particularly the usage of *mine*, is a surge in children's declarations of *no*, or the a verbal attempt to negate the will of others (Hay, 2006). This finding suggests an important milestone in children's agentive expressions. That is, children's use of possessive personal pronouns appears to help advance their self-interests in interactions with others.

The use of personal pronouns is, among others, one signal that the child is attaining a *first-order, reflective agency*. Given that children's earliest use of personal pronouns coincides with classic mirror self-recognition (Lewis & Brooks-Gunn, 1981; Lewis & Ramsay, 2004), Lewis (2003; Chapter 11, this *Handbook*, this volume) concluded that these verbal and behavioral forms of self-knowledge signal the emergence of an explicitly conscious representation of self, the recursive understanding of "I know that I know." In much of the developmental literature, this level of self-knowledge is argued to be a nascent "theory of mind," or one of the critical steps toward understanding the mental lives of others. However, the theory of mind tradition has assumed, in a split Cartesian vein, that an individual's access to their own mind is relatively unproblematic. If the ability to represent oneself (and others) is instead thought to develop, it might be better characterized as a "theory of agency" (Russell, 1996; Sokol & Chandler, 2003), or children's ability to reflect on themselves as agents in the world.

Language and social interaction play a foundational role in the process of the development of reflective agency, and they are also a source of individual differences. Parents and other caregivers use language to refer to the child's own and others' agency in everyday conversations. Caregivers' comments may serve to spotlight children's, as well as others', agentive actions and their consequences. For instance, mothers have been studied using *mind-minded* language (Meins et al., 2003) and *mental state talk* (Taumoepeau & Ruffman, 2006, 2008) to discuss their children's interests and activities. These conversations begin well before the child reaches the symbolic representational level of knowing that ushers in language and reflective agency. Once a symbolic reflective sense of agency emerges, and with it language, children will begin to use these terms associated with caregivers in social interaction with parents and others who differ in their use of mental state talk. These differences can influence the child's own linguistic development and social understanding (e.g., Denham, Zoller, & Couchoud, 1994; Jenkins, Turrell, Kogushi, Lollis, & Ross, 2003; Recchia & Howe, 2008; Ruffman, Slade, & Crowe, 2002; Wellman, 1990).

Although there has been much speculation concerning the relation between mental representation and linguistic functioning (for review, see Carpendale & Lewis, 2006), little research has conceptualized age-related changes in linguistic and self-representational skills in terms of agency. If this body of research is recast as part of the development of an "objective awareness of me" (Courage & Howe, 2002), children's early symbolic and linguistic development seems absolutely central to the emergence of a first-order level of reflective agency. Bretherton and Beeghly (1982), who were among the first to document the mental state vocabulary of young children, found that children's mastered the use of volitional words (i.e., *want, need, have to, can*) before emotion (e.g., *feel*) or cognition (e.g., *think*) terms. Perhaps unsurprising to parents, Bretherton and Beeghly (1982) also found that nearly all toddlers used the word *want*; similar patterns of acquisition were reported in a study with German-speaking youngsters (Kristen, Sodian, Licata, Thoermer, & Poulin-Dubois, 2012). These volitional terms can also be expanded to include expressions about needs (e.g., Hay, 2006), goals and intentions (Recchia & Howe, 2008), or references to preferences or lack thereof (*care, like*, *dislike*).

Interestingly, parents also initially use more agentic terms when talking to young children, that is, those dealing with desires (e.g., *like, want*), relative to other mental states (e.g., *think, know*), only subsequently stabilizing relative to other mental state terms (e.g., Jenkins et al., 2003). These early conversations seem directed more at the child's actions, "providing labels such as 'want' and 'like' for the child's mental states . . . [and] also will often simply entail a plan of action for satisfying the child's desires" (Taumoepeau & Ruffman, 2006, 2008, p. 299). Nelson (2005) claims that children will acquire language and concepts about their own and others' minds in the course of conversations with others, and, similarly, Harris, de Rosnay, and Pons (2005) concluded that "language makes a difference" (p. 72) in both children's own linguistic skills and the specific language input of those with whom children interact. Certainly, children's earliest self-assertions—*Let me do it! I want to do it!*—coupled with parents' reactions to these utterances, whether support, opposition, or dismissal (e.g., Recchia & Howe, 2008) may serve as a possible starting point for individual differences in the development of reflective agency. Family talk, in this sense, is likely to further scaffold children's emerging sense of agency, as well as contribute to individual and cultural differences that come with age in more highly reflective forms of agency (e.g., Trommsdorff, 2012). Accordingly, we draw attention to the possible interpersonal, relational, and pragmatic functions of language in children's acquisition of more explicit expressions of agency, some of which appear in changing linguistic functioning and others in articulating intersubjective processes (e.g., theory of mind).

Variability in children's personal pronoun use may also depend on parental linguistic patterns (e.g., Smiley et al., 2011). Smiley et al.'s conversational analysis of family talk replicated prior studies describing variation in the extent to which parents' discourse featured a mix of self- and other-referring pronouns and names in different sentence positions (i.e., as grammatical subjects, objects, or possessives) or other patterns of use, for example using persons' names more often than pronouns, or alternatively using pronouns more frequently than names. Although more research with larger and different samples is needed, results provided preliminary evidence that parental input may contribute to individual differences in children's rates of acquisition of self- and other-referring pronouns. Given that there appears to be variability in parental input of terms for person-reference, it is possible that there is also variability in the way parents incorporate these linguistic forms into utterances that highlight or diminish attention to agency. As we describe in the next section, different kinds of family talk have been shown to relate to other aspects of agentive development, particularly as they are expressed through children's self-regulatory skills.

Regulatory Functions

Although regulatory functions in dynamic self-organizing systems do not necessarily require symbolic operations, it is no coincidence that at the reflective level of agency language development facilitates considerable growth in children's self-regulatory abilities (Winsler, Fernyhough, & Montero, 2009). Language, in many ways, becomes a lever for ratcheting up prereflective and practical forms of activity to higher reflective levels (Müller, Carpendale, Budwig, & Sokol, 2008) and lending new avenues for guiding action. Or, as Fernyhough (2010) has noted in the context of regulatory functions, basic prelinguistic self-regulatory processes, such as monitoring, inhibiting, and planning, "begin to relate interfunctionally" (p. 63) in new and richer ways through developing linguistic abilities. Fernyhough (2010) further states: "[C]hildren gain enhanced control over their own behavior when words which were previously used to regulate the behavior of others, or which others used to regulate the child's behavior, become employed in regulating the self" (Fernyhough, 2010, p. 63).

To the extent, then, that agency is conceptualized as the self-conscious reflective ability to choose and plan actions, it has been characterized in the developmental sciences, as *self-regulation*, or sometimes, *executive functions* (see McClelland, Geldhof, Cameron, Wanless, Chapter 14, this *Handbook*, this volume). In fact, Bandura's (2006) description of "the four core properties of human agency" (p. 164)—*intentionality, forethought, self-reactiveness, and self-reflectiveness*—all revolve around the self-regulatory functions of monitoring one's conduct, responding to feedback, setting goals, and making plans. As these concepts suggest, self-regulatory processes are typically seen as higher-order functions involved in the control and monitoring of thought and action (Carlson, 2005; Kerr & Zelazo, 2004), but also situated in the broader psychological system of the developing person (Dick & Overton, 2010). A question that frequently arises in the self-regulatory literature is just *who* the self or executor is, particularly as these processes are sometimes identified with subpersonal brain regions, rather than the whole person. In such accounts, the executor, or decision center, is "little more than a homunculus" (Baddeley, 1998, p. 524), showing how prominent split Cartesian tendencies in psychology admit to the necessity of human agency, only then to submerge agentive processes external to the identity of the individual (Dick & Overton, 2010).

Some of the roots of the self-regulation literature can be located in the functional approaches of Luria (e.g., 1973) and Vygotsky (for further discussion, see Zelazo, Carter, Reznick, & Frye, 1997), who argued that self-regulation was coconstructed, shared with others, and socially distributed (Luria, 1980/1966). From a developmental perspective, it is clear that children develop the ability to plan and control their actions in and through social contexts (Sokol, Müller, Carpendale, Young, & Iarocci, 2010), whether through a parent's help in solving a problem (e.g., Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012) or in regulating negative emotions, or controlling certain prohibited behaviors (Kochanska & Thompson, 1997). This fact highlights how the development of agency is co-constituted in social interactions with others who play a prominent role in scaffolding children's early self-regulatory experiences. That is, getting things done and accomplishing one's goals—even perhaps the goal of simply getting from here to there—occurs initially with the help of others, especially caregivers, before children are able to effectively self-regulate in more independent ways. Although this may seem like an obvious conclusion to anyone watching a young child learn to walk or crawl, it has profound consequences for conceptions of agency.

More specifically, differences in patterns of social interaction have been associated with differences in agentive control. To illustrate, Perez and Gauvain (2010) reviewed studies of children's planning skills in family contexts. Summarizing an earlier study (Gauvain & Huard, 1999), Perez and Gauvain (2010) show how parenting styles, as measured during observations of parent-child discussions at home, differentiated children's planning skills. Specifically, children whose parents were more authoritarian "initiated fewer planning discussions in middle childhood and adolescence than did children whose parents used other parenting styles" (p. 371). In addition, Gauvain and Perez (2005) longitudinally investigated family practices and routines that provided a social context for planning skill development in 7- to 9-year-olds. They found that with increasing age both Latino/a and European American children participated at increasing levels in everyday planning of organized activities, but also that group differences emerged. Specifically, "European American families and more acculturated Latino families, consistent with a value of child independence, planned their informal activities more often than did children in less acculturated Latino families" (Gauvain & Perez, 2005, p. 380).

These findings described by Gauvain and Perez (2010) raise the question of whether the development of agency may vary in significant ways across cultural contexts. Using a language development analogy, Ratner (2000) proposes that diverse manifestations of human agency are influenced, at least in part, by broader sociocultural patterns of interaction and meaning-making.

> Everyone has the capacity for language and everyone expresses some language to some degree. However, the specific kind and level of language that a person expresses depends upon her position in a particular society. In the same way, agency is merely a potential (capacity) which must be developed through social intercourse into a specific form. Throughout the world, individuals no more possess the same kind of agency than they use the same language. (Ratner, 2000, p. 426)

Work by Trommsdorff (2012) and others (e.g., Markus & Kitayama, 1991) suggests that Ranter's analogy might not be far from the mark. Trommsdorff (2012) has argued, in particular, that "different cultural demands foster different developmental pathways for regulation" (p. 22), which in Asian contexts often manifest in intentional forms of self-restraint, whereas in Western contexts more typically results in promoting self-achievement. In a related vein, Lerner (2004) indicates that "how a person must function to manifest structurally valued regulation will vary from social-cultural setting to setting" (p. 89), noting that many democratic societies value individual freedom and social equality. Finally, McAdams (2013) makes a more general case that cultural contexts "set norms and constraints on behavioral expression . . . provide timetables, scripts, and strong priorities for the agent's articulation of goals and values . . . [and] provide the psycho-literary menu off of which [a person] chooses the very images, metaphors, and narratives that can be used to make narrative identity" (p. 286). These latter choices become especially important within the context of self-appropriation processes that contribute to the development of agency through the construction of moral identities (Blasi, 2004a).

Moral Functions

Notions of human agency are especially salient in the research literature on children's moral development. Much of this attention is owed to the highly influential contributions of Kohlberg (1981, 1984). Following Piaget, Kohlberg not only adopted a constructivist approach to development, which assumed basic agentive self-organizational properties of socio-emotional-cognitive growth, he also argued that moral acts are necessarily purposeful and intentional. That is, both moral and immoral acts turn on the mental states underlying persons' actions (Turiel, 1990, 2010, Chapter 13, this *Handbook*, this volume). Citing acts of disobedience to illustrate (e.g., Henry David Thoreau's tax evasion to protest military appropriations), he described, just as Immanuel Kant did in the prologue to *Groundwork for the Metaphysics of Morals*, "when the question is of moral worth, it is not with the actions that we see that we are concerned, but with those inward principles of them which we do not see" (Kant 1785/1959, p. 23). The overt protests of Gandhi or Martin Luther King Jr. carried moral significance because they were rooted in principles of justice and fairness. Without this, they would have been cast as "rebels without a cause" and their actions as mere acts of noncompliance or rule-breaking. Accordingly, Kohlberg targeted in his research the "inward principles" that structured moral reasoning. By documenting the developmental changes in these moral reasoning structures, he showed how moral agency is constructed over time as individuals confront various dilemmas and grapple with day-to-day moral decisions.

A similar exploration of moral reasoning was present in Piaget's early work, particularly *The Moral Judgment of the Child* (1932/1965). Although this work is more generally a critique of the social determinist tendencies apparent in Durkheim's sociology, Piaget used examples of children's reasoning to illustrate differences in the interpretation of moral rules and the agentive processes at work in their construction. In a now classic set of interviews, he described children's understanding of accidental versus intentional moral infractions (i.e., breaking cups). Children's responses in these interviews suggested at least a nascent conception of "responsible agency" (C. Taylor, 1985), or the idea that intentional actions reflect a person's will and carry with them a kind of ownership that opens individuals to moral scrutiny and accountability. Piaget's claims about all this sparked, in turn, a litany of studies (for reviews, see Karniol, 1978; Keasey, 1977; Lapsley, 1996, esp. Chapter 2; see also Grueneich, 1982; Karniol, 1980) attempting to determine exactly what children understand about moral accountability and when persons' intentions become a critical feature in children's responsibility judgments.

This early work on children's responsibility judgments has resurfaced in studies of children's conceptions of moral emotions, where again questions of human agency appear to play a critical role (Krettenauer, Malti, & Sokol, 2008). In studies investigating what young people understand about the emotional consequences of victimizing others, children generate responses that tend to either privilege individuals' personal agency (i.e., whether they fulfill immediate desires) or conform to moral standards (i.e., whether they refrain from harming others). Specifically, in what has become known as the "happy victimizer phenomenon" (Arsenio & Kramer, 1992; Keller, Lourenço, Malti, & Saalbach, 2003; Lourenço, 1997; Murgatroyd & Robinson, 1993; Nunner-Winkler & Sodian, 1988), early school-aged children tend to attribute positive emotional states (i.e., "happy") to both themselves and others who meet their immediate goals, even if others have been harmed along the way. By contrast, slightly older children attend more to the normative constraints of a situation and, as a result, attribute negative emotions reflecting remorse or guilt for violating moral standards. This shift in children's emotion attributions has led researchers, such as Harris (1989), to claim that the turning point in reasoning about emotional matters, and particularly acts of victimization, comes when young people acquire a new recursive layer in their views about others' agency, or, as he put it, a shift from "seeing people as simply agents" to "seeing them as observers of their own agency" (p. 92). Central to this account, which Harris acknowledges borrows heavily from the classic writings of other early pragmatist philosophers (e.g., Cooley, 1902), is the idea that children eventually come to internalize an *external audience* that, in the end, allows them to evaluate their own and others' actions from a more distant, third-person perspective. Not coincidentally, Harris's views are in accord with claims in the perspective-taking literature (e.g., Martin et al., 2008) suggesting that agentive possibilities are constituted by individuals' abilities to reframe situations and see alternative courses of action for others and themselves (Martin, 2008).

Building, at least in part, from these findings on children's conceptions of moral emotions, other developmental researchers (Bergman, 2004; Colby & Damon, 1993; Damon, 1984) have argued that individuals' *moral selves* are constructed from the earliest expressions of human agency, or the *will*. Blasi (2004a, 2004b, 2005), in particular, has suggested that disjunctures in children's emotion attributions, like the happy victimizer phenomenon, are an indication that moral rules—although certainly known and understood by young children to some degree—remain unintegrated with respect to their developing self-system, and therefore lack motivational force. Integrated moral selves emerge with the development of the will. Blasi, relying heavily on Frankfurt's (1988) philosophical work, notes, "In willing, one appropriates certain desires . . . and makes them especially one's own, investing oneself in and identifying oneself with them" (Blasi, 2004b, p. 342). These first-order desires do not begin as one's own nor do they initially manifest themselves in orderly ways, but all of this changes as individuals develop their own agency. As he claims, "[i]n agency, the subjective self feels the owner; the sense of mineness is its central feature" (Blasi, 2004a, p. 12). Accordingly, it is over the course of development that second-order desires and volitions begin to emerge and create the structures needed to regulate more immediate, first-order desires (Blasi, 2005). As Blasi (2004a) describes,

> The will is structured through appropriation and rejection of one's characteristics. Whatever their origin—biological or social—these characteristics (desires, motives, inclinations, traits) are given facts about people's lives. But people have the capacity to desire to have or not have some of these characteristics (second-order desires); they may even want for these second-order desires to be effective in determining one's actions and ordering one's life (second-order volitions). (p. 14)

Self-appropriation, according to Blasi's model, is the principle vehicle by which agency is made manifest in individuals' moral selves.

Although Blasi has attempted to characterize the moral self in developmental terms, he has been criticized (e.g., Nucci, 2004a, 2004b) for overly emphasizing adolescent forms of self-understanding and neglecting developmentally earlier psychosocial processes contributing to moral agency and selfhood. Working to address these criticisms, Krettenauer (2013) has proposed a model of moral selfhood that has its roots in the different forms of agency found in early and middle childhood. He calls these: *intentional, volitional*, and *identified agency*. Each marks an important transition in young people's moral selves and develop in hierarchical fashion, although over the life span all three forms of agency may coexist. Krettenauer's (2013) treatment of the moral self has some common features with our own interfunctional views of the development of agency and draws from many of the same multilayered, psychosocial processes. However, Krettenauer does not acknowledge the earliest forms of human agency outlined earlier in this chapter.

According to Krettenauer (2013), evidence of an early form of intentional agency (or what could be characterized as first-order reflective agency) is found at the intersection of 2- to 3-year-olds' basic folk psychologies (Wellman & Phillips, 2001), their prosocial impulses to help others (Dunfield, Kuhlmeier, O'Connell, & Kelley, 2011; Eisenberg & Mussen, 1989; Warneken & Tomasello, 2009), and their abilities to distinguish between social-conventional and moral rules (Nucci, 1981; Smetana, 2006, 2011; Turiel, 1983, 2010, Chapter 13, this *Handbook*, this volume). Children's use of mental states such as beliefs, desires, and intentions—the early conceptual building blocks of individuals' theories of mind—becomes an important tool for harnessing their nascent prosocial impulses and conceptions of moral rules to construct the first moral desires on which they act. These early moral desires, although an indicator of a developing moral self, are unstable, however, and readily give sway to outside influences. The young child's moral will is not entirely her own, or, in Piagetian terms, it is more heteronomous than autonomous.

The preschool-aged child's fleeting moral self begins to stabilize with the emergence of what Krettenauer (2013) calls volitional agency, or increasing self-regulatory abilities, which promote success in delaying gratification (Mischel, 1974; Tobin & Graziano, 2010) and imagining a temporally extended sense of self (Barresi, 2001; Moore, 2010). These growing abilities are especially critical in allowing children to reflect on future conditions that are contingent on present decisions, and then to prioritize particular desires over others. Or, as Piaget (1981/1954) would say, to construct a *conservation of values* (see also Sokol & Hammond, 2009), which "consists of subordinating a given situation to a permanent scale of values" (Piaget, 1954/1981, p. 65). Importantly, decisions about which values to prioritize may not be moral, especially given the egoistic and instrumental ways that young children tend to reason (Svetlova, Nichols, & Brownell, 2010). Moreover, the degree of internalization of particular values, moral or otherwise, may be superficial, and largely the result of external impositions. On the other hand, values that are integrated with aspects of one's identity, or what Krettenauer (2013) calls identified agency, reflect a deeper personal commitment to valued norms and the realization that behaving according to such norms is a form of self-expression.

Krettenauer's (2013) ideas regarding identified agency draw particularly from Deci and Ryan's (2000, 2002) *Self-Determination Theory*, which also posits a close connection between internalization of norms and self-regulatory processes. In Self-Determination Theory, the two most autonomous modes of self-regulation occur when a person has either *identified* with or *integrated* a particular norm. On the identified level, individuals express a basic personal agreement with a norm or societal expectation, whereas on the integrated level norms are experienced as self-ideals that the person does not want to betray. That is, although norms or values may initially be imposed on young people, they may still choose to personally value certain norms or standards (i.e., identify with the norm) and synthesize them into their own belief system (i.e., integration). In this way, a social expectation, say of parents or teachers, may be transformed into a personal goal or motive. This process resembles Blasi's (2004a, 2004b) notions of self-appropriation and taking *ownership* of particular values.

Although the burgeoning literature on moral selfhood (e.g., Lapsley & Narvaez, 2004) holds a great deal of promise for capturing the central features of human agency, another prominent strand of the moral development literature merits consideration. The growth of *moral character*, much like our discussion of moral selves, has also been described in agentive terms. Specifically, Berkowitz and Bier (2005) define character as "*the composite of psychological characteristics that serve to promote moral agency*" (p. 268, italics in the original; see also Lapsley & Narvaez, 2006; Sokol, Hammond, & Berkowitz, 2010). Not only does this definition capture the interfunctionality of character, just as we have tried to do here with agency, it also further highlights how the growth of human agency implies social responsibility and promoting civic virtue, especially in educational contexts. Indeed, rising interest in the study of civic engagement (Lerner, Fisher, & Weinberg, 2000; Sherrod, Torney-Purta, & Flanagan, 2010) and civic education (Althof & Berkowitz, 2006; Haste, 2010) has important ties to developmental research on moral agency (e.g., Youniss & Yates, 1997) and moral identity (e.g., Hart, 2005). As Hart, Atkins, and Donnelly (2006) have pointed out, "Participation in community service provides a real-world context in which participants can explore moral questions, engage in moral discourse, perform moral actions, and reflect on complicated moral issues. It is for these reasons that community service has been extolled as a context for moral development" (p. 644).

Although these connections to community service are no doubt important, still others (e.g., Lerner, 2004) have argued for a deeper, constitutive relation between moral development and civic engagement. Youniss' insights on fostering the growth of civic life, in particular, stem from early work elaborating on Piaget's (1932) view of moral agency and the different social-relational dynamics associated with adult caregivers and peers (Youniss, 1978, 1980, 1981, 1987; Youniss & Damon, 1992). Although Piaget was never as overtly political as his peer Wallon, idealistic notions of transcendence and democracy are seeded in Piaget's earlier writings (Vidal, 1998), and come to fruition in Youniss and his colleagues' research on civic engagement and democratic participation (e.g., Yates & Youniss, 1996; Youniss, McLellan, & Yates, 1999). Here we can see an important parallel between moral agency and civic growth. Civic life, much like young people's moral lives, occurs within a broad field of power differentials that are experienced through symmetrical and asymmetrical relationship structures (e.g., parent-child, peer-peer). These relationships, in turn, promote, as well as constrain, to differing degrees the development and expressions of civic agency. Some relationships, especially those rooted in democratic forms of participation and mutual reciprocity, appear to promote an understanding and commitment to social justice and the need for sociopolitical transformation; whereas as others, particularly more didactic or less participatory social relationships, lead to attitudes and priorities that conform to social convention and preserve the status quo (Kahne & Sporte, 2008; Moely, Furco, & Reed, 2008; Moely & Miron, 2005; Westheimer & Kahne, 2004).

Evidence showing these important ties between moral and civic life leads to further questions regarding the extent to which human agency, characterized here at a psychosocial level of agency, may be tied to a broader view of sociocultural dynamics in which patterns of shared values and norms could further empower individuals' actions. Or, drawing from Giddens (1984), to what extent is agency more than just "being able to act" and instead about "being able to make a difference" (p. 14) in one's own and others' lives? To properly answer this question, we must turn to issues of political or civic agency: the power for individuals and groups to bring about effective change in collective life, or enact social change (Coole, 2005). By concluding our investigation and analysis with a discussion of civic agency, we want to further emphasize why human agency is best understood as a relational phenomenon.

CIVIC LIFE AND THE SOCIOCULTURAL DIMENSIONS OF AGENCY

By exploring the sociocultural dimensions of agency—or, from our earlier definition in the introduction: the dynamic patterns of shared values and norms of cultural systems, both past and present, that extend and limit (i.e., empower and constrain) individual and collective actions—we do not mean to suggest that people, for whatever more proximal or localized powers over their actions they possess, are from a broader, societal level passively tossed about by the cultural and historical currents that envelop them. Certainly history and culture have an impact on human life, but like Elder-Vass (2010) and other social scientists (e.g., Archer, 1996, 2000; Giddens, 1984; Loyal & Barnes, 2001), we take the position that acknowledging human agency is still compatible with social influences on individual behavior: "Human action may be affected by social causes without being fully determined by them" (Elder-Vass, 2010, p. 87). But even beyond such claims, we have argued that human agency is unique because persons are at the nexus of biophysical and sociocultural constitutive forces that also empower them to act according to their own wills, even if will here must be conceived in psycho-social-relational terms. That is, human agency, or "the will," is always embedded in a complex system of relations (Bandura, 2001), making a person less about being "biologized, psychologized, or sociologized," as Lerner and Walls (1999) have remarked, "[r]ather, the individual is 'systemized'" (p. 13).

The systemized, or relational developmental systems view we hold offers an explanatory framework for reconciling claims about human agency with the sociocultural factors that also empower and constrain individuals' actions. Our view has much in common with Lerner and Wall's (1999) notion of *embeddedness*, or "that any level of analysis is reciprocally related to all others" (p. 11). It also has affinities with Bandura's sociocognitive views, which frames agency as *triadic reciprocal relations* (Bandura, 1989, 2006), or the system of "internal personal factors, in the form of cognitive, affective, and biological events, behavioral patterns, and environmental influences [that] all operate as interacting determinants that influence one another bidirectionally" (Bandura, 2001, pp. 14–15). As Bandura (2001, 2006) has gone on to argue, the implications of such multilayered, bidirectionality (←→) is that human beings—by monitoring their biological systems, receiving social feedback, and anticipating future outcomes—can effectively adapt their conduct and their environments to further enhance their agentive capabilities. Lerner and Walls (1999) take a similar position in recognizing that "individuals, in action with their changing context, [are] seen to provide a basis of their own development" (p. 9). Changes to these contexts may apply in more immediate and perhaps subjective ways, such as when individuals set an alarm clock to change their sleeping behaviors. They may also apply more collectively, such as when groups of people establish voting policies and procedures to further empower (or perhaps curtail) opportunities for sociopolitical change. What makes these claims particularly compelling, especially when applied to views about civic life, is that *human agents produce the conditions for their own agency*. Or, as Ratner (2000) has remarked, "Agency is only enhanced by enhancing social relations which constitute it" (p. 426).

Social Capital and Human Capabilities

The idea that human agentiveness is constituted in the currents and connections of human relationships suggests another important layer of meaning to the work of collective organizations and community agencies promoting various dimensions of civic life and the public good (e.g., education and health care access, career consultation and training, neighborhood safety and business opportunities, recreational services). Many beneficial human services and resources can be seen to flow from the collective efforts of such groups. But, another benefit or asset—one that is certainly hard to quantify or pinpoint—appears to be embedded in the relational networks themselves that these social organizations form. In sociological quarters, this asset has often been called *social capital* (Bourdieu, 1985), a way of characterizing the inherent positive value of particular kinds of social networks. Some of the benefits of social networks flow directly as private goods to individuals participating in those networks. For example, informal social networks are often useful to someone who is searching for a job. Other benefits of social networks are considered public goods. When communities are well organized with dense networks of neighbors, the neighborhood will experience lower crime rates, which benefits even those who do not live there.

As Portes (1998) has noted, the notion of social capital is not particularly new in sociology, having close affinities to the benefits of social life described in the seminal contributions of Durkheim and Marx. Still, the idea has gained import, especially in current day public policy circles, because of the compelling way it captures "positive consequences of sociability" in "nonmonetary forms . . . of power and influence" (Portes, 1998, p. 2). Just as we have described human agency, the power of social capital is relational in nature.

> Whereas economic capital is in people's bank accounts and human capital is inside their heads, social capital inheres in the structure of their relationships. To possess social capital, a person must be related to others, and it is those others, not himself, who are the actual source of his or her advantage. (Portes, 1998, p. 7)

Recognizing this relational power, particularly for the development of young people, Coleman (1990) has defined social capital as "the norms, the social networks, and the relationships between adults and children that are of value for the child's growing up. Social capital exists within the family, but also outside the family, in the community" (p. 334).

Although relationships are critical, social capital is not merely a matter of social bonding through shared norms and values (Bankston & Zhou, 2002). Increasingly, social capital is described in agentive terms, as a way of meeting goals and facilitating actions, both personally and collectively. "Social capital theory," according to Bankston and Zhou (2002), "envisages shared norms as part of the production of capital only insofar as the norms promote productive behavior" (p. 287). Accordingly, Coleman (1988) has also characterized social capital in terms of its function: "some aspect of social structures . . . [that] facilitate certain action of actors—whether persons or corporate actors—within the structure" (p. 98; see also Coleman, 1990, p. 302). Human action is moved to the foreground in such definitions of social capital, and the background becomes the "[s]ocial networks, relationships, and norms . . . the stages in the production of goal-oriented behavior" (Bankston & Zhou, 2002, p. 288).

Some of the definitional ambiguities about social capital, particularly whether normative structures or goal-directed acts should be prioritized, appear to be a holdover from the structure-agency debates in sociology. Such either-or divisions tend to cloud what should otherwise be obvious. Social capital, like human agency, is a relationally constituted process, not a material thing. As Bankston and Zhou (2002) have argued, "The tendency to confuse definition with causation is a consequence of confusing a process with a substance" (p. 289). Our claims about human agency are similarly process-oriented, but this makes the social-relational backgrounds in and through which human agency emerges—that is, those "stages" on which goal-oriented behavior take place, as Bankston and Zhou (2002) would say—all the more critical. This is especially the case when considering sociopolitical issues of governance and citizenship.

Human agency and autonomy is as much a function of individuals as their social conditions (Barber, 1984/2003). Taking a relational view, and emphasizing the coconstructive aspects of human thriving and civil society, Lerner (2004) has argued that agency hinges on "increasing consistency between an individual's behavioral attributes and those characteristics of personal and social functioning requisite for maintaining and enhancing developmental regulations associated with liberty" (p. 91)—the ideals of American democracy. Such a view emphasizing the sociopolitical conditions of democracy can be applied to social capital as well, such as in the influential work of Putnam (2001). Putnam's (2001) exploration of social capital and democracy in the United States led him to study the connections between social capital and educational achievement. Putnam (2001) found that revitalizing community life appears to be a prerequisite for improving American education. In addition, there is a strong correlation between social capital and educational performance, even stronger than that between socioeconomic or racial characteristics and educational performance. He argues that rather than blaming teachers, curriculum, young people, or school administrators, the actual "culprit for the educational misadventure of American youth over the past several decades may be the civic lethargy and social disengagement of American citizens" (p. 87).

Capabilities Approach and Agency

A similar point regarding the relation between education and democracy has been made by political philosopher Martha Nussbaum (2006). Her claims that "Nothing could be more crucial to democracy than the education of its citizens" (Nussbaum, 2006, p. 387) harkens back to the appeals of the founders of the United States when arguing for the creation of American colleges and universities.

> [N]othing is of more importance to the public wealth, than to form and train up youth in wisdom and truth. Wise and good [people] are, in my opinion the strength of a state: much more so than riches or arms, which under the management of ignorance and wickedness, often draw on destruction. (Benjamin Franklin, 1750, as cited in Harkavy & Hartley, 2008)

Nussbaum's (2006) appeals, however, are not necessarily aimed at just lending support to American democracy. Rather, they are directed more globally to concerns regarding human rights and development on an international scale. Nussbaum's arguments are part of the *capability approach*, a philosophical perspective pioneered by economist Amartya Sen (1992, 1999).

The capability approach has become influential over the past two decades as a normative framework for assessing social arrangements, social justice, equality, and quality of life, as well as for designing economic and public policies aimed at development (Robeyns, 2011). From a public policy perspective, it presents an alternative to the typical way of assessing the state of a nation based on financial income and economic growth, usually captured in numbers such as gross domestic product (GDP). The approach argues, instead, for a *people-centered* perspective of human well-being (Alkire & Deneulin, 2009), emphasizing assessment strategies that target health, education, nutrition, political freedoms, human security, and environmental sustainability. For this reason, the approach is understood as the basis for a theory of social justice, but also as an evidence-driven enterprise seeking empirical support for its arguments to reduce social exclusion and inequalities and to enhance global justice. According to Sen (1992), "A person's capability to achieve functionings that he or she has reason to value provides a general approach to the evaluation of social arrangements, and this yields a particular way of viewing the assessment of equality and inequality" (p. 5). As the central question behind such assessment, human agency becomes a clear focal point: "What is each person able to do and to be?" In other words, when evaluating societies on the extent to which basic human welfare and justice are being met, the capability approach takes each person as an end in themselves, "asking not just about the total or average well-being but about the opportunities available to each person" (Nussbaum, 2011, p. 18) for positive growth and to make choices. Within this approach, human development is fundamentally understood as “the process of widening people’s choices” (United Nations Development Programme, 1990, p. 9), not simply for the sake of increasing the number of choices individuals have, but as the basis for bolstering the general “quality” of human life (Alkire & Deneulin, 2009, p. 34). Expressions of agency must, therefore, strike a balance between the effective power of individuals and more collective responsibilities and commitments to others. Depriving others of choices, especially as a way to harm or humiliate, is not a form of agency in the capability approach. “Agency,” as Alkire and Deneulin (2009) note, “expands the horizons of concern beyond a person’s well-being to include concerns such as solidarity” (p. 37).

Social Responsibility and Empowerment

Acting out of concern for others’ well-being is not without pitfalls and unexpected negative consequences. Responsible agency does not erode the agency of others; rather, it should empower others. Individuals and organizations offer many charitable forms of humanitarian aid, especially in terms of food and shelter, to meet others’ most urgent and basic needs. But it can be argued that even the compassion behind these generous actions work against empowering others. As Sen (1999) argued, “people have to be seen . . . as being actively involved—given the opportunity—in shaping their own destiny, and not just as passive recipients of the fruits of cunning development programs” (p. 53). For this reason, Rao and Walton (2004) argued for a shift in social policies that diverge from emphasizing *equality of opportunity* to those that promote *equality of agency*—that is, from interventions where the underserved and marginalized are essentially powerless to “creating an enabling environment to provide the poor with the tools, and the voice, to navigate their way out of poverty” (p. 361). If properly designed, these environments can promote effective agency for everyone involved.

Still, to be successful in the creation of empowering environments, the philosophical outlooks behind both public- and private-sector humanitarian efforts, and perhaps even the meaning of citizenship, need to change. Most state-centered conceptions of social policy, as they currently stand at least, view citizens as *recipients* of state-delivered programs. By contrast, market-led versions of social welfare, originating in the private sector, tend to see clients as *consumers*. Arguably, consumers may participate by exercising choice from a range of services, but even here the level of agency is limited to the kinds of services being offered. Cornwall and Gaventa (2000) have argued for an alternative approach to social policy that treats citizens not only as “users or choosers, but more as active participants who engage in making and shaping” (p. 2) social policy and provisioning. Barnes (1999), in describing user groups in the disability rights field, has similarly argued that direct involvement of users in processes of decision making over public service provision “demonstrates their capability to be active agents ‘making and creating’ the services they receive, rather than simply consuming them” (p. 84). These further reaching claims regarding the centrality of civic agency in constructing social policy align closely with the views of the capability approach (see also Lerner, 2004, especially Chapter 5).

Citizenship and Educating for Democracy

Emphasizing agency, as the capability approach and others in the public policy sphere have done, raises important conceptual issues about the nature of participation, citizenship, and social policy itself. Cornwall and Gaventa (2000) have argued that the concept of social citizenship should be expanded to include not only concepts of social rights, but also of social responsibilities exercised through agency based on self-action and self-identity, and of social accountability achieved through direct forms of democratic governance. Following from this view, democratic participation is understood as a fundamental right of human beings. Lister (1998) argued, for example, that the

> right of participation in decision-making in social, economic, cultural and political life should be included in the nexus of basic human rights. . . . Citizenship as participation can be seen as representing an expression of human agency in the political arena, broadly defined; *citizenship as rights enables people to act as agents*. (p. 228; emphasis added)

Whether citizenship, on such a definition, really is best conceived as a basic human right, it should be clear that the social conditions needed to support citizenship are the same as those needed to optimize and sustain human agency. Moreover, such a view of citizenship returns us to our initial claim that human agents create the conditions for their own agency. They accomplish this not only by promoting, creating, and participating in democratic social structures and procedures, but also by ensuring that citizens are properly educated to engage in such participation (Bergan, 2005). Citizens, as Barber (1984/2003) has noted, are not born, "but made as a consequence of civic education and political engagement in a free polity" (p. xxix).

Democratic Engagement

Increasingly the role of education around the globe is being connected to notions of citizenship and social responsibility. This connection is evidenced by broadly construed programs such as the United Nations' "Global Education First" initiative (2012), which lists "global citizenship" as a main priority, or the Council of Europe (2007), which claims that higher education must lead to "preparation for life as active citizens in democratic societies" (cited in Bergan, Harkavy, & van't Land, 2013, p.16). In the United States especially, higher education was envisioned to promote democratic ideals and the skills of citizenship. Such a democratic vision, for instance, was part of Thomas Jefferson's rationale for founding the University of Virginia, and Benjamin Franklin's efforts at the University of Pennsylvania (Benson, Harkavy, & Puckett, 2011; Thomas & Levine, 2011). This vision also carries through to the seminal works of American pragmatist philosopher, John Dewey (1916), who argued that civil society is rooted in education, and in progressive educational leaders such as Boyte (2008, 2009) who asserted that the central aim of colleges and universities in the 21st century should be the development of civic agency.

Educating for citizenship, according to these views, describes a cultural stance, or a way of being and interacting, as opposed to the promotion of specific political platforms or agendas. In his discussion of the role that universities play in democratic societies, Ottersen (2013) claimed,"[Democracy] is about form rather than content" (p. 37), echoing a position taken by Dewey (1916) that democracy is "primarily a form of associated living, a conjoint communicated experience" (p. 93; see also Saltmarsh & Morton, 2011). As such, democratic education "presupposes mutual recognition and the acceptance of divergences of opinion, of the right to be heard, of the obligation to listen to others and of respect for common norms" (Ottersen, 2013, p. 37). Similarly, Boyte (2008) has claimed that civic education must emphasize the capacities of citizens to work collaboratively across differences such as partisan ideology, faith traditions, income, geography, and ethnicity to address common challenges, solve problems, and create common ground. Democratic citizenship is more than just making political decisions; it fundamentally means making a public life together. For this reason, educating for citizenship can be argued to have less to do with gaining knowledge about democratic institutions and elections, and more to with what American poet Walt Whitman called "the highest forms of interaction between men, and their beliefs" (cited in Mack, 2006, p. 149). "To be literate as a citizen," as former university president, Richard Morrill (1982), has stated, "requires more than knowledge and information; it includes the exercise of personal responsibility, active participation, and personal commitment to a set of values. Democratic literacy is a literacy of doing, not simply knowing" (p. 365; cited in Jacoby & Associates, 2009). In other words, democratic literacy is a form of human agency.

Community Service

This *literacy of doing*, as Morrill (1982) suggests, is one of the key reasons that democratic education is commonly tied to academically based community service (Benson et al., 2011, p. 63), or what is more popularly called *service-learning* (Brandenberger, 2006; Bringle & Hatcher, 1995; Rhoads, 1997). Service-learning is an instructional tool by which teachers utilize volunteer activities outside of the classroom to guide students' understanding of concepts specific to academic courses and disciplines. One characterization of service-learning suggests that direct experience or "contact" with challenging realities, as Kolvenbach (2000) says, has greater educational value than exposure to abstract "concepts"—that is, "When the heart is touched by direct experience, the mind may be challenged to change" (Kolvenbach, 2000). Perspectives on service-learning particular to the psychological sciences are increasingly available in the literature (Bringle & Duffy, 2006; Kenny, Simon, Brabeck, & Lerner, 2002; Sokol & Kuebli, 2011) and generally seen as rooted in the prominent psychological theories of Piaget and Erikson (Brandenberger, 2006; Youniss & Yates, 1997), as well as Dewey (Saltmarsh, 1996)—all significant contributors to our understanding of the development of human agency. The civic value of service-learning, though, has its clearest expression in work that attempts to integrate moral development with academic learning (e.g., Colby, Ehrlich, Beaumont, & Stephens, 2003; Youniss & Yates, 1997).

Even if academically guided volunteer experiences offer constructive avenues for democratic growth and the development of actively engaged human agency, the sociorelational dynamics of service contexts set important constraints on the development of civic agency. Returning to the notion of solidarity, or mutual empowerment, described by proponents of the capability approach, community service needs a backdrop that avoids casting students' activities as merely charitable acts. As Barber (1992) has remarked: "The language of charity drives a wedge between self-interest and altruism, leading students to believe that service is a matter of sacrificing private interests to moral virtue. The language of citizenship suggests that self-interests are always embedded in communities of action and that in serving neighbors one also serves oneself" (p. 249). Dewey (1908) also argued against notions of charity that assumed "the continued and necessary existence of a dependent 'lower' class to be recipient of the kindness of their superiors" (p. 348; cited in Saltmarsh & Zlotkowski, 2011, p. 63). Charity has a tendency to reinforce hierarchical power structures (i.e., "power over" others; see Kreisberg, 1992) and relational asymmetries (e.g., more skilled or competent, more financially stable, more social capital *versus* less) that fortify the distinction between self and other, and ultimately builds a split "us-versus-them" mentality. This view runs counter to more relational democratic forms of action aimed at seeking "the public good *with* the public, and not merely *for* the public" (Saltmarsh & Hartley, 2011, p. 20, italics in original). Civic agency against a democratic backdrop signals a form of solidarity that emphasizes "doing with" others. The basis of such relationships promotes mutuality, or relational symmetries, that breakdown differences between individuals and blur self-other distinctions (i.e., "power with" others; Kreisberg, 1992). The result is a communal perspective: We are all in this together.

In educational contexts in which community service is a salient part of the curricular experience, students are often surprised when instructors suggest that their volunteer efforts might run counter to democratic ideals and actually *disempower* people (Boyte, 2008). That is, volunteer efforts can sometimes erode the confidence and capacities of those being helped by individuals with so-called credentialed expertise. In the United States especially, many institutions have grown away from their original democratic purposes as they have become more focused on discipline-specific pedagogy and research. The result has been a growing technocracy, particularly among larger, research-oriented universities. Technocractic relations weaken civic agency (Saltmarsh & Hartley, 2011). "When [democratic] learning is absent, graduates come to understand themselves as detached experts providing service *for* people, not as citizens working *with* fellow citizens on public problems" (Boyte & Mehaffy, 2008, p. 3). Thus, human agency is undermined. As a way to counter these potentially negative consequences of community service, civic engagement programs have begun to incorporate notions of social justice (see Lerner, 2004; Lerner & Overton, 2008). These justice-oriented programs focus on teaching interpersonal relationship skills, such as learning to work with others with whom one disagrees, reading the political and cultural dynamics of settings, learning how to act in open-ended situations with no predetermined outcomes, respecting others' capacities for self-directed actions, and being responsible for one's own actions and accountability to one's peers (Boyte, 2008). By emphasizing social justice, the disempowering aspects of assisting others can be reversed, leading to more agentive outcomes.

CONCLUSION

The relational developmental systems conception that frames our views about human agency makes clear that the most basic form of agency is already present in the dynamic, self-organizing activities of living systems. From the earliest point in the development of persons, agency manifests in different forms and grows through the interrelations of various biopsychosocial functions. These functions can be organized into the general levels that we proposed in our introduction and elaborated throughout the main sections of the chapter.

- ***Biophysical agency*** constitutes the activities of a self-organizing system to regulate and sustain itself.
- ***Psychosocial agency*** constitutes the deliberate, intentional acts of a self-aware system to determine a course of actions and construct meaning from them.
- ***Sociocultural agency*** constitutes the dynamic patterns of shared values and norms of cultural systems, both past and present, to extend and limit (i.e., empower and constrain) individual and collective actions.

The most flexible and richest forms of agency seen in adulthood build from developmental processes evidenced throughout the life span: infants' sensorimotor and perceptual functioning, toddlers' symbolic representational and linguistic functioning, the child's self-regulatory functioning, and adolescents' and young adults' moral functioning. The outline we have offered here by surveying parts of the developmental literature provides some of the conceptual structure needed to frame a more robust relational developmental systems picture of how agency pervades human life, and yet through its diverse expressions and manifestations often eludes systematic study. We have acknowledged and drawn from the notable exceptions to our claim that agency is a neglected area of research. That is, the works of Bandura (1989, 2001, 2006), Brandtstädter (1998, 2006), Martin (2008; Martin et al., 2010), Russell (1996), and others have made significant contributions to our understanding of human agency and its development. We bypassed a thorough review of many of these particular contributions in order to draw together relevant theoretical perspectives and research findings that have not always been framed as part of the development of agency. This approach freed us to explore a diverse range of literatures, including many of the philosophical cornerstones that have influenced the psychological study of agency, and sometimes led away from a viable conception of human agency. Our approach has also allowed us to introduce relevant contributions from the literature on civic and democratic engagement, particularly as a way to better understand the importance of sociocultural expressions of agency and the social conditions that enable human agency to thrive. Lerner (2004) and his colleagues (e.g., Lerner et al., 2000; Lerner & Overton, 2008), in particular, have examined many of these social conditions, concluding that the democratic ideals of liberty, equality, and justice stand to promote youth development in the most positive and healthy ways, as well as coactively contribute to the growth of civil society.

In our review, we specifically emphasized the theoretical value of the *capabilities approach* (e.g., Nussbaum, 2011; Sen, 1992, 1999) to our understanding of human agency, especially at the sociocultural level of policy and program formation, and we began to illustrate programmatic efforts within higher education designed to promote engaged citizenship and democratic participation, that is, a sociocultural manifestation of agency. Different kinds of experiential learning, or service-learning (e.g., Bringle & Duffy, 2006; Kenny et al., 2002; Rhoads, 1997; Saltmarsh, 1996; Youniss & Yates, 1997), have not only been central to these educational efforts at colleges and universities, this active form of learning for individuals—or what some have called a *literacy of doing* (Morrill, 1982)—has direct ties to the development of personal agency, and clearly show ways that psychosocial forms of agency can be promoted and sustained through efforts directed at the sociocultural level. In short, service-learning, as well as other forms of community engagement, provide compelling and rich examples of the ways by which "individuals, in action with their changing context, [are] seen to provide a basis of their own development" (Lerner & Walls, 1999, p. 9)—or what we characterized as *human agents producing the conditions for their own agency*.

Agency, then, is woven throughout human experience. We see agency in psychosocial functions—from sensorimotor and perceptual to symbolic representational and linguistic, from self-regulatory to moral—that contribute to its growth over the life span. Moreover, agency is embedded in the fabric of sociocultural forms and practices as persons create the conditions to promote and sustain their own agency. Expressions of civic agency and the societal structures that support these expressions are just as critical, and relevant to a programmatic investigation of human agency, as manifestations of personal agency in toddlers' language development or experiences of planning in children's households. The relational developmental systems framework—and the biophysical, psychosocial, and sociocultural levels of organization—that we have adopted in this chapter should make expressions of agency more identifiable for future investigations, as well as allow us to draw out important parallels in the structures of agency that are organized at different functional levels. We conclude here by briefly noting one such parallel between the way Piaget (1954/1981) has described the psychological structure of the will, or personal agency, and Palmer (2011) has characterized the structures of engaged, democratic citizenship, or civic agency.

Piaget (1954/1981) claimed that the will is not a psychological faculty per se, but a process involving the coordination and integration of an individual's desires and personal values, operating in much the same way that perspective taking does in coordinating multiple points of view (see also Sokol et al., 2013). As an individual's will develops over time, these processes help to organize different, often conflicting, desires that are nevertheless held together in a dynamic tension made possible by the construction of higher-order values and principles. Palmer (2011) describes democratic citizenship in a similar fashion, or as "learning to hold tension creatively" (p. 71) in the many perspectives that are part of public life, in order to "generate a sense of personal voice and agency" and to further "strengthen our capacity to create community" (p. 45). As Parker (2011) argues, democratic forms of government are "designed not to suppress our differences but to keep the energy of their tension alive so that it [can] animate the body politic" (p. 75). This comparison suggests that democratic institutions and a citizen's participation within them hinge on a similar kind of creative tension that animates an individual's will. We believe that further explorations of personal and civic agency, as well as comparisons such as this one, stand only to enrich our understanding of the development of human agency more generally, and the particular ways that we can further empower ourselves and others.

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CHAPTER 9

Dialectical Models of Socialization

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Socialization is the process by which individuals are socially guided to become competent members of their society and culture. More broadly, socialization is a process of cultural reconstruction by which individuals in each new generation are guided to construct some semblance of cultural continuity. The ecology of children includes multiple sources of social guidance such as parents, peers, schools, media, and emersion in the practices and social meanings of the surrounding culture (Kuczynski & Knafo, 2013). However, parents—including all primary caregivers acting in the role of parents—are regarded as the most important agents of socialization, who lay the foundations for the child's subsequent interactions with the world outside the family.

Prior to the 1970s, theories about the causal nature of social guidance in socialization tended to be linear and deterministic. Wrong (1961), for example, suggested that the focus on ideas such as conformity to social norms and roles and stable transmission of values between generations, evident in research at that time, assumed that society is much more integrated than it really is and that human nature is much more conforming and socialized than it really is. A turning point for socialization theory occurred when new ideas appeared that drew attention to the importance of child effects (Bell, 1968); the agency of the child (Rheingold, 1969); and bidirectional causal processes in parent-child interactions (R. M. Lerner & Spanier, 1978; Lewis & Rosenblum, 1974; Sameroff, 1975a, 1975b). It can now be argued that socialization is a process of constant adaptation and change throughout the life span. In childhood, change in the process of socialization is driven by both development of the child's skills, behavior patterns, ideas, and values, as well as change in ecological contexts in which self-regulation is required (McClelland, Geldhof, Cameron, Wanless, Chapter 14, this *Handbook*, this volume). In adulthood, change in social development is driven by the expectations and experiences of shifting life-span transitions and contexts, such as parenthood, marriage, and work. The parental role itself requires constant change and resocialization as parents adapt to the direct impact of having children as part of their environmental context (Palkovitz, Marks, Appleby, & Holmes, 2003) and as they adapt to life transitions as well as social changes in the surrounding culture. Thus, socialization is a phenomenon that involves not only continuity and conformity but also change and the emergence of novelty. Parents often depart from the framework of their own childhood experiences and rear their children with values that differ from those that were acquired in their own socialization. Children and parents evaluate and may reconstruct for themselves behavior patterns and values different from those of the previous generation. It is the new emphasis on qualitative change and novelty that brings the study of socialization into the realm of developmental science.

During the unidirectional era, the parents' causal role in children's socialization was considered to be direct and uncontested (e.g., Sears, Maccoby, & Levin, 1957). Although many of the parenting variables, dimensions, strategies, and styles that continue to be discussed today were identified, this was an era that was more concerned with the outcomes of childrearing—catalogs of associations between broad parent variables conceptualized as antecedents and child variables conceptualized as outcomes. However, there was little research on the underlying processes of social interactions and continuous developmental and contextual change by which antecedents became transformed into child outcomes.

Kuczynski's (2003) review of the early socialization literature revealed a number of implicit background assumptions that supported a mechanistic and linear model of causality in parent-child social interactions. Kuczynski identified four such assumptions: a *unidirectional model of causality*, a *model of unequal agency* where parents were considered to be active and children passive in the process of socialization, a model of context that considered parents and children interacting as *separate unrelated individuals*, and a model of *static unequal power*.

In the parent-child relationship these background assumptions of socialization theory were gradually challenged and replaced. Important milestones along the way included the ideas of dialectical transaction (Sameroff, 1975a, 1975b), the idea of social interactions in relationship contexts (Hinde, 1979; Maccoby & Martin, 1983), and the idea of parents and children constructing and interpreting their interactions with each other (Grusec & Goodnow, 1994). In place of the unilateral assumptions, Kuczynski (2003) proposed a reformulated set of bilateral background assumptions—a *dialectical model of bidirectional causality*, considering parents and children as *equally agents, culturally embedded relationships as context* for parent-child interactions, and a model of *interdependent power asymmetry* in parent-child interactions. Kuczynski argued that these bilateral assumptions provide a better fit for understanding contemporary knowledge about the dynamic nature of parent-child social interactions.

Dynamic concepts such as bidirectional causality, contextual specificity, and child agency receive wide endorsement at the theoretical level (e.g., R. M. Lerner, 2006; Overton, 2006, Chapter 2, this *Handbook*, this volume; Sokol, Hammond, Kuebli, & Sweetman, Chapter 8, this *Handbook*, this volume). However, these ideas have not not been implemented to a significant extent in socialization research and practice. In a comment on the state of the socialization literature, leaders in the field (Collins, Maccoby, Steinberg, Hetherington, & Bornstein, 2000) stated that textbooks, empirical studies, and popular opinion often continue to favor views of parental influence as linear and deterministic.

The parenting style literature presents an example of this linear deterministic approach to socialization. Baumrind's (1971) conception of *parenting styles*, a typology based on different combinations of parental control and parental warmth has dominated the socialization literature for 50 years. This work has drawn attention to an important pattern of parenting. However, Darling and Steinberg (1993) observed that despite consistent evidence that the authoritative style—parents who are warm but firm in the exercise of control—leads to competent children, the underlying processes of social interaction remained and remain unclear. Indeed, the constituent practices underlying the construct of *firm control* are still being debated (Baumrind, 2012; Farkas & Grolnick, 2010). Moreover, there is little conceptualization of *warmth* as a parenting practice or analysis of the causal role of warmth in determining the reported outcomes. Direction of effect has also been disputed. For example, Lewis (1981) argued that measurements of the authoritative parenting style conflated the parent's behavior with that of the child and left open the possibility that the parent's control style was an adaptation to children's preexisting dispositions for compliance. Stattin and Kerr (2000) found that parental knowledge of children's activities, which was once understood to be a consequence of the parental control practice of monitoring, is more strongly predicted by children's voluntary disclosure to parents. Extending their analyses of the child-influenced measurement of parental knowledge to parenting styles Kerr, Stattin, and Özdemir (2012) found that measures of parental control that focused only on parental behavior resulted in weaker association with adolescent adjustment than traditional measures of control that include items based on parental knowledge. Moreover, adolescent behavior predicted changes in parenting style, and these child effects were stronger than parent effects.

Research on parenting styles is an example of a literature where there has been an imbalanced focus on the predictive utility of abstract variables to the detriment of an understanding of underlying process. Correlational research, including, structural equation modeling, is useful in identifying associations between broadly conceived parent and child variables but does not illuminate the intervening processes of social interaction and relationship formation that underlie abstract measured variables. Moreover, the implied static, decontextualized conceptions of parental behavior and linear notions of their effects are simply not valid (Holden & Edwards, 1989). Accumulating additional correlations between child outcomes and decontextualized parental behaviors has limited usefulness for advancing knowledge on the process of socialization (see also Peterson & Bush, 2012). The challenges are conceptual and no amount of statistics will advance knowledge without commensurate innovations in the conceptualization of variables and processes.

Implementing dynamic developmental models of socialization is difficult because it requires a knowledge translation process between different levels of theoretical analysis including: worldviews, ontological/epistemological frameworks, substantive theory, and models and variables developed for particular areas of enquiry. Ideally, substantive theory should guide the choice of methods for collecting data and the constructing of empirical findings. However, even this depiction of knowledge translation is limited because it considers only the case of the scientist creating knowledge for its own sake. Another level of analysis, is knowledge translation to the level of practice which, in the ideal of the science practitioner model, the therapist, social worker, or service provider looks to research for practical guidelines for assessment, and intervention.

Researchers who work at different levels of analysis, metatheoretical, theoretical, empirical, and applied are often different people with different interest in engaging in abstract concepts. This situation creates a potential for gaps in knowledge translation between the levels of analysis. Theoreticians working at the metalevel of overarching frameworks may or may not engage the interest of empirical researchers and may use terminology based on a background knowledge that is not shared. This lack of translation makes the ideas inaccessible to researchers when connections to specific phenomena have not been made explicit. In turn, empirical researchers may or may not influence the work of practitioners. Applied scientists often have little use for the theoretical concepts and the findings of empirical research. This is because empirical research often produces findings whose meaning is rendered abstract by research designs that require aggregation of variables and generalization to populations rather than individuals or social relationship who are the real-world context of practitioners (Smedslund, 2009). Abstract concepts and findings offer little direction when applied to clients who are agents who make choices about what they want therapy to look like, what homework they are willing to do, and whose reality is highly contextualized and arises from diverse experiential histories.

Success in the flow of knowledge translation requires scientists who have a foot in each of the adjoining levels of theoretical analysis such that knowledge flows in both directions at each level. There is a need for research efforts that translate metatheory to the study of substantive phenomena or to translate the products of substantive theory and empirical findings into a form that can be communicated to or applied to real people in real-life circumstances. The goal in this chapter is to propose such a translation from metatheoretical metaphors based on dialectics to substantive theory (the dialectical/transactional approach of social relational theory) to implications for applied practice.

TWO METAPHORS FOR SOCIALIZATION: THE ONE-WAY ARROW AND DIALECTICS

Metaphors have been and continue to be foundational in scientific theories and models constructed for the purpose of understanding socialization and parent-child relationships (Kuczynski, Lollis, & Koguchi, 2003; Overton, 1991). The approach to metatheory in this chapter is to examine two underlying metaphors of process in socialization research, the one-way arrow → and dialectics ←→. The one-way arrow, which corresponds to a *mechanistic* ontology that considers phenomena in terms of decontextualized behaviors, passive reactivity, continuity, and linear outcomes (Overton & Reese, 1973). The conception of *dialectics* in this chapter is consistent with the organismic-contextualist conception of Dynamic Systems Theory (Witherington, 2011, Chapter 3, this *Handbook*, this volume) as well as the Relational-Developmental-Systems approach (R. M. Lerner, 2006; Overton, 2013, Chapter 2, this *Handbook*, this volume; Overton & Lerner, 2012) that emphasize dynamic coaction that characterizes the relations among components of any system.

Early socialization research was influenced by the one-way arrow metaphor (i.e., parent → child) that reflected cultural ideas of parents as shapers of children's development (Kuczynski et al., 2003). Research associated with the one-way arrow tended to conceive of parents and children as static bundles of traits that behave in predictable, unchanging, and consistent ways, and analyses of parents and children, respectively, as agents and objects or causes and effects.

The mechanistic conception of socialization was preserved in early models of bidirectional influence between the parent and the child during social interactions. Sears (1951) conceived of social interactions as an interconnected series of stimulus–response sequences in which each person's behavior was simultaneously a reaction to the other's previous behavior and a stimulus for the partner's subsequent response. These exchanges have been conceptualized in various ways. A child may reciprocate a parent's smiles or irritable responses with smiles or irritable behaviors of their own; a parent may soothe a crying child in the manner of a homeostatic control system (Bell & Harper, 1977), or a parent and child may reciprocally provide contingent negative reinforcement for each other's coercive behavior (Patterson, 1982). Empirically such models translate into an emphasis on continuity or additive, incremental change over time, instead of transformation; impact of early experiences, instead of adaptation; and transmission and shaping instead of construction and problem solving.

The principal alternative metaphor in psychology is dialectics (Overton, 2006, Chapter 2, this *Handbook*, this volume; Valsiner, 2012). Dialectics is a metatheory about the dynamic nature of all phenomena. All phenomena and every process consist of an opposing system of forces that actively relate to produce continuous qualitative change. This basic idea of dialectics has appeared in Western and Eastern cultures throughout history and has been communicated in a variety of metaphors. For example the "thesis–antithesis–synthesis" metaphor suggests that the mind recognizes an inherent contradiction in ideas and in the struggle to overcome the resulting tension, forms a new synthesis that temporarily resolves the contradiction in a novel way. Similarly, the yin-yang, ☯, metaphor from Chinese philosophy describes how polar opposites or seemingly contrary forces are inherently interconnected and interdependent in the natural world, and how they give rise to each other in the process of relating. Overton (2006, Chapter 2, this *Handbook*, this volume) interprets dialectics as described, but includes several subsumed concepts such as the *embodied mind*, which captures the behavioral, symbolic, and biological nature of individual functioning in a relational context.

The metaphor of dialectics conveys a view of causality that is more complex but more realistic and experientially recognizable than the metaphor of the decontextualized, one way, cause → effect arrow metaphor commonly used in socialization research. Dialectics draws attention to ideas of context, change, and nonlinear synthesis. This approach is a metaphor that is better fitted to modeling lived experience. A popular website, Dialectics for Kids (http://home.igc.org/-venceremos/index.htm), argues that dialectical processes are so pervasive that they are the basis for the everyday understanding of physical, biological, and psychological phenomena and that even children can quickly grasp the ideas.

> Dialectics is a tool to understand the way things are and the way things change. Understanding dialectics is as easy as 1–2–3. One-Every thing (every object and every process) is made of opposing forces/opposing sides. Two-Gradual changes lead to turning points, where one opposite overcomes the other. Three-Change moves in spirals, not circles. (What the Heck is Dialectics? http://home.igc.org/~venceremos/whatheck.htm)

Dialectical ideas are present in all *organismic* approaches (e.g., Overton, Chapter 2, this *Handbook*, this volume; Overton & Reese, 1973) and are implicit in theories and research that emphasize the importance of human agency and in the process of meaning construction. These domains of scholarship include research on social cognitions in social and developmental psychology, relationship theories, attachment theory, and ecological theory (Glassman, 2000). In short, aspects of dialectics have had an important impact on psychology but the origin of the ideas in dialectics have not always been explicitly acknowledged or comprehensively unpacked for use in research and practice. Constructivism (Smetana, 2011), social constructionism (Morrow, 2003), and social cognitive theories (Grusec & Goodnow, 1994) share with dialectics the core assumption of human agency, even if they are not comprehensive or consistent in considering the full implications of a dialectical approach. Advances in these areas can be made with a more complete implementation of a dialectical perspective within a transactional model of socialization.

There are alternative approaches to dialectics and different systems have drawn on different features of the dialectic concept as well as fundamental conceptual differences. Reese (1982) distinguished dialectical idealism from dialectical materialism. In dialectical idealism syntheses are conceptualized as states of continuously better integration as contradictions are resolved. An example is Piaget's stage theory of cognitive development. Dialectical materialism assumes that there is no "ideal" state toward which synthesis progresses. Examples include contextualist dialectics in personal relationship theories (see Baxter & Montgomery, 1996, for a review). Contextualism focuses on action in the here and now, and on contradictions that appear in those acts. The approach to dialectics in this chapter is contextual-organismic in nature (see Overton, 2006, Chapter 2, this *Handbook*, this volume; Witherington, Chapter 3, this *Handbook*, this volume). This approach is integrative and while asserting the importance of holism and contradiction, includes a focus on the developmental implications of the concept of *synthesis*. Synthesis is a critical concept for understanding nonlinear outcomes that result from the coactions of contradictory components in the whole.

The Transactional Model

The *transactional model* of development proposed by Sameroff (1975a, 1975b, 2009) is a model of qualitative change. Children and the environment are engaged in continual transformation as each responds to new emerging characteristics of the other (see Figure 9.1). According to

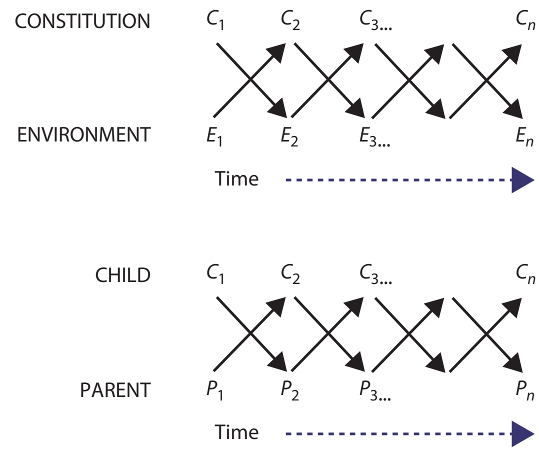

Figure 9.1 The original transactional model and its adaptation for parent-child transactions.

Source: From "Early Influences on Development: Fact or Fancy?" by A. Sameroff, 1975, *Merrill-Palmer quarterly*, *21*, pp. 267–293. Copyright © 1975 by the Wayne State University Press. Reprinted with permission.

Sameroff (1975b),"The child alters his environment and in turn is altered by the changed world he has created" (p. 281). Sameroff (1975a) asserted that the underlying process of the child's transactions with the environment was dialectical in nature. "In every developing system, contradictions are generated and it is these contradictions which provide the motivation which lead the organisms to the higher level of organization found in developmental series" (p. 74). The innovation in the transactional model concerned the qualitative transformations occurring in the parent and the child over time. Conceptually, the model anticipated current dynamic systems approaches that emphasize the dynamic nonlinear and mutually constitutive relations between the individual and its context (Overton, 1975, 1991).

Despite the importance of the transactional model for consolidating the idea of bidirectional influence, few researchers have taken up the challenge of Sameroff's dialectical conception of transactional processes. Instead, most have interpreted the parent to child and child to parent directions of causality as discrete arrows, which lead to a conception of bidirectionality in terms of reciprocal exchanges of behaviors (Kuczynski & Parkin, 2007). For example, in social interactional theory (Patterson, Reid, & Dishion, 1994) bidirectional influences are linear and the elements are not changed by their experience with other elements.

A major concern of the transactional model was to improve prediction of both child and parent outcomes (Sameroff & Chandler, 1975). In the original depiction of the model presented at the top of Figure 9.1, Sameroff

(1975b) highlighted the child's temperamental constitution and its dynamic relation to the distal environment such that both the environment and the child were equally important in the process of mutual transformation. However, as noted by Sameroff (2009), the compelling examples of the role of contradiction in microsocial transactions occurring between parents and children promised to illuminate the understanding of underlying proximal socio-emotional processes. When applied to parents and children (Figure 9.1, bottom) the location of the transaction was the change in meaning that occurred as parents and children attempt to make sense of the contradictions generated by their interaction. As stated by Sameroff (1975b):

> The contradiction that has occurred consists between a meaning system which sees the child as an object to be manipulated, and one which sees the child as a center of needs and desires existing independently of the needs and desires of his parents. . . . The dialectical model would posit at each stage the contradictions with which the mother is faced in trying to understand her child. (p. 77)

More generally, contradiction and qualitative change occurs whenever an individual changes a representation of an event causing the individual to think or act differently than before the change (Sameroff, 2009). Although this conception shares assumptions with symbolic interactionism (Mead, 1934) about the capacity of human agents to interpret each other's behaviors, it added dialectical assumptions concerning the role of contradiction is producing qualitative change.

Despite introducing a dialectical model for understanding social transactions, Sameroff did not fully explicate how an organismic-contextual model of dialectics can inform assumptions about parents and children and the processes by which they relate to each other. The dialectical transactional model was ahead of its time and required a framework of supportive theoretical models and empirical knowledge regarding parent-child relationships. This chapter outlines a social relational theory perspective to explore how reformulating conceptions of context, antecedents, processes, and outcomes using dialectical conceptions of transaction supports the study of dynamic parent-child socialization processes as well as provides direction for clinical application. The chapter uses the core idea of transaction (Sameroff, 1975a, 1975b) as a building block for new applications of the model for understanding the dynamics of parent-child relationships, and the nature of bidirectional influences that occur during transactions.

Social Relational Theory

During the past decade, Kuczynski and colleagues (Kuczynski, 2003; Kuczynski & Parkin, 2007, 2009; Kuczynski, Pitman, & Mitchell, 2009) have been developing social relational theory as an open-ended dialectical framework for studying socialization processes in the family in a more dynamic way than was possible under mechanistic assumptions of socialization. In social relational theory, parents and children are considered to interact as human agents as components of a culturally embedded social relationship. A distinctive feature of social relational theory is that it places equal emphasis on the perspectives and actions of children as well as those of parents. In addition, parent and child agency is understood using the principle of *holism in a dialectical context*. Thus, although the model draws attention to the separate goals and interpretations of parents and children, both parents and children are assumed to cope with or resolve conflicting views because they share a continuing interdependent relationship. The model also assumes a dialectical concept of causality that is interpreted through the dialectical metaphors of contradiction and synthesis. Contradictions give rise to uncertainty that creates opportunities for novel syntheses, which sets the context for further developmental change. Dialectical bidirectional influence ←→ comes about during social transactions as parents and children interpret or construct meanings from each other's behaviors and resist, negotiate, and accommodate each other's perspectives within the constraints of their relationship (Kuczynski & Parkin 2007). This concept of causality is consistent with other complex models of causation, including *reciprocal determination* (Overton & Reese, 1973), *fusion*, (Greenberg, 2011; Partridge, 2011), *relational bidirectional ←→ causality* (R. M. Lerner, 2006), *relational ←→ causality* (Gottlieb & Halpern, 2002; Overton, 2006, Chapter 2, this *Handbook*, this volume), and *circular causality* (Witherington, 2011, Chapter 3, this *Handbook*, this volume).

The discussion in this chapter is limited to bidirectional ←→ influence in parenting as it pertains to children's development. However, an implication of the transactional model is that the act of parenting is also a driver of the parent's continuing adult development and socialization. The argument is that people who become parents, have children as part of their environment, and are involved in the bidirectional childrearing process, follow a different developmental trajectory than people who do not engage in parenting roles (Palkovitz et al., 2003). Having children in parents' environment has a massive impact on all aspects of parents' lives, and their outcomes as individuals (Ambert, 2001; De Mol & Buysse, 2008a).

In the next sections, each dialectical concept is described at the level of dialectical metatheory and this is followed by translations of its implications for research on socialization and parent-child relationships within social relational theory. A subsequent section considers the implications of a social relational theory for clinical interventions in families.

HUMAN AGENTS: THE INTERACTING COMPONENTS IN THE DIALECTICAL WHOLE

The nature of a phenomenon in dialectics is an ontological question that is dependent on the specific subject matter. For the phenomenon of socialization in the family, the question is whether parents and children should be regarded as living, active agents coacting as components in a long-term relationship context, implying an organismic-contextual ontology, or should they be regarded as inert, passive objects whose properties are independent of context, implying a mechanistic ontology. *Agency* refers to the active contribution of human beings as components–parts—of a complex dynamic causal system. The parts of a holistic, dynamic, dialectical system are inherently active, self-organizing, self-regulating, and change independently of external forces. In fact, the very definition of self-organization is "a process of creating structure and order without explicit instructions or guidance from outside" (van Geert, 2003, p. 654). In contrast, the elements of a mechanical system—defined as an aggregate of elements—are inert, and change only when some external force or efficient cause is applied.

Social relational theory makes a number of stipulations as a complex starting point for conceptualizing agency in parent-child relationships. First, parents (or caregivers) and their children are equally human agents with inherent capacities to make sense of the environment, initiate change, and resist domination by others. Second, although parents and children are equally agents, they are unequal in power. Third, the dynamics of parents' and children's agency and asymmetrical power must be understood in the holistic context of their mutual relationship. This complexity reflects a considered attempt to transcend historical problems regarding agency as a theoretical construct. As reviewed by Kuczynski (2003) these problems include the narrow disciplinary or topic-bound definitions of agency; uneven attribution of agency to parents and children, cultural barriers to the perception of children's agency; and insufficient analysis of the relation of agency to other concepts such as "influence" and "power." The following sections emphasize the perspective of children's agency because it is children's agency that historically has been discounted in the socialization literature. Subsequently, the implications of considering parent and child agency in parallel are discussed.

Universal Manifestations of Agency

The universal aspect of agency refers to the ontological assumption that to be human is to be an agent. People are intentional, self-organizing, proactive, self-regulating, and self-reflecting organisms who actively contribute to their life circumstances (Bandura, 2006; Deci & Ryan, 2002, Overton, Chapter 2, this *Handbook*, this volume) and the foundations for agency are present at birth. Analytically, agency can be partitioned into three aspects *autonomy*, *construction*, and *action* (Kuczynski, 2003). However, in practice, these aspects represent motivational, cognitive, and behavioral features of agency that are coordinated in a single process. Individuals construct because they act, and autonomy motives reflect and protect the individual's inherent need to function as agents.

Autonomy

Autonomy is the motivational aspect of agency and refers to a universal motive for self-determination and self-preservation. *Self-determination* refers to the system of basic human needs for competence, relatedness, and autonomy as described by self-determination theory (Deci & Ryan, 2002). Needs for feeling effective in one's ongoing coactions with the social environment, for feeling connected to caring for and being cared for by others, and for perceiving that one is the origin or source of one's own behavior even when actions are influenced by outside sources, are inherent characteristics of being human. Fulfilling these needs are essential for growth, an integrated self, and psychological well-being. *Self-preservation* is the motive that results when a person's ability to fulfill his or her needs is blocked or thwarted in areas and contexts that matter to the person. An important manifestation of self-preservation is resistance (Brehm & Brehm, 1981). When people experience threats to their behavioral freedoms, experience impositions of meanings or standards that contravene their self-constructed understanding of social situations (Turiel, 2010, Chapter 13, this *Handbook,* this volume), or perceive injustice, they attempt to restore their autonomy through overt and covert resistance. Even in contexts of extreme oppression, where it is not safe to resist overtly, people express resistance in indirect, covert, and creative ways (Scott, 1990). The idea that resistance is a manifestation of autonomy development is found in classic theories of toddler negativism (Wenar, 1982). However, parallels between phenomena of toddler negativism and resistance in adulthood suggest that although its form may change, resistance is a continuing theme in development throughout the life span (Kuczynski & Hildebrandt, 1997).

Construction

Construction refers to the capacity of parents and children to interpret their coactions with the environment and to create new meanings from their experiences. The construction of meaning necessarily entails both emotions and cognitions. This inclusive definition of construction is informed by the concept of *embodied action*, the idea that people are active agents with a particular kind of lived body (Andersen, 2007; Overton, Müller, & Newman, 2008). Embodiment refers "not merely physical structures, but *the body as a form of lived experience, actively engaged with the world of sociocultural and physical objects*" (Overton, 2006, p. 48). The *body as form*, represents the holistic integration of the biological dimension of life, the *body as lived experience actively engaged* represents the integration of the psychological person, and the *body actively engaged with the world* points to the integration of the sociocultural and physical context. Thus, embodiment entails the synthesis of how we, as active agents (psychological persons), influence and are influenced by our biological and sociocultural worlds.

During the 1990s, developmental researchers began to adopt a view of children as actively constructing their knowledge and values in the process of socialization (Grusec & Goodnow, 1994; Kuczynski, Marshall, & Schell, 1997; Lawrence & Valsiner, 1993; Smetana, 2006). All internalized products of socialization, even that of intergenerational similarity must be constructed by children from the messages and reactions presented by their social context. Parents are active in packaging the message so that children can accurately interpret and accept the parent's perspective (Grusec & Goodnow, 1994). However, the constructive capacities of children places limits on parental influence. Both the interpretation and the acceptance of the message ultimately depend on the child's agency.

According to *social domain theory* (Smetana, 2006; Turiel, Chapter 13, this *Handbook*, this volume) children make sense of social situations by interpreting received messages, and acting on these interpretations. In this way the child constructs distinctions among various domains of values including those that are moral (avoiding harm, justice, equal treatment fairness), conventional (situation specific standards of appropriate behavior), prudential (safety and well-being), and personal (preferences). They also develop different modes of reasoning to work through conflicts and dilemmas and use principled rationales to defend their positions on future occasions. Further, according to the social domain position, to the extent that parents provide domain-appropriate information and use domain-appropriate socialization strategies they may promote their children's moral development. Lawrence and Valsiner (1993, 2003) argued that the potential for innovation occurs not only as children internalize social messages but also as they apply (externalize) their constructed knowledge for their own purposes in the social world. Through the child's interpretation of the social context and through their appropriation of these meanings for their own purposes, personal sense is given to the ideas, messages, roles, and relationships that pertain to the person's culture.

Action

To act, "means being able to intervene in the world or to refrain from such intervention, with the effect of influencing a specific process or state of affairs" (Giddens, 1984, p. 14). The term *action* is used in preference to behavior because emphasizes the guidance of behavior by internal processes including meanings, intentions and goals. Following Brentano (1874/1995), all acts, even those occurring at the most sensorimotor level of functioning, intend some object; thus, all acts are intentional. However, this fact does not mean that all acts are self-consciously intentional. People may be unaware (i.e., lack self-conscious or symbolic intention) of the reasons for their choices (De Mol & Buysse, 2008a), or for the meanings underlying their emotional responses (Patterson et al., 1992) during social interactions.

Updates on the growing understanding of the actions and strategies that children use to influence parents have been presented with regularity in research reviews over several decades (e.g., Grusec & Goodnow, 1994; Kuczynski, 2003; Maccoby & Martin, 1983). The new discoveries generally take the form of learning to "see" agency in what was previously perceived as passivity, reactivity, or submission. Thus, young children's nonverbal behaviors such as smiles and cries (Rheingold, 1969) or their approach and avoidant attachment behaviors in stressful situations (Cummings & Schermerhorn, 2003) have been reinterpreted as actions that reward and punish parental behavior. In other instances, agency has been located in phenomena were the child was previously conceptualized as passively complying with parental control. For example, Kochanska, Kim, and Boldt's (2013) research on children who are receptive toward the parent's agenda or complied willingly to parental requests indicates that agency can occur within compliance. As well, Stattin and Kerr (2000) found the sources of parental knowledge of adolescents not in parental control through monitoring and surveillance but through children's voluntary self-disclosure.

Research on parental discipline is especially compelling in revealing children's agency because disciplinary encounters are contexts where parents are assumed to have more power to set agendas and enforce outcomes (Hoffman, 1975). Children have been found to influence parents in all phases of the discipline encounter. Depending on the issue, children may challenge parents about the definition of the transgression, for instance, whether the behavior is under the jurisdiction of the parent or the child (Smetana, 2006). Children between the ages of 2 and 5 develop strategies that are increasingly assertive and skillful for challenging parents in overt conflict (Kuczynski & Kochanska, 1990). In middle childhood and early adolescence, children effectively use their own coercive strategies to evade or sidetrack the parent's ability to enforce compliance and to intimidate parents into avoiding future confrontations (Patterson, 1982). They also show a growing complexity of overt and covert strategies for resisting unwelcome parental requests and for achieving their own goals (Kuczynski, Pitman, Parkin, & Rizk, 2011). Parkin and Kuczynski (2012) found that adolescents express overt resistance assertively and engage in an array of covert forms of resistance when they wish to avoid confrontation. For example, they may comply with parental requests in a minimal way following the letter, but not the spirit, of parental requests. Alternatively, they may behaviorally comply, but cognitively reject the parents' message (Parkin & Kuczynski, 2012). Adolescents strategically manage parents' knowledge of their activities and whereabouts, thereby undermining parents' ability to intervene in aspects of their lives that children wish to keep private (Smetana, 2011; Tilton-Weaver & Marshall, 2008).

Individual Differences Supporting Exercise of Agency

There are also individual differences, originating in biology, experience, and context that affect the quality of expression and effectiveness of agency. For example, the concept of embodiment (Andersen, 2007; Overton et al., 2008) suggests that each individual has a qualitatively unique style of expressing agency comprised of characteristic patterns of action and ways of interpreting the environment, and unique concerns and intensities regarding their experience of autonomy. Thus, concepts such as "personality" or "temperament" can be reframed as reflecting embodied qualities in the expression and experience of agency.

Individual differences in the expression of agency can also be considered as reflecting differences in *interpersonal power resources* (French & Raven, 1959). Although all humans are agents, they differ in the resources that they have to support their actions as agents. (See J. Lerner et al., 2012; R. M. Lerner, Lerner, Bowers, & Geldhof, Chapter 16, this *Handbook*, this volume; Overton, 2010, Chapter 2, this *Handbook*, this volume, for further discussions of system resources.) Stated in another way, parents and children are equally agents but they are unequal in power. Conceptualizing power as resources allows a dynamic and nuanced assessment of the assets that parents and children bring into their social interactions with each other. Kuczynski (2003) described three categories of power resources that pertain to both parents and children: individual, relational, and cultural.

1. *Individual resources* include the capacities to back up or resist influence attempts with physical strength and capacity to reward. Individual resources also include expertise, information that can be brought to bear in rational arguments, as well as the capacity to think ahead, and to set goals.
2. *Relational resources* are an individual's access to personal relationships as a support for their exercise of agency. This happens when individuals can enlist the aid of others to act for them when they cannot exert direct influence or when they act collectively to achieve goals that are beyond the scope of individual action (Bandura, 2006). In the sociological literature a parent's or child's personal relationships in the family and outside of the family is an important component of the concept of *social capital* (Morrow, 1999). An example of a parent's use of relational resources includes acting with a spouse in a parental alliance or accessing social supports such as friends and community relationships to achieve a socialization goal. Children's effectiveness as agents is greatly enhanced by relational resources. For example, children rely on their relationships with parents to

obtain social and material resources for themselves as well as access to other resources under the parents' control. They may also enlist the support of parents to intercede for them with their siblings, or with peers, teachers, and mentors outside of the home.

3. *Cultural resources* refer to the rights, entitlements, and constraints conveyed to individuals by the laws, customs, and practices of a culture. For example, parents draw from culture their legitimate authority to define certain of their children's actions as "misbehaviors" and to set and enforce compliance to their rules. Culture may also be an important source of the child's power. Western culture is notable for recognizing numerous rights of children for appropriate standards of care, rights to education, freedom from maltreatment, as well as providing norms for expression of autonomy. Such norms constitute resources that legitimize and enable children's power and puts constraints on the kinds of power that parents can exercise over children. In cultures where children are accorded fewer rights or other resources, children continue to act, interpret, and resist as agents, but their effectiveness as agents will be diminished and the way they express their agency will take qualitatively different forms that are afforded by their cultural context.

Assumptions About Unequal Power and Causality

The assumption that power between parents and children is unequal or asymmetrical is fundamental to any understanding of parent-child relations. Parents have more knowledge, physical strength, control over resources, and their legitimate authority is endorsed by culture (Maccoby, 2000). Although asymmetrical power in parent-child relationships is indisputable, the argument that parents have more power than children has been a conceptual barrier preventing deeper acceptance of such concepts as bidirectionality (←→) and the significance of the agency of the child. For example, in response to a growing literature on child effects, Hoffman (1975) used the argument of unequal power to reinstate a unidirectional interpretation of causality in socialization. His argument was that, child influence notwithstanding, parents *must* have more influence because parents have more power to back up their roles as influence agents than children.

Kuczynski (2003) acknowledged that there is unequal power between parents and children but questioned implicit conceptions of unequal power as a fixed imbalance in resources that determined the direction of causality in a mechanistic way (i.e., more power is equated with greater causality). A static conception of asymmetrical power is not useful for understanding many ordinary phenomena of everyday family life. Frequent parent-child conflict, child assertion and resistance, parental receptivity to children's influence, and parental vulnerability and loss of influence in families presenting at clinics (Kuczynski, 2003) suggest that parents do not exercise or experience power in a way consistent with a model of static asymmetry. Kuczynski (2003) proposed that unequal power in parent-child relationships can be conceptualized as a dynamic *interdependent asymmetry*.

- Power is a bilateral phenomenon such that both children and parents have individual, relational, and cultural resources to draw on to support their actions as agents. Because of their inherent capacities to engage in interaction and to provide rewarding and aversive responses to parental efforts (Rheingold, 1969), even infants have individual resources.
- The parent-child relationship is crucial in understanding the dynamics of power in parent-child interactions. The assumption is that power dynamics between persons in an interdependent long-term relationship differs from power relations between complete strangers (Kuczynski, 2003). For instance, parents and children can make predictions gained from knowledge regarding the others' personalities, preferences, and vulnerabilities gained in the long-term relationship (see holism: the systemic context, this chapter), and an implication of interdependence is that both parents and children are receptive and vulnerable to the others' influence. These power dynamics stem from their distinctive relationship context and are not available to unrelated dyads.
- The relative power inequality between parents and children is dynamically negotiated during social interaction. Porta and Howe (2012) found that the relative power between parents and children and the specific power resources used by them change according to context throughout the day. Moreover, the young child's immature self-regulatory capacities (Kopp, 1982; McClelland et al., Chapter 14, this *Handbook*, this volume) paradoxically place constraints of the kinds of demands that a parent can realistically make of their child and constrain parents to follow the pace of the child's capacities. The child's individual resources, including social skills, rapidly increase throughout development so power differentials in various resources will vary considerably across age. By adolescence, the individual's physical

strength, expertise in various areas (peer culture, use of technology), and persuasive skills may match or become greater than those of the parent.

The construct of interdependent asymmetry suggests that research should explore how various power resources enter into parent-child transactions to produce dynamic changes in relative power. Consistent with the dialectical perspective in social relational theory, transactions between individual, relational, and cultural resources in parent-child relationships create novel syntheses such that both parents and children are receptive and vulnerable to each other's influence.

Contribution of Agency Perspectives

A focus on human agency clarifies the causal contributions of parents and children to the process of socialization. Future research would benefit from a focus on questions regarding process: What does the child do and think regarding parental actions in different contexts, at different ages, and in relation to their different parents? These research questions require equal attention to what parents do and think with regard to children's actions. Considering parents and children as equally agentic can guide researchers to ask parallel questions about parent-child influence and agency. The same basic understanding of agency is also the best guide for research designed to explore the social strategies, goals, motives, and interpretive activities of both parents and children.

An enhanced focus on children's agency is a corrective strategy regarding the neglected aspects of children's actions and constructions in the process of socialization. Valsiner, Branco, and Dantas (1997) coined the term *filiating* to counter the unidirectional implications of *parenting* and to focus attention on the child's actions and perspectives in the parent-child relationship.

An enhanced focus on parental agency can also lead to a better understanding of what parents contribute to the socialization of children. According to Holden and Edwards (1989), parental behavior has not been studied in a way that illustrates parental intelligence. These authors argue that parental behaviors, dimensions, and styles have been studied in a static decontextualized way that is not consistent with what is known about the dynamic, relational bidirectional ←→ and situational specific dependency of parental behavior. "Typically, the surveys portray children as generic, parents as trait-like and unthinking, and parent-child interactions as unidirectional and a-contextual" (Holden & Edwards, 1989, p. 490). Moreover, the preponderance of research on parental behavior such as discipline has studied parents in a reactive mode, when children have already transgressed and parents have relatively few options in responding to a problem that has already occurred (Holden, 1985). This means that measurement approaches that focus exclusively on decontextualized discipline strategies do not give parents much scope to display intelligent behavior.

Examples of approaches that do shed light on parental intelligence highlight parental agency. Holden's (1985) conception of *proactive behavior* emphasizes parents' use of long-term or short-term future-oriented strategies that prevent problematic behaviors from occurring in the first place. Research on parental goals emphasizes the contextual nature of complexity of parental actions and the competing goals that they consider when responding to a child's transgression (Dix & Branca, 2003; Hastings & Grusec, 1998; Kuczynski, 1984). The concept of *meta-parenting* (Holden & Hawk, 2003) conceives of parenting as a process of problem solving and reflection, before during and after specific childrearing situations. In addition, models of *mindful parenting* (Duncan, Coatsworth, & Greenberg, 2009) promise to shed light on parental cultivation of intentional awareness to parent-child interactions thereby aiding their conscious self-regulation of their parenting actions.

Another direction for research to consider is the joint agency of parents and children in their transactions with one another. There is a need for concepts that consider parents and children interacting "as if" they recognized each other's agency, thus anticipating and accommodating each others' interpretive capacities, autonomy motives, and different perspectives. This would be a logical development in the history of socialization research that can be conceptualized as beginning with a unilateral perspective of agent/object relations, and moving to a bilateral perspective of parents and children engaged in agent-agent transactions. However, for a full dialectical perspective to be implemented, an additional step is needed: and that is to consider parents and children interacting as components in the holistic context of their shared relationship.

HOLISM: THE SYSTEMIC CONTEXT

The principle of holism refers to the systemic structure of phenomena in which interdependent parts or components always exist in a dynamic context. As conveyed by the yin-yang metaphor of unity of opposites, the structure of systems in dialectics is both complex and dynamic because systems contain contradictory components that coexist side by side in a tension-filled state. Moreover, the whole and its components are mutually constituted such that the components dynamically interact not only with each other but also with the context that they mutually make up. An important implication is that the *whole is different than the sum if its parts*. That is, individual components must be understood as interrelated parts of a whole system because neither individuals nor their social or physical environments are causal on their own.

It must be recognized that any system under consideration is part of a larger whole system of relations, each of which constitutes a different level of analysis. Whole and part are relative terms because wholes are embedded in larger wholes and the specific meanings of these terms change according to the context in which they are applied (Overton, 2006, Chapter 2, this *Handbook*, this volume; Wagoner, 2011). Biologists have long recognized that organisms are complex hierarchically organized systems, in which higher processes regulate lower processes. Gottlieb (1991) visualized the components of the system as interconnected bidirectional ←→ levels of analysis extending all the way down from individual behavior to neural activity and genetic activity and all the way up to the social environment and culture (see Figure 9.2). This bidirectionality is the reason that Gottlieb and colleagues (e.g., Gottlieb, 2003; Gottlieb, Wahlsten, & Lickliter, 2006) and others (e.g., Overton, 2006, Chapter 2, this *Handbook*, this volume) have argued that the concept *coaction* or *transaction* should replace the term *interaction* except when referring to statistics of the linear ANOVA model. There are continuous bidirectional ←→ influences between parent-child social interactions and physiological and neural process of parents and children (Bugental, Olster, & Martorell, 2003). Similarly, individuals in family relationships, peer relationships, and cultural contexts constitute overlapping systems that have properties that

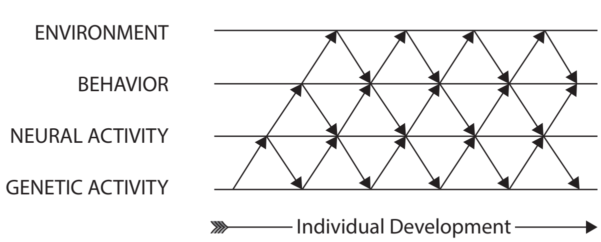

Figure 9.2 Bidirectionality joining biological to individual to social environment (Gottlieb, 1991).

cannot be reduced to the individuals within it. To make dialectical systems amenable to research, it is necessary to apply the principle of hierarchical organization (Wagoner, 2011) in which a given system is isolated for study while acknowledging relations to biological and cultural systems in which they are related.

HOLISM IN SOCIAL RELATIONAL THEORY

An important step in a dialectical analysis is to describe the structure of the whole, and the complex causal relations between the whole and its components. In social relational theory, the minimum level of analysis for the whole is the parent-child relationship. Socialization throughout the life span occurs within a system of close personal relationships (Reiss, Collins, & Berscheid, 2000). Different relationships, including relationships with parents, siblings, peers, teachers, and other adults (Piniata, 1999), come into salience as contexts for socialization as children develop. Thus, in selecting the parent-child relationship as a context for development it is important to recognize that it is a subsystem of a larger system of relationships that are relevant for the phenomenon of socialization.

The dialectical concept of the parent-child relationship as a systemic context departs from treatments of parents and children in unidirectional socialization research. The unidirectional parent-child socialization research tradition operates on the assumption of a decontextualized relationship of isolated interacting individuals. The dialectical research approach, on the other hand, conceptualizes a relational parent-child context of coacting agents embedded in an enduring, interdependent relationship. A classic example of the decontextualized approach is illustrated in the early behavioral model of parent-child interaction and parental management (Patterson, 1997) that focuses on the immediate reinforcement and punishment contingencies of behaviors exchanged in the present. Neglect of relationship context in theorizing about causality may help to explain why the idea of child influence as well as bidirectionality ←→ has met with resistance historically. It is only when one considers the special features of the parent-child relationship as a context for parent and child actions that the very idea that children influence parents despite differences in power makes sense.

Another example of the departure of the dialectical perspective from the traditional decontextualized perspective concerns the measurement of relationship attributes. The traditional approach considers relationship attributes (e.g., parental warmth) to be individual qualities whose linear associations to outcomes are studied. According to dialectical social relational theory, the parent-child relationship is not a static variable. Rather, it is a dynamic process that emerges from and contributes to the dynamics of social interactions. Parents and children are not only influenced by the relationship context but also construct the relationship through their coactions as agents. Phenomena such as enhanced bidirectional ←→ influence between parents and children, the experience and exercise of agency, and the dynamics of power, stem from the relationship context (Kuczynski, 2003; Kuczynski & Parkin, 2007).

WHAT IS THE PARENT-CHILD RELATIONSHIP?

A legacy of the traditional decontexualized approach is that there has been little analysis of the structure of parent-child relationships or of dynamics that emerge from the relationship as a whole. Instead, socialization research has traditionally been constructed around separate parenting functions such as control, teaching, caregiving, and attachment. There has been little attention paid to how these functions relate to each other within the parent-child relationship or the implications of the whole relationship context for the dynamics of parent-child interactions within each function of the relationship.

Dialectical social relational theory draws from general theories of personal relationships (Hinde, 1979; Kelley et al., 1983) and attachment (Bowlby, 1969), as well as the applications of these theories to the parent-child relationship (e.g., Collins & Madsen, 2003; Maccoby & Martin, 1983). Central to most theories is the distinction between a social interaction and a social relationship. *Social interactions* are discrete, moment-to-moment exchanges between individuals, whereas *social relationships* incorporate the psychological and historical context between two individuals beyond the immediate interaction. Two basic properties of the relationship are interdependence and time (Kelley et al., 1983). A relationship requires the *interdependence* of the relationship partners, the degree to which the behaviors, emotions, and thoughts of two people are mutually and causally interconnected. Thus, interdependence means that a close personal relationship must involve bidirectional ←→ influence. *Time* concerns the timeline of close relationships that endure and involve strong frequent and diverse interconnections over time. Hinde's (1979) theory of relationships elaborated the process by which relationships are constructed out of a history of interactions. As dyads accumulate a history of interactions over time, they form relationships, and the emergent relationship subsequently becomes context for future interactions. Hinde and Stevenson-Hinde (1987) describe the process in this way:

> When two individuals interact on successive occasions over time, each interaction may affect subsequent ones, and we speak of . . . having a relationship. Their relationship includes not only what they do together, but the perceptions, fears, expectations, and so on that each has about the other and about the future course of the relationship, based in part on the individual histories of the two interactants and the past history of their relationship with each other. (Hinde & Stevenson-Hinde, 1987, p. 2)

Psychologically, the relationship is a cognitive construction, that represents more than the sum of interactions that objectively occurred in the history of the relationship (Hinde & Stevenson-Hinde, 1987; Lollis, 2003). Each partner in the dyad interprets the others' behavior and creates expectancies, which are representations of themselves and the other in that relationship. These meanings become consolidated in representations of the relationship, including emotions, which then form the filter through which parent and child behaviors are experienced and predictions are made about the others' behavior. Similar conceptions of relational expectancies can be found in *cognitive expectancy models* of relationships (Levitt & Cici-Gokaltun, 2010) and *working models of attachment* (Bretherton & Munholland, 1999).

There is a growing appreciation of the distinctive nature of the parent-child relationship as a context for development. Maccoby (2000) argued that the parent-child relationship is unique and cannot be understood using concepts developed for adult personal relationships. The parent-child relationship is distinctive from other relationships because of the immense number and diversity of interactions that make up their history, the interdependence of the relationship and its involuntary nature. Power dynamics in parent-child relationships are also complex. Russell, Petit, and Mize (1998) argued that horizontal power in addition to vertical power is characteristic of parent-child relationships. This more complex view of parent-child relationships has been incorporated in *domain models* in which parents and children cycle through different domains within the relationship and the goals, functions, and power dynamics underlying parent-child interactions change throughout the day (Grusec & Davidov, 2010; Lollis & Kuczynski, 1997). Taken together, these ideas from the study of relationships provide the basis for a relational perspective on socialization that broadens the idea of what it means to parent a child beyond discipline and control strategies and beyond a focus on immediate contingencies between behaviors exchanged by parents and children during social interactions.

Figure 9.3 presents a *transactional model of parent-child relationships* that depicts the dynamic whole in social relational theory. The model is based on Lollis and Kuczynski (1997) who considered the implications of Hinde's (1979) theory for parent-child relationships. The present model is adapted to reflect changes in the theoretical and empirical literature. One change is the conceptualization of social interaction. In contemporary theory, Hinde's emphasis on the representational expectancies that agents form during interactions corresponds to the dialectical concept of transaction (Kuczynski & Parkin, 2007; Sameroff, 2009), rather than social interaction, which generally refers to exchanges of behavior. Thus, transactions are depicted as the building blocks of relationships. Parent-child interactions are transactional in nature because they involve mutual interpretations of each other's actions in the context of a previous history of social interactions. A single interaction between unfamiliar individuals does not constitute a relationship, but a relationship begins to be formed once individuals begin to predict each other's actions from their representation of what happened before.

The model as a whole represents just one child's working model of the relationship with one parent in a particular cultural context. Transactions between the parent and the child create a relationship context that incorporates the past history and anticipated future course of the relationship as well as experiences of the diverse relationship domains in which they engage on a daily basis. For example, a parent-child relationship considered at Age 10 is based on a history of transactions, including emotions and cognition, occurring over 10 years, and a projected history of the relationship that continues across the life span of the parent and the child. The relationship itself occurs within a cultural context that contributes socially constructed meanings to the relationship as well as to the interactions occurring within the relationships.

Past and Future Dimensions of Relationships

Relationships are constructed over time and are expected to endure. Thus they have a past, a present, and a projected future. The transactions that contributed to the relationship occurred across diverse relational domains, including repeated confrontations with parental authority, situations where the child's attachment security was threatened and was met by parental responsiveness or unresponsiveness, and moments of parent-child intimacy. Expectancies from past transactions, transactions in different relational contexts, and anticipations of the future are sources of relational information that the parent and the child use in interactions occurring in the present.

The intersection of the horizontal and vertical rectangles in Figure 9.3 represents the *relational present*.

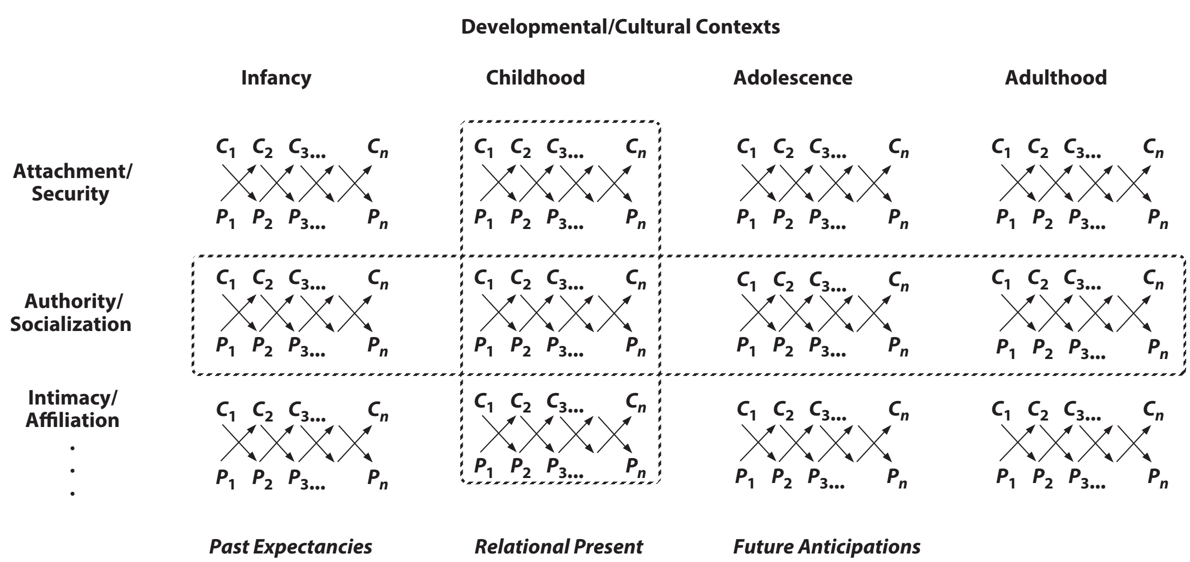

Figure 9.3 The transactional model of parent-child relationships embedded in culture.

In the relational present, parents and children interact with representations of the past and the future of the relationship not just with behaviors that are objectively present. As discussed by Abbey (2012), transactions occur in a boundary zone in irreversible time where, on the one hand, an individual's consciousness is colored by a rich accumulation of past experiences and, on the other hand, an individual's consciousness is anticipating and preadapting to an unknown future. The past and future cannot directly affect the present but interpretations of the meaning of past transactions (Lollis, 2003) and assumptions about what could be the case in the future can guide one's actions (Abbey, 2012).

It is readily apparent to any investigator who has interviewed parents about their childrearing practices that parents think about and reflect on their relationships with children. Transcripts of open-ended interviews generally reveal that participants rarely give a straightforward behavioral description of what they do. When given the chance, parents contextualize their behaviors and strategies in lengthy "digressions" concerning past interactions, felt emotions, personality, and comparisons with the sibling of the target child. Relationship cognitions have also been demonstrated in "own versus other" research designs that compare a parent or a child's reaction to people who vary in their relationship with the informant. For example, Dawber and Kuczynski (1999) found that parents use different influence strategies in their relationships with their own children than they do with unfamiliar children. These parents justify their differential actions by referring to relational knowledge of their own child's personality, past behavior, as well as predictions of their child's responses.

The projected future of the relationship contributes anticipations, conceptualized as goals to interactions occurring in the present. Knowing that the relationship will persist beyond the present may result in parents acting in a way that promotes future, rather than immediate, goals for a child during disciplinary interactions. The finding of Dawber and Kuczynski (1999) of a higher frequency of future goals for parents' interactions with their own children than with unfamiliar children lends support to the argument that the presence of future goals for the other is a relational phenomenon. Such goals include long-term socialization goals (Kuczynski, 1984), child-oriented goals (Dix, 1992), and relationship goals (Hastings & Grusec, 1998) designed to promote and maintain the mutual relationship context.

Multiple Domains

The presence of multiple relationship domains (Grusec & Davidov, 2010; Lollis & Kuczynski, 1997) adds to the complex nature of the expectancies that each person forms as they integrate information from diverse contexts. The parent-child relationship is not a monolithic relationship of vertical power. Instead, parents and children routinely interact in different domains of the relationship that are engaged in different contexts.

Three domains provide a foundation for understanding parent-child relationships: authority, attachment, and intimacy. Each domain has different underlying dynamics that are the result of the parents and children's varying perspectives and goals during everyday situations.

1. The *authority domain* engages the parental role of socialization agent and bidirectional ←→ dynamics occur in a context of interdependent power asymmetry. In this authority domain parents attempt to exercise their greater power in relation to a child who may or may not wish to accommodate the parent's expectations.
2. The *attachment domain* engages the parental role of caregiver and bidirectional ←→ dynamics occur in a complementary power relationship. In the attachment domain the child seeks, and the parent responsively provides, protection and security (Bretherton, Golby, & Cho, 1997).
3. The *intimacy domain* was proposed by Oliphant and Kuczynski (2011) as a specific conception of interactions in the horizontal or reciprocal power domain of relationships during middle childhood. Other conceptions of this domain focusing on infancy and early childhood include MacDonald's (1992) conception of the evolutionary significance pleasurable interactions; mutual attunement (Grusec & Davidov, 2010) and shared positive affect or mutually responsive orientation (Kochanska, 2002). Weingarten (1991) conceptualized parent-child intimacy as transient interactions in which parents and children share or cocreate meaning. Empirical examples of such intimate interactions were reported by Oliphant and Kuczynski (2011) and include perceptions of shared thoughts, ideas, emotion, and activities that are experienced as moments of mutuality during routine activities such as mealtime, bedtime, car trips, and chores, as well as intentional, idiosyncratic intimacy rituals set up to create the opportunity for mutual pleasure. Harach and Kuczynski (2005) found that

intimacy is the primary way parents describe desired relationships during middle childhood. Conceptually it is the principal domain in the relationship that benefits parents as well as children. According to Oliphant and Kuczynski (2011) parent-child intimacy is an inherently equal power domain of relationships that requires that parents and children coordinate their actions to achieve mutuality

Lollis and Kuczynski (1997) argued that transactions taking place within one domain influence the dynamics of interactions that take place within other domains. Examples include findings that children's compliance in the authority domain is associated with secure attachment relationships (Matas, Arend, & Sroufe, 1978) or an experience of responsive interaction (Parpal & Maccoby, 1985). Harach and Kuczynski (2005) reported findings that suggest that a desire to maintain an enjoyable intimate relationship may constrain parents' use of coercive power when disciplining children. Adolescents have been found to avoid aversive confrontational strategies in order to avoid damaging positive aspects of their relationships with parents (Lundell, Grusec, McShane, & Davidov, 2008; Parkin & Kuczynski, Wojciechowska, Dawczyk, & Pitman, 2012). The context created by interactions in the intimacy domain can also advance broader socialization or caregiving goals in the authority domain. For example, Kuczynski, Wojciechowska, Dawczyk, and Pitman (2012) found that parents create relationship contexts such as routine intimate interactions where children spontaneously disclose information that enable parents to gain knowledge about their activities, friendships, and internal states. Important questions for future research are how expectancies developed in different domains of the relationship are represented in present interactions as well as how parents maintain an optimal balance between conflicting domains in their relationships with children.

Relational Representations

Another symbolic product of social interactions is that people construct meanings about their relationship with the other partner. Watzlawick, Beavin, and Jackson (1967) argued that every interpersonal communication is not only an exchange of information about some topic, but also simultaneously a message regarding the relationship between the interacting partners. Thus partners in a relationship respond not only to the objective content of the interaction but also create and communicate meanings about the relationship. Emery (1992), for example, argued that family conflicts can be analyzed according to their surface (interactional) meanings and deep (relational) meanings. The surface meaning refers to the topic of disagreement. However recurrent conflicts may reveal a metacommunication about what its process of resolution or its outcome conveys about the broader structure of the relationship. According to Emery the deep meaning of conflict concern the functions of asserting (or testing) and changing (or resisting change) in the intimacy or power structure of family relationships. Thus, the dynamics of conflicts may reflect relational meanings beyond the immediate situation.

Transactions within the specific domains of authority, attachment, and intimacy may have metacognitive implications for the interacting partners representations of the relationship as a whole. For example, Cavell and Strand (2003) speculate that children develop a *sense of containment*, which is the expectancy that adults have the capacity to impose firm limits and prevail if goals conflict and cannot be negotiated. This suggests a relational reinterpretation of what is accomplished by parent-management strategies such as *time out*, which have been interpreted behaviorally as a form of punishment that weakens a response (MacMahon & Forehand, 2003). Successfully implementing time out for the first time is a long drawn-out process in which the parent is coached to stand firm in the face of child resistance until the child complies. A relational interpretation is that successful experiences of time out changes the child's representation of the power relationship with the parent such that the child learns that the parents' power will prevail when there is conflict. Similarly, in the attachment domain, experiences of parental responsiveness or nonresponsiveness in stressful situations has implications for the child's interpretation of the relationship as secure or insecure as well as the child's sense of agency in the relationship (Cummings & Schermerhorn, 2003). Finally, in the intimacy domain, experiences that one can participate in constructing a moment of mutuality in the relationship may have implications for one's sense of closeness or compatibility in that relationship as well as one's sense of *mattering* in the relationship (Marshall, 2001). Marshall and Lambert (2006) found that parents experienced that they mattered to children during interactions when children responded to their initiations during intimate interactions.

Distinctiveness

Each relationship in the family has a distinct history of transactions. A mother's relationship with one child will be different from her relationship with a second child because their relationship developed in a different bioecological context (Bronfenbrenner & Morris, 1998). The parent and child may have different perspectives on the relationship based on their different experiences as well as their different ways of perceiving and understanding interactions. In the case of a newly reconstituted family after divorce, a child may have few expectancies from the sparse history of the new relationship to guide their interactions with a stepparent and so the relationship and the stepparent's role in it may be tenuous until a history is allowed to accumulate. Similar scenarios can be constructed for stepparent–child relationships, children's transitions into foster homes, or reconnecting transnational families after long separations.

Culturally Embedded Relationships

Hinde's (1979) relationship theory stressed the reciprocal influences among the various levels of human complexity, that is, individuals, relationships, groups, and the sociocultural structure. Each level has to be understood as context and meaning constructor for another level. The embedding of relationships within culture has implications for the specific persons who form the proximal context for children's development. In many cultures the nuclear family is not the norm as a context for children's socialization and development. For example, Goh and Kuczynski (2009, 2010) argue that the appropriate unit of analysis for families in contemporary China is the intergenerational parenting coalition, consisting of grandparents, the parents, and one child who generally live in one household. Thus, the dynamics that need to be considered for Chinese families include the child's bidirectional ←→ relationships with the grandparent, the mother, the father, and the caregiving coalition considered as a whole.

Culture is a semiotic context (Moscovici, 1988) that provides social representations or meanings about values, ideas, and practices that enable individuals to orient themselves and communicate in their social worlds. Trommsdorff and Kornadt (2003) argued, for example, that cultures differ in their ideas about the relative roles of mothers, fathers, and grandparents in parent-child relationships, the appropriate power relations and patterns of intimacy, and communication in parent-child relationships, and the desired balance of autonomy and interdependence in the relationship and these cultural meanings affect the nature of bidirectional influence in different cultures. Kuczynski et al. (2003) discussed how social representations apparent in aphorisms about childrearing and the natural language used to describe parent and child behaviors affect how direction of influence between parents and children is perceived and how parents and children's actions are evaluated. Moreover, Peterson and Bush (2012) suggest that cultural ethnotheories regarding the meaning of parental authority in a given culture, may affect adolescents' evaluations of their parents' wisdom, competence, or trustworthiness and, thereby, affect their inclination to be influenced or not to be influenced by their parents. The implication from a social relational perspective is that although bidirectional ←→ influence is a universal assumption for parent-child relationships, the cultural meanings associated with the relationship may influence how agency is experienced in the relationship and how partners coact in their social relationships.

The Relational Origins of Socialization

Contemporary research diverges along two principal pathways to socialization: one emphasizing the *primacy of parental discipline and control*, and one emphasizing the *primacy of relationships*. The discipline and control pathway emphasizes parents' use of power assertion to elicit compliance and to suppress noncompliance with parental requests. Failure to suppress early noncompliance is assumed to place parents and children on a trajectory driven by negative cycles of bidirectionality. The most influential model is coercive process theory (Patterson et al., 1992) whereby, noncompliance, conceptualized as coercion, elicits coercive responses from the parent by a process of mutual negative reinforcement. These processes of mutual coercion escalate and become consolidated into habitual patterns of interacting that spread to relationships with teachers, peers, and, eventually, romantic partners as children age. Consistent with this mechanistic conception of causality, behavioral clinical interventions traditionally give priority to behavior management over relationship enhancement on the assumption that good relationships are a consequence of children's compliance rather than set the stage for compliance (Patterson, 1997).

The relational pathway emphasizes the causal role of relationships as the foundation of positive trajectories of socialization experiences driven by positive cycles of bidirectionality (Kochanska, 2002; Kuczynski & Hildebrandt, 1997). In the relational perspective a disposition of receptivity to parental influence emerges from history of mutual responsive interactions. Two veins of research support the relational trajectory. Stayton, Hogan, and Ainsworth (1971) argued that maternal behaviors that promote attachment, such as responsiveness to children's distress, also promote children's cooperation with mothers' commands. Research by Matas, Arend, and Sroufe (1978) found that early compliance was predicted by secure attachment as assessed using the Strange Situation. Research (e.g., Leerkes, Blankson, & O'Brian, 2009) found that maternal sensitivity to distress, rather than nondistress predicted fewer behavior problems and greater social competence in toddlerhood.

Maccoby and Martin (1983) argued that a more general relational process underlies the associations between compliance and attachment. Namely, children acquire a disposition to be receptive to parental requests by learning habits of reciprocity from a relationship history characterized by mutual compliance and responsiveness. This relational perspective has received substantial support from research indicating that children's tendency to comply is enhanced by brief experiences of responsive play with mothers (Parpal & Maccoby, 1985) as well as a substantial body of research by Kochanska and colleagues (see, e.g., Kochanska, 2002) indicating the mutually positive interactions and shared positive affect predict a willingness to comply and a mutually positive orientation during social interactions. Although there is a current debate regarding the ability of responsiveness to distress versus responsiveness to nondistress to predict various outcomes (see Grusec & Davidov, 2010; Leerkes, Weaver, & O'Brien, 2012), both forms of responsiveness highlight the importance of relationship processes.

Kochanska and Kim (2012) reported longitudinal research indicating that in the context of insecure or unresponsive relationships parent-child dyads engage in negative cycles of reactivity such that temperamentally difficult children elicit parental punitive behavior, which leads to further negative escalations and behavioral problems. But in the context of relationships that are secure and responsive, the maladaptive cycle is defused. Even if the child has a difficult temperament, the parent does not become more coercive and parental confrontation is not toxic in its effects. Moreover, positive discipline, and the development of a willing, cooperative receptivity work better when relationships are responsive and secure.

Relationship Construction and Maintenance

The relational perspective broadens the focus on socialization practices to include parents' actions that create and maintain the relationship context, which is the foundation for children's receptiveness to parental efforts. Relationship maintenance has been a topic of research in the literature on friendship and romantic relationships (Dindia, 2003) but it has not received much research with respect to parent-child relationships where the continuing existence or stability of the relationship appears to be taken for granted. An explanation for the dearth of studies on the process of constructing and maintaining parent-child relationships may be the traditional mechanistic orientation of the socialization literature where the relationship is viewed unimportant, except as a variable that may mediate the effects of direct control strategies.

A basic issue in the process of maintaining the parent-child relationship concerns parents' initial decisions to engage in the relationship. Palkovitz et al. (2003) raised the question of parent engagement in the context of father-child relationship, especially after divorce, when the decision to be involved in children's lives appears to be an active choice. Palkovitz's suggestion draws attention to the more general possibility that there is an intentional component in parents' choice to engage in their relationship with their children. At least one aspect to engaging in the relationship is the choice to be responsive to the child. The choice to be responsive means consciously opening up oneself to the child's influence, thereby engaging in a bidirectional ←→ process in which parents and children build a mutually responsive relationship.

Studies have explored parents' perceptions of their efforts to maintain an intimate relationship with children (Harach & Kuczynski, 2005; Oliphant & Kuczynski, 2011). Parental strategies include making time for mutually enjoyable interactions, managing their power in relationship to the child, communicating at the child's level and refraining from overpowering the child by imposing meaning, or making relational repairs through communication and apology. Parents report that children engage in analogous behaviors as their part in creating intimate interactions.

Relationship as Context for Agency

Social contexts have long been understood as constraining human agency by guiding meaning making and placing limits on individual choices. However, social contexts have also been constructed by collective and individual actions for the purpose of enabling and supporting agency (Giddens, 1984). The relationship context may constrain parental actions, during conflict. For instance, the desire to maintain an intimate relationship may prevent parents from employing coercive tactics that are damaging to the relationship. This dynamic has been observed in contexts in which children attempt to protect the relationship even when they resist parental demands (Parkin & Kuczynski, 2012). Adolescents report that even when they transgress against parental rules, or use their own judgment when engaging in prohibited behaviors with peers, they keep their experimentation with autonomy within bounds so as not to damage their relationship with parents or their parents' good opinion of them. In addition, they are guarded in their disclosures to parents or conceal the full extent of their autonomous actions not merely to avoid aversive consequences, but also to maintain positive relationships and protect their parents' feelings. Relational constraint can also be found in adolescents' overt resistance strategies such as negotiation and argument where adolescent attempt to accommodate parental perspectives while at the same time pursuing their own goals (Parkin & Kuczynski, 2012). Although negotiation and argument can be experienced as aversive by parents, these may constitute healthy forms of resistance because adolescents continue to engage in the relationship, thus indicating that the relationship matters to them.

The relationship context may enable children's exercise of agency by affording children leeway to negotiate the nature of the constraints placed upon them. The phenomenon of *leeway* was proposed by Goodnow (1997) to explain flexibility in parental expectations for children. Parents communicate a variety of positions with regard acceptable, tolerable, or "out of the question." Children, in turn, discover how much value-stretch their parents' position affords and how much leeway there is for their own creative interpretation. Goodnow (1997) proposed three forms of leeway: (1) The first lies in the nature of parental expectations. Not all values are of equal importance with some considered essential and others as trivial. This allows leeway in options for children to behave, from the parents' perspective, with "acceptable ignorance" or "acceptable incompetence." (2) The second form of leeway is related to a time frame when children are allowed flexibility to delay or explore alternative values before carrying out an expectation. (3) The third form of leeway concerns domains of decision making where children are specifically encouraged to express their creativity. Goodnow (1997) suggested that parents begin with certain expectations of their child, such as high achievement, and then their values undergo "stretch" as they come to realize their original expectations may have been too ambitious. Thus, leeway for children's agency is afforded by the parents' changing expectations based on their experiences with their child.

Parents may most often signal areas of negotiability and grant or cede leeway in the personal domain, which is generally considered to be under the child's jurisdiction, as well as trivial instances of social conventions where parents may have less investment (Smetana, 2011). However, children play a larger role in detecting and creating leeway in areas of ambiguity such as in mixed domains, where there is a struggle over definitions of what is conventional and what is personal. Children may also exploit leeway when the bottom lines of parental values are ambiguous or parents are adjusting their expectations to changing circumstances. For example, Parkin & Kuczynski (2012) found that beyond some bottom lines (which, nevertheless could be worked around) adolescents find it difficult to identify rules that are rigidly expressed or enforced. Instead, most rules are perceived to be coconstructed between the parent and the child and there is considerable flexibility that allowed room for negotiation. Children's agency and children's effectiveness as agents is enabled by the relationship, and as argued by Kuczynski and Hildebrandt (1997) the competent expression of agency involves accommodating to the mutual constraints of a reciprocal relationship.

Relationship Dynamics

The principal dynamics considered by the traditional social interactional perspectives (Patterson et al., 1992) concern the immediate contingencies between the behaviors of the participants in dyadic social interactions. In contrast, a relational perspective provides new dynamics that stem from the relationship context of social interactions (Table 9.1). Each of the dynamics listed in Table 9.1

TABLE 9.1 Relational Dynamics: Implications of Acting as if the Other Was a Partner in a Close Relationship

Level of Dynamic	Relationship Principles
Interdependence	Act as if the others' responses, actions mattered
Relational representations	Interpret interactions for meaning of self and other in relationship
Past expectancies	Act as if there was a past: others' personality, strengths, vulnerabilities, habitual ways of responding, one's own history
Future anticipations	Act as if there will be a future: socialization goals, proactive behavior, relationship goals
Domain complexity	Act as if what happens in one domain will affect another domain
Distinctiveness	Each relationship has a distinct history and dynamics
Cultural embeddedness	Cultural meanings of interactions and relationships

considers parents interacting in the relational present (i.e., they act "as if" they were in a relationship, not just an interaction between unconnected individuals). Dynamics of *interdependence* consider that the actions of relationship partners not only involve bidirectional ←→ influence but also that each partner draws meaning from the other's responses. What parents and children do and do not do is always meaningful to the other at an emotional level, making each receptive and vulnerable to the others' influence. Relationship-specific meanings relevant to socialization processes include *relational representations* of parents or children in relationship to the other, *past expectancies* from the history of the relationship and *future anticipations* of the relationship's continuance that give rise to future-oriented goals. The dynamics of *domain complexity* considers the causal relations between subdomains of the whole relationship (e.g., authority, attachment, intimacy). The dynamics of *distinctiveness* raises the possibility that the processes of socialization interactions are not only situation specific (Grusec & Goodnow, 1994; Grusec & Kuczynski, 1980; Kuczynski, 1984), they are also specific to relationships. Steinberg (1987), for example, found that mother-adolescent relationships have more frequent conflicts and are also more intimate than father-adolescent relationships. One possible explanation for this finding is that mothers may allow greater leeway for the expression of dissent and tolerate resistance or different points of view because they are more focused on maintaining a positive parent-child relationship. The dynamics of *cultural embeddedness* of relationships imply that the caregiver-child relationships that are most relevant as proximal contexts of development as well as the meanings generated by social transactions are specific to larger cultural contexts.

CONTRADICTION: THE SOURCE OF CHANGE

The dialectical principle of *contradiction* asserts that all phenomena consist of opposing components (thesis and antithesis) as an inherent aspect of their makeup. The nature of the contradictions depends on the physical, biological, or psychological system under investigation. Riegel (1976) identified inner dialectics and outer dialectics as two general kinds of contradictions of psychological systems. *Inner dialectics* are contradictions within a person such as simultaneously held opposing ideas. *Outer dialectics* are contradictions between an individual and another person or between an individual and some aspect of the environment. Because these opposites coexist and coact as a part of a whole, dialectical researchers tend to use a "both/and" rather than an "either/or" logic when studying and describing phenomena (Baxter & Montgomery, 1996; Holquist, 1990; Overton, 2006, Chapter 2, this *Handbook*, this volume). An either/or logic considers differences between components as mutually exclusive. This is the logic underlying unidirectional interpretations of socialization in which the effects or agency of the parent are emphasized, whereas the agency and contribution of the child are ignored or downplayed. The logic of both/and reasoning accepts that one component simultaneously coexists in a dynamic tension with an opposing component and outcomes will be a novel reflection of the action of both components. Conceptualizations such as coactions, coregulation, coconstruction, coevolution, mutuality, intersubjectivity, joint activity, dialogue, and shared meaning (Kuczynski et al., 2003) indicate a both/and logic. In each of these conceptions, adaptive processes are conceived as the coordination of potentially opposing active agents so as to achieve a joint goal. However, for phenomena that the contradictory components more clearly opposed, contradictions may still be generative. Using the example of the inherent contradictions of living in close relationships, Baxter and Montgomery (1996) argue that a healthy relationship is not one in which contradictions are resolved or prevented but one in which each partner manages to satisfy conflicting perspectives or goals.

For researchers who take a contextualist perspective on dialectics (e.g., Baxter & Montgomery, 1996) identifying contradictions is important principally as a way of describing the structure of phenomena, but for researchers who take an organismic-contextualist perspective, including the present authors, contradictions are also important because of their role as the source of change (see Overton, Chapter 2, this *Handbook*, this volume, for a further elaboration of this distinction). Any system will have aspects that are harmonious as well as aspects that are dissonant. The potential for change exists in the unstable "goodness of misfit" (Valsiner & Cairns, 1992) of the coacting components that has the potential for generating novel outcomes. Dialectical researchers focus on the contradictory aspects of systems because the tension that emerges from contradiction provides opportunities for change whereas harmony and consensus serve to maintain stability and continuity (Riegel, 1976). Although harmony is a pleasant and desirable state, in dialectics, it still requires active coordination to create and maintain.

Valsiner (2000) developed the ideas of *systemic causality* and *catalytic causality* to reframe contradiction as a relation between components in dynamic systems. "In the case of systemic causality, the given outcome (B) is a result of mutually interdependent relations of the parts of the causal system (for example, system A {Z < > X <> Y} . . . None of the parts (Z, X, Y) taken separately causes B, but their systemic interaction leads to B" (p. 75). *Catalytic causality* refers to the capacity of contexts to change the nature of the causal relations of living systems. Using the metaphor of chemical reactions, catalyzed refers to a set of conditions that need to be present for a particular causal linkage to occur, and the absence of which does not allow the causal process to lead to an outcome. According to Valsiner (2012), a given system of meanings may be maintained on a narrow or conservative trajectory of thesis/antithesis/synthesis where the prevailing meanings inhibit breaking away from that trajectory. Each system is always in a potential tension-filled state of transformation that is held in check as long as the external context remains the same. However, a change in context introduces new conflicting meanings to the system that may create the conditions for a new interpretation or create a space that enables new flexibility for exploring various meanings. An outcome of a catalyzing event could be the resolution of a contradiction, which may lead to a new qualitatively different trajectory, or it may lead to a failure of resolution, which leads to a path of continued tension, at least temporarily.

Contradiction in Social Relational Theory

Figure 9.4 is the general model of contradiction and its role as a causal process that informs social relational theory. The process begins with a catalyst—an event, a change in the environment, or a developmental or life-course transition—that creates patterns of behavior that are unexpected or clash with the parent or child's current understanding (thesis). The catalyst may also bring into awareness problematic patterns of behavior that may have occurred without reflection in the past. In making sense of the change the parent or child recognizes a contradiction (antithesis), which may be experienced in various forms including conflict, expectancy violations, ambivalence, and ambiguity. These experiences have in common that they entail uncertainty and create an affective state of tension. In other theories, these tensions have been conceptualized such as ruptures, turning points, critical events, crisis, perturbation, and disequilibration (see Witherington, Chapter 3, this *Handbook*, this volume).

In seeking a resolution to the contradiction the parent or child may engage in a process of problem solving, which may be resolved by a temporary qualitatively new understanding of the situation sending the parent, the child, or the relationship on new trajectories. Alternatively, the individuals may attempt to ignore or live with the contradiction, in which case the tension continues to be a factor in their lives. In the analysis that follows, the nature of contradictions is described first, followed by processes by which contradictions relate to causality. The nature of trajectories, conceptualized as syntheses, are discussed in the subsequent section.

Parent-child relationships constantly create both external and internal contradictions that feed into the dialectical process. Parents and children, considered as agents, have separate and potentially conflicting needs, perspectives, and goals. However, they are also continually embedded within the unity and interdependence of their shared relationship. Because the relationship is involuntary or individuals are invested in the relationship, the tensions must be managed in some way.

Parenting inherently involves constant adaptation to a rapidly changing organism (Holden & Ritchie, 1988). Children change continually as they develop from infancy to young adulthood. From the perspective of the parent, the child is a constantly moving target and strategies that worked previously may no longer work in the present. Holden and Ritchie (1988) used the concept of outer dialectics and inner dialectics (Riegel, 1976) as a starting point

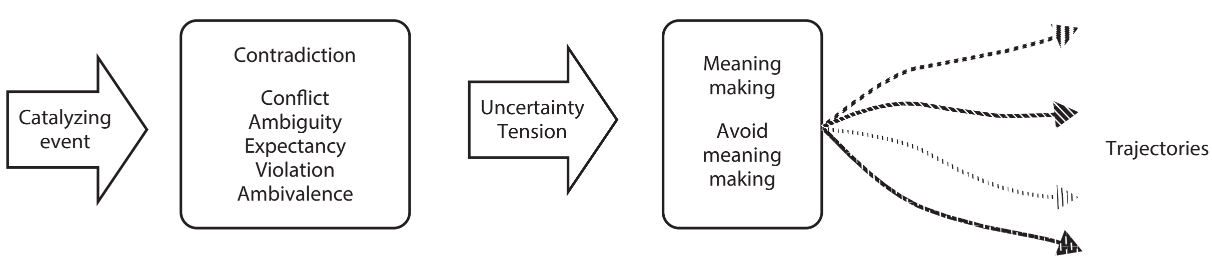

Figure 9.4 Psychological processes underlying causality in dialectical systems.

for identifying the contradictions that parents encounter in the competing roles of childrearing. Their examples of outer dialectics included contradictions between the parents' needs and the child's needs or between the parents' experience of childrearing and competing child advice from the culture, experts, and other caregivers. Holden and Ritchie devoted most of their analysis to inner dialectics, namely internal debates within the parent about how to carry out the different childrearing roles of caregiving, managing, and nurturing.

In the caregiving role, inner contradictions included competing goals such as allowing exploration but guarding against danger; being receptive to the child's requests but not spoiling the child and being warm but not seductive. In the managing role, contradictions included seeking obedience and respect but allowing assertion and questioning of authority; being firm and consistent versus flexible; being honest and open with the child versus protecting the child from harsh realities. In the nurturing role, contradictions included being involved but not intrusive; granting independence but maintaining dependence; encouraging mature behavior versus allowing children to be children; teaching versus allowing children to discover on their own; and changing the child versus accepting the child's shortcomings. In addition to the contradictions noted by Holden and Ritchie (1988) there may be contradiction between the parents' needs and those of the child. Parents may feel tensions between the responsibility of parenting and the impact of rearing children on their own well-being, careers, and aspirations.

Other contradictions arise from managing close personal relationships. In families reconstituted after divorce there may be contradictions specific to the stepparent-stepchild relationship. Particularly when the family is reconstituted after middle childhood, the child's relationship with the stepparent initially does not have the same rich history of interaction compared to biological parent-child relationships to provide a foundation for the new parent's roles. Baxter, Braithwaite, Bryant, and Wagner (2004) found that stepchildren reported that they often appreciate closeness with and involvement by the stepparent, but experience distance and discretion, and resist granting the stepparent full parental status in the relationship. Cissna, Cox, and Bochner (1990) demonstrated that parents also experience tension between the time and effort devoted to establish the newly formed marital relationship and the time and effort required to construct the stepparent relationship.

Contradictions in relationships are always contextually dependent and must be studied with regard to particular relationships or relationship types. Dialectical analyses of communications in close personal relationships, such as friendships and romantic partners, have found that there is a dynamic interplay between the tendency for connection and integration and the competing tendency of separation and autonomy (Baxter & Montgomery, 1996). These are expressed as three basic contradictions: autonomy-connection (the desire to be connected versus the desire to be a unique individual), openness-closeness (the desire for self-disclosure versus privacy and discretion), and certainty-uncertainty (the desire for stability and predictability versus spontaneity and novelty in the relationship).

There is growing awareness that even professional relationships have a horizontal power aspect that is the source of tensions between various domains of relationships with clients. Investigators who study professional relationships such as in social work (Alexander & Charles, 2009), nursing (McGuire, Dougherty, & Atkinson, 2006), psychotherapy (Wampold, 2001), and teaching (Manning-Morton, 2006) have argued for the recognition of the therapeutic role of a personal relationship domain in interactions between clients and professionals. Service providers are aware of the mutuality and reciprocity in their relationships with clients as well as the tension between their lived experience and the undermining restrictions placed on them by professional norms of their disciplines. For example, researchers studying early childhood education teachers' relationships with young children have conceptualized teaching in a way that recognizes the inherent complexity of the teacher-child relationship, which involves participating in an affective interpersonal relationship while simultaneously carrying out teaching and attachment or caregiving functions (Howes, 1999; Manning-Morton, 2006). The relationship domain of professional teacher, with norms for objective distance, has been found to coexist in a relationship system with an attachment/caregiver domain and a personal relationship/intimacy domain (Quan-McGimpsey, Kuczynski, & Brophy, 2011). Three principal contradictions have been found for early childhood education teachers when relating to individual children; these included interacting with one child versus the entire class, exclusive versus shared closeness, and engaging in a parental role versus the role of early childhood education teacher (Quan-McGimpsey et al., 2011).

Psychological Processes Underlying Contradiction

Contradictions can be further analyzed by considering underlying psychological processes. Kuczynski and colleagues have interpreted contradiction as occurring in four recurring phenomenona of daily experience: conflict, expectancy violations, ambivalence, and ambiguity (Kuczynski et al., 2009; Kuczynski & Parkin, 2009).

Conflict

Conflict occurs during interactions that pit the parents' needs, goals, will, or interpretations of events against those of the child. These external contradictions may be manifested in overt conflict. During the 1980s, parent-child conflict began to be viewed as an inevitable and mutually tolerated aspect of living in close relationships. Moreover, a dialectical interpretation emerged that conflict is a necessary condition for change and may have positive functions for the individual or for the relationship (see Shantz & Hartup, 1992, for a review of this perspective).

Expectancy Violations

Expectancy violations occur when one receives information that violates previously established ways of understanding. Sameroff (1975b) used an example of expectancy violation to illustrate the transactional process where contradictions between the parent's initial model of the child as pliant object and the parent's actual experience lead to a qualitatively different image of the child as a separate agent who exists independently of the parent.

Collins and Madsen (2003) proposed the *expectancy violation realignment model* as an explanation for how families adapt to change as children move through adolescence to adulthood. According to their model, developmental change may lead to new behaviors that contradict the representation of the child that the parent had previously formed. This contradiction initially creates conflict, puzzlement, or emotional upset, but a new basis for interaction will occur when the parent adapts to the new reality by reinterpreting the meaning of the child's behavior. The argument is that parents may initially interpret developmental changes in the child in a negative way as "attitude" or "defiance," but eventually adapt by interpreting the child's behavior as legitimate signs of adulthood, thus putting the relationship on a new, less conflictual trajectory.

Parental violations of children's expectations also create internal contradictions that children must reconcile or to which they must adapt. Youniss and Smollar (1985) documented how in early adolescence, children view parents as unilateral authority figures but eventually come to understand parents as individual personalities with unique strengths and weaknesses. Although this has been understood as an individual change in the adolescent's declining egocentrism, expectancy violations that occur as the adolescent becomes aware of parental vulnerabilities and strengths may also play a role.

The *social expectations model* of close relationships (Levitt & Cici-Gokaltun, 2010) is a model of relationship development continuity and change processes applicable across specific relationships and through the life span. According to this model, repeated transactions with a relationship partner build expectations about the partner's behavior that provide a basis for the development of close relationships. These relationship expectations, once established, are thought to provide the basis for continuity within relationships and generalization across relationships. However, relationships can change when individuals encounter circumstances that exceed or violate their expectations of, for example, trust, reciprocity, or a good image of the partner. The model suggests that relationship expectations that are untested will remain stable, expectations that are violated may lead to relationship change in a negative direction, and expectations that are surpassed may promote positive change in the relationship.

Ambivalence

Ambivalence is the experience of simultaneously positive and negative emotions, evaluations, or opposing directions for action. The construct of ambivalence has been used in a variety of ways in the social sciences. In sociocultural research, ambivalence has attracted attention for understanding the emergence of meaning. Abbey (2012) described the meaning-making process as the individual's attempt to overcome the ambivalence between their present understanding and the possibilities of an uncertain future. Many of the examples of parental contradictions described by Holden and Richie (1988) can theoretically be understood as ambivalence resulting from competing but equally desirable goals, which may come to mind when parents respond to a given childrearing situation. These include child-oriented goals for keeping the child happy, parent-oriented goals for the parents' convenience, socialization goals to foster the child's capacities (Dix, 1992), and relationship goals to maintain a satisfactory parent-child relationship (Hastings & Grusec, 1998). Each of these goals may also have short-term versus long-term considerations that may create ambivalence (Kuczynski, 1984).

Parent-child relationships also entail considerable ambivalences that are temporary or permanently irreconcilable. Family members frequently express mixed feelings toward each other, such that warmth and affection occur together with antagonism and irritation. Lüscher and Pillemer (1998) proposed a theory of intergenerational ambivalence as a tool for understanding how adult children and their aging parents experience and manage contradictory impulses and perceptions in their close relationships. Fingerman and Hay (2004) found ambivalence to be more characteristic of relationships involving romantic partners, mothers, fathers, sons and daughters, and siblings than those with extended family or friends. They argued that much of the tension between aging mothers and adult daughters is caused by their mutual struggle for independence and the older generation's desire and demand for more contact and involvement than the younger generation.

Methodologically, the phenomenon of ambivalence requires a both/and approach to measurement. For example, a parent may love a child but experience the child's behavior as aversive. A child may approve of the parent's socialization goals for achievement, but deplore the parent's methods. A child may reject the parent's beliefs or values but love and respect the parent's sacrifices on their behalf and resolve to care for them in old age (Kuczynski et al., 2009). These simultaneous strong positive and strong negative pulls are obscured in quantitative ratings of "somewhat close" on forced-choice global assessments of relationship dimensions.

Ambiguity

Ambiguity most directly corresponds to the idea that contradiction creates uncertainty, the state that drives the meaning-making process. Human goals and actions are future-oriented and because the future is unknowable, always involve some level of uncertainty. As described by Valsiner (2006), "Every next immediate moment in the life of an organism is ambiguous as a step between the already known and the still unknown. This state is the normal state of affairs during which an unexpected and unpredicted new phenomenon may emerge" (p. 118).

In addition, individuals may be required to act in the context of uncertainty when they have only partial knowledge about a catalyzing event. Rumsfeld (2002) described the many degrees of uncertainty from which politicians and bureaucrats must make their future-oriented policies. "As we know, there are known knowns, there are things we know that we know. There are known unknowns. That is to say, there are things that we now know we don't know. But there are also unknown unknowns. There are things we do not know we don't know" (February 12, 2002, press conference). Similarly, parenting is an ambiguous enterprise where parents act in the context of many shades of unknowns. There is often minimal information or clarity about the circumstances of the childrearing situations such as "what happened?" or "who started it?' or where children are, who they are with, or what they are up to, and whether or how to intervene.

Dawczyk and Kuczynski (2012) found all four forms of contradiction—ambiguity, ambivalence, parent-child conflict, and expectancy violations—in an interview of parents of 8- to 13-year-old children. Although no specific questions were asked regarding contradiction, parents spontaneously offered many digressions and incomplete or uncertain responses to the questions that were asked about their childrearing practices. These portions of interviews are normally regarded as a nuisance and are disregarded by the researcher who generally seeks for complete and unambiguous responses. However, viewed from the perspective of dialectics, these ambiguous portions of the interview may constitute an important reality of parental experience. Contradictions were found to stem from two sources: internal sources (originating from uncertainties within the parent) and external sources (originating in the child's unexpected behavior).

Contradiction is assumed to provide the motive force of dialectical tension, which drives individuals to work toward some resolution. The dialectical tension experienced by the individual can vary in intensity. Using the example of ambivalence, Abbey (2012) argued that tensions between opposing meanings is strong when ambivalences involve tension between opposing meanings where the meanings directly oppose each other with equal force. However, tension can be comparatively mild when one meaning is stronger than, and can overcome, the other. In social interactions and relationships, dialectical tension can be experienced as mild dissonance or as expressed emotion. Dawczyk and Kuczynski (2012) found that the majority of parents' descriptions of their experiences of contradictions were accompanied by expressions of emotions indicative of anxiety, stress, surprise, anger, and sadness. This finding suggests that dialectical tension may be manifested in uncomfortable emotional states that require resolution.

An important question is what agents *do* with dialectical tensions. An adaptive strategy is to seek some resolution to the contradiction either by taking action or reducing uncertainty by creating new meaning. Either of these approaches imply qualitative change. However, Abbey (2012) noted other possibilities. One is a prejudicial strategy where one adopts one meaning over another and creates artificial clarity by refusing to consider other options. This is an inflexible approach that does not reflect the changing reality. Another approach is to ignore the contradiction and disengage in the meaning-making process and living with the tension at least temporarily. Writing on ambivalence in intergenerational relationships, Lüscher (2011) argued:

> As a consequence of dealing with ambivalence, we may observe the confirmation of established, traditional patterns of action and of relationships. Or it may generate innovative, emancipatory actions and forms of relating. Or it may mean ending a situation or a relationship or being stuck in endless quarrels or in terminating a relationship by leaving a setting. Or, in the extreme, people may lose the ability to act and enter a stage in which their personality is completely divided. (p. 196)

An important question for the future is how to conceptualize contradiction as a central process in socialization. One approach is to explore how inherent contradictions in parent-child relationships are managed in daily life so as to keep damaging conflict between generations from arising. For example, there is evidence that parents tolerate or adjust to children's increasing resistance in middle childhood (Kuczynski, Burke, & Robson, 2013) as well as the ambiguity created by children's increasing engagement in unsanctioned peer activities that occur out of the parents sight (Kuczynski et al., 2012). It is possible that such parental toleration is moderated by a qualitative reframing of these contradictions as normal development of autonomy or "normal deviance" that parents remember being part of their own adolescent experience.

Another approach is to consider parenting as process of resolving contradictions or problem solving. Holden and Hawk's (2003) conception of metaparenting considers the intentional and reflective thought processes that parents use to evaluate and solve problems of childrearing. Metaparenting often takes place outside of immediate childrearing problems and consists of the processes of four interrelated forms of problem solving. *Anticipating* involves thinking about problematic situations before they occur. *Assessing* involves evaluating the reasons for a particular childrearing situation. *Problem solving* involves various activities such as recognizing the problem, identifying the source of the problem, and generating possible solutions, and testing and evaluating the success of the solution. *Reflecting* concerns longer-term evaluations of their behavior, their child's behavior, or parent-child interaction outcomes. Holden and Hawk (2003) argue that metaparenting plays an important role in mediating qualitative changes in the parent's attitudes, values, or goals, as well as their ability to act on and maintain new goals.

Dawczyk and Kuczynski (2012) found in their study of naturally occurring contradictions that many parental contradictions were not resolved but were at different stages in the problem-solving process. These included describing the contradiction, information gathering and reflection, and acting on the contradiction. *Describing the contradiction* implied that parents were aware of and acknowledged the contradiction, but they had not begun to process or manage the contradiction. *Information gathering and reflection* occurred when parents drew on their knowledge of the child, reflected on past experiences in the parent-child relationship, or engaged in self-reflection in an attempt to gain an understanding of the current situation causing the contradiction. *Acting on the contradiction* involved strategic efforts to manage contradictions through cognitive justification or reframing of their or their child's behavior, or plans to alter either the child's behavior or their own responses to the behavior.

The choices that parents and children make when confronted with contradiction determine the likelihood of change. Individuals could choose to ignore contradictory information, or avoid communication about contentious topics, or they may manage their state of uncertainty. In this case, the contradiction would remain unresolved, at least temporarily, thus maintaining their prior understanding and, therefore, stability, following a transaction. Choosing to confront contradiction, on the other hand, opens the possibility for constructing new meanings that can instigate qualitative change, for better or worse. Choosing to communicate so as to arrive at new solutions, reframing the meaning of emerging behaviors, or going into therapy all may result in qualitative changes in behaving, relating with others, or perceiving situations.

SYNTHESIS IN DIALECTICS: NONLINEAR OUTCOMES

A defining feature of dialectics is its focus on qualitative change or the emergence of novelty (see R. M. Lerner & Benson, 2013; Overton, 2006, Chapter 2, this *Handbook*, this volume). The dialectical leanings of a theory can be recognized by concepts such as transformation, working models, changed representations, bifurcations, phase shifts, and turning points (see Witherington, Chapter 3, this *Handbook*, this volume). These concepts represent the dialectical metaphor of temporary synthesis, the idea that the resolution of contradictions creates novel outcomes. The process of synthesis is unending because each new synthesis becomes the basis of a new contradiction.

Dialectical causality assumes a continuous process of change in a changing context where outcomes are always in process. The idea of qualitative change is often subverted by research questions and conceptualizations of outcome that turn dynamic processes into linear models (Sameroff & MacKenzie, 2003). These put a premium on findings of stability and continuity across time and regard findings of instability (insignificant correlations) as errors in measurement (Appelbaum & McCall, 1983). However, an exclusive focus on continuity is only possible from a mechanistic perspective of causality. Continuity and similarity are not the expected outcomes in dialectical approaches to human development. Valsiner (1989) provided a formal description of synthesis in the dialectical process.

> The relations between X and Y is *contradictory* (a basic assumption of the dialectical perspective) in the sense that the two parts (X and Y) are opposing each other while remaining mutually necessary parts of the system. As a result of the opposition of the subparts of the whole, the whole system "leaps" to a novel state of being (incorporating a new part (Z)). (p. 67)

Conceptualizing nonlinear change is a major focus of various systems approaches to development, and approaching nonlinearity using the dialectical idea of synthesis is a focus of sociocultural theory (Valsiner, 2012). Most dialectically inspired empirical research has stopped at the point of listing contradictions in a phenomenon but does not go on to analyze the potential of dialectical tensions to create new syntheses. A current challenge is to develop concepts about what synthesis looks like. Valsiner (2012) has critiqued a number of conceptualizations of synthesis. For example, synthesis should not be considered as a selection of alternatives where considering the pros and cons of conflicting arguments lead to one opposite dominating the other. Also unsatisfactory are ideas of synthesis as optimal blends of the oppositional components. According to Valsiner, neither selection nor optimization of conflicting alternatives adequately capture synthesis as the construction of truly novel forms as the organism moves unpredictably from the known and unknown.

Synthesis in Social Relational Theory

The idea of synthesis alerts researchers that the outcomes of socialization processes must be more than conformity or the mere transmission of similarity from the older generation to the younger generation. Change and the emergence of novel syntheses are also the expected outcomes of socialization and development. There are several directions that may lead to advances in the conceptualization of synthesis in research on socialization. These are a dialectical reformulation of interpersonal influence, the concept of synthetic outcomes, and the concept of nonlinear trajectory.

Relational Influence

In the socialization literature parental influence is often conceptualized as parental control. *Parental control* has been conceptualized as a parenting dimension, a parental practice, a process, and an outcome. What is not clear is the meaning of *control*. Baumrind (2012) argued that parental control ideally should be conceptualized as confrontative power assertion rather than as coercion. However, confrontative power assertion itself was defined in a deterministic way. Confrontative power assertion was operationalized as "confronts when child disobeys, cannot be coerced by the child, successfully exerts force or influence, enforces after initial noncompliance, exercises power unambivalently, uses negative sanctions freely, and discourages defiant stance" (p. 37). For example, in the authoritative parenting style (Baumrind, 2012), the parent considers children's attempts to negotiate, but in the end, the parent decides, exercises control to enforce compliance.

From a dialectical perspective the concept of control is problematic because it raises a distinction between linear deterministic models of causality and dialectical models of causality. The term *control* may be appropriate if it means no more than a power-assertive pattern of behavior; however, it is problematic from a dialectical perspective when *control* refers to the process of influence or the outcomes of a control attempt. Control as an outcome or causal process implies an underlying mechanistic model of linear cause and effect, which is inappropriate for conceptualizing influence between human agents.

Bateson (1972) used Lewis Carroll's famous account of flamingo croquet in *Alice in Wonderland* to illustrate the difficulty of applying traditional notions of linear causality to interactions among biological organisms. In this game (Figure 9.5), Alice must play croquet using a live flamingo as a mallet with the goal of propelling a live hedgehog as if it were a ball through wickets formed of doubled-up soldiers. The game proved difficult because the flamingo and the other components of the game were not inanimate objects but active agents with goals of their own and capacities to act and to think ahead. Alice's control of the flamingo was illusory because the poor mechanical coupling of Alice to the flamingo made it difficult for her to "control" the flamingo or determine the hedgehog's trajectory in any predicable way.

Playing the game with living organisms requires dialectical ground rules. First, the idea of control needs to be abandoned and replaced with a concept of relational influence compatible with influence between active agents. For example, Alice's influence in the game may improve if she assumed that the components of the game are agents and use strategies adapted to the agentic nature of the participants and perhaps her relationship with them. Second, Alice may have to adjust her expectations so that they anticipate that the outcomes will be something different than exact compliance to her wishes.

Figure 9.5 Flamingo croquet: Metaphor of linear causality when applied to agents.

In the literature on close relationships, the term *influence* is used instead of *control* to denote causal processes whereby relationship partners affect each other's thoughts, behaviors, and emotions (Huston, 2002). Building on this usage, we propose the construct of *relational influence* as a dialectical model of causality for understanding transactions between human agents in a relationship context (Figure 9.6). In the process of relational influence, outcomes of influence attempts are dynamically constructed in bidirectional ←→ transactions as individuals construct new meanings from each other's verbal and nonverbal communication. The model of relational influence is useful for understanding how differences are created between the intention of a parental attempt to "control" a child's behavior and the child's response.

The model of relational influence in Figure 9.6 is an elaboration of Sameroff's (1975a, 1975b) transactional model of development, which depicts parents and children engaging in qualitative change as they respond to each other over time. However, as discussed by Sameroff (2009), transaction also occurs at the micro level when parents and children interpret each other's behavior during social interactions. The process of transaction in relational influence depicted in Figure 9.6 is elaborated by Lawrence and Valsiner's (1993, 2003) conception of the internal processing that occurs between the input from the external environmental and the person's output back into the external social world. They argue that there are two internal processes to consider, internalization and externalization. *Internalization* refers to the cognitive processing (internalization transaction) that takes place as individuals make personal sense of messages from the environment. Internalization may consist of interpreting events based on their existing knowledge, evaluating the message along with competing messages from the environment, and reconstructing the message for their own use (Kuczynski et al., 1997). *Externalization* refers to the further processing that takes place as they manifest or act on what they know (externalization transaction).

The latter relation takes the form of externalization of one's "personal culture"—organization of one's environment and external appearance in ways that fit the person's

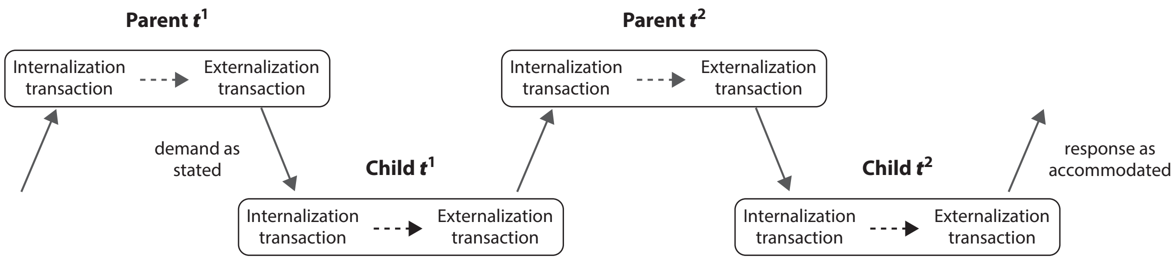

Figure 9.6 Relational model of influence: Construction of novelty, impossibility of control.

internalized psychological "needs." The externalization of the person's (previously) internalized psychological processes reintroduces the products of internalization into the sphere of social transaction (Lawrence & Valsiner, 1993, p. 288).

As depicted in Figure 9.6, a command that initiates an influence attempt by a parent is embedded in a previous history of parent-child transactions such that the parent's choice of influence strategy has already been preadapted (internalization transaction) to the child. In the parent's externalization transaction the parent may consider usefulness of the proposed action for achieving their goals for the child, predictions of the child's responses on the basis of expectancies developed in the past, or consider the consequences for the parent-child relationship. Similarly, the child interprets and evaluates, cognitively and emotionally, the parents' communication (internalization transaction) and chooses a response that accommodates or resists the parents' communication (externalization transaction). Thus, in the process of a control attempt messages may repeatedly undergo one process of transformation as they are internalized and another process of transformation as they are externalized back into the social world.

The argument is that relational influence always contains a qualitative transformation or synthesis. There may be the appearance of control in the sense of the child's externalized cooperative behavior; but children can interject creative components into a cooperative response. Also, one can never know if the other has accepted the message or in what way the individual has transformed it. Thus whatever intentions-goals-strategies the parent or the child may have or use, for his or her effect on the other the parent or child is dependent on the other. Parents or children may *want* to control but the best they can hope for is relational influence.

Other venues of nondeterministic parental influence may occur when the purpose is not to directly influence the child's behavior but to influence the holistic contexts that may beneficially guide the child's choices. Examples of such holistic indirect influences may include contributing to a responsive relationship context to which the child has a stake, or managing the child's ecological environments such as the child's neighborhood, school, and network of peer relationships (Parke et al., 2003). Managing these proximal and distal contexts may serve to constrain the child's agency but in a nondeterministic way that allows the child scope for action.

Synthetic Outcomes

The dialectical conception of relational influence implies a dialectical conception of *synthetic outcomes* that reflect the coregulated nature of outcomes in close relationships. Two conceptions of outcomes that are iconic in unidirectional models of socialization are the constructs of *compliance* (Kuczynski & Hildebrandt, 1997) and *intergenerational transmission* (Kuczynski et al., 1997). Both of these conceptions connote an expectation that outcomes in the younger generation are linear reflections of the input of the older generation. A way forward is to reconceptualize compliance as the synthetic outcome of accommodation and negotiation and intergenerational transmission as the construction of working models.

Accommodation and Negotiation

A deterministic conception of outcomes is most explicit in behavioral perspectives on compliance to parental demands. According to researchers who take a behavioral perspective (e.g., MacMahon & Forehand, 2003; Patterson, 1982), the operational definition of an appropriate child response is immediate compliance within seconds after a parental command. Ideally, children should comply immediately, completely, and without complaint, a definition that implies an expectation of an exact match between the child's response and the parent's command. Moreover, Patterson (1982) defines alternative child responses as noncompliance, which is considered to be a form of coercion. This does not allow possibilities of considering as legitimate the novelty that emerges from the transactions between human agents.

Grusec, Goodnow, and Kuczynski (2000) argue that although there are situations in which parents do expect immediate or strict compliance, such as when there are issues of safety or morality, such situations are relatively infrequent in daily life. Thus, Goodnow (1994) suggests that parents communicate a variety of positions with regard to their acceptance of children's behaviors ranging from what is ideal to what is acceptable, tolerable, or "out of the question." Similarly, Kuczynski and Hildebrandt (1997) argue that in close relationships the goal is less often to obtain exact compliance than it is to obtain conflict resolution or a compromise of the original desires of the participants. During the history of their relationship, parents and children evolve shared understandings of what will pass for compliance in different situations. It is only rarely that the shared understanding approximates the complete, immediate submission that is implied by immediate compliance. Accordingly, they proposed that the constructs of accommodation and negotiation as dialectical reformulations of compliance and noncompliance for children's cooperative and noncooperative responses in close relationship contexts. The idea is that these terms convey the synthetic nature of the process and outcomes of many episodes of socialization. They are synthetic outcomes because they incorporate novelty that results from a dialogic engagement of the opposing perspectives of parents and children.

Accommodation conveys both a cooperative response, and also that the form of the cooperative response will be chosen by the recipient rather than by the sender of a request. Thus, an accommodating response by children may acknowledge that the parent has been heard, that children will attempt to coordinate the parent's wishes with their own plans or that children are willing to negotiate an alternative course of action. Children's responses, even when cooperative will contain a novel component creatively constructed by their actions and interpretations. For example, a child who is disposed to cooperate may wish to do so at a time or in a manner (e.g., whistle while working, listening to music while studying) of their own choosing, thus infusing creative agency into their accommodative action. Similarly, *negotiation* is a synthetic outcome of two opposing causal forces, the parents' demand and the child's resistance to the demand, as constrained by the relationship context. Just as children must regulate their cooperative behaviors in a social context, they must also regulate their autonomous behaviors within a context that contains other individuals, including parents, whose choices clash with their own. Consequently, the main argument is that socially competent children display a coregulated but nonexact form of cooperation or resistance—a synthesis—that represents their expression of agency within the constraints of a close parent-child relationship.

Working Models

The idea that children internalize the values of the parents or that culture is transmitted from one generation to the next also has deterministic connotations. Strauss (1992) described the construct of *intergenerational transmission* of values or culture as incorporating FAX metaphor that implies that parents directly and faithfully transmit a copy of their own values to their children. The idea of transmission not only discounts the agency of children but also implicitly discounted the agency of parents who were considered to be passive conduits of their own socialization experiences (De Mol, Lemmens,Verhofstadt, & Kuczynski, 2013; Kuczynski et al., 1997). The transmission idea also does not incorporate the possibility of intergenerational change in social values or that members of each generation actively construct their own values in the process of internalization. The flip side of intergenerational continuity is cultural and social change. Since the 1970s there have been vast changes in values concerning gender equality, racial, cultural, family, and sexual diversity, and the rights of children. There is a new concern for the impact of human activities on the environment. The role of media and globalization of knowledge drives increasingly rapid change occurring in the present. Yet the socialization literature has not had the conceptual tools to study the developmental implications of these phenomena.

Kuczynski et al. (1997) maintain that the concept of *working models* can appropriately replace the deterministic conception of internalization as a static transmission of similarity, with a conception that internalization is an ongoing process of synthesis where beliefs and values are continuously being constructed and challenged throughout life. The model in Figure 9.7 considers the ecological context of socialization and internalization, reframed as a dialectic between parents and children's engagement with the social world at the macro level, processing of information at the individual level, and transactions occurring between the parent and the child in the proximal context of the family.

The macro contexts of the parents' internalization (which may differ for the mother and the father) and the macro context of the child's internalization are depicted

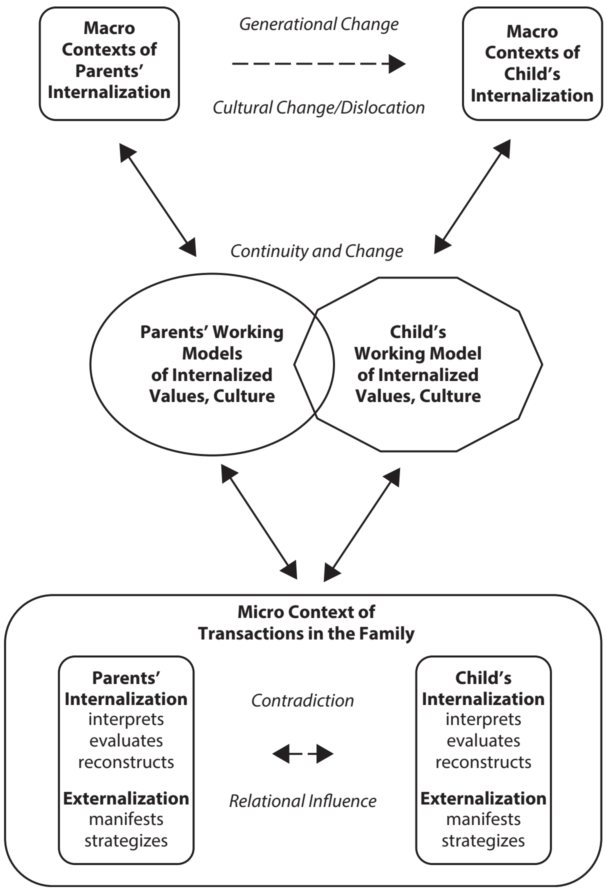

Figure 9.7 Dialectical model of intergenerational transmission.

at the top of Figure 9.7, conceptualized as culture and generation. The concept of *generation* is concerned with continuity and change produced through the agency of people born and learning at succeeding periods of historical time. Generational change comes about through external forces and collective actions such as immigration, war, economic changes, new technology, and the introduction of new ideas by individuals and groups. According to Mannheim (1928/1952) young people form a generation by being exposed to specific social, historical, and political events and ideas of a particular time period. They develop shared ways of interpreting and evaluating situations, and may form generational groups that react to issues in similar ways. The different generations of parents and children form the context of external ideas to which parents and children are exposed. The parent generation and the child generation are separated by the historical time in which they were growing up. Many families also may experience abrupt change in culture due to immigration. For immigrant parents and children, therefore, there are differences in the external influences of direct socialization such as schools and other institutions as well as differences in to their exposure the process enculturation, or emersion in the everyday practices of the encompassing culture.

The micro context of transactions within the family is depicted at the bottom of Figure 9.7. Parents and children are depicted as engaging in transactional processes of internalization and externalization (Lawrence & Valsiner, 1993, 2003) as they face contradictions that emerge from their separate perspectives within the constraining influences of a valued, interdependent, long-term relationship. Parents and children must reconcile the different sources of information from their surrounding ecology as well as their interactions from each other to affirm or reconstruct their own ideas and to decide how to interact with each other. Kuczynski and colleagues (Kuczynski et al., 1997; Kuczynski & Knafo, 2013; Kuczynski, Navara, & Boiger, 2011) suggest that studying the acculturation of immigrant families in a new culture offers new insights into the process of creating the syntheses that are the working models of parents and children. Thus, family acculturation involves not only processes such as teaching, modeling, and discipline that have been studied in within-culture socialization, but also processes that are unique to the problem of fostering aspects of the parents culture of origin to children in the new cultural context. Their reviews of the literature included novel strategies such as cocooning, prearming, intentional enculturation, guided participation, on the part of parents; cultural brokering, negotiation, resistance, and accommodation on the part of children; as well as relationship management so as to protect the relationship despite differences in perspective on the part of both parents and children.

At the center is the expected dialectical outcome of internalization, a synthesis that incorporates both similarity and change. Because of the different life experiences, different transactions with each other, and their different exposure, loyalty, and susceptibility to ideas of generational peers, media or other institutions in their ecological contexts, each member of the family develops different personal working models of their values.

Nonlinear Trajectories

Socialization is often conceived of preparing the child for future success in society. However, there is little conceptualization of the future as an outcome. The idea of a nonlinear trajectory consisting of a general orientation with a wide range of possibilities as outcomes offers a nonlinear conception of progress toward the future. The idea of trajectories was depicted earlier in Figure 9.6, as possible syntheses that result from the processing of contradictions. The *trajectory equifinality model* proposed by Sato, Hikada, and Fukuda (2009) conceptualizes trajectories as a continuing process of development that entails further contradictions and syntheses along the way to an uncertain future. The trajectory equifinality model assumes that individuals are agents who produce their own development (R. M. Lerner & Busch-Rossnagel, 1981). The model also builds on the principle of equifinality, which means that in open systems a given end state can be reached by many potential paths (McClelland et al., Chapter 13, this *Handbook*, this volume; Overton, 2010, Chapter 2, this *Handbook*, this volume; von Bertalanffy, 1968). However, the model adds a conception of the activity of the individual, the role of social forces, and a conception of a broad zone of possible endpoints.

The trajectory equifinality model begins with an individual's goals and vision of a possible future, which may be quite broad. Operating on the individual's progress toward the future are two social forces, *social direction* from cultural and external powers that keep an individual in line, and may be a barrier to individual choices, and, *social guidance*, which are the available social supports for the individual's goals. From these conflicting directions, the individual creates a *synthesized personal trajectory*. Along the way barriers and opportunities provide multiple bifurcations or choice points where decisions are made about deviations from the trajectory or alternate routes on the trajectory. The trajectory moves toward a *multifinality* where there is more than one concrete goal, or a *zone of finality* if the general direction but not the specific goals are clearly visualized.

Holden (2010) discusses the idea of trajectory from the perspective of the parent providing social guidance for children's progress toward the future. Parents initiate trajectories by selecting environments that expose children to experiences and invest resources in particular activities, such as music lessons that may or may not pan out. Parents may support trajectories through proactive and sustained efforts, including encouragement, time, and helpful messages and material assistance. Parents mediate trajectories that are chosen by the child by helping the child to interpret roadblocks and helping them to avoid problematic trajectories. Finally, parents provide guidance by reacting positively or negatively to child-initiated trajectories by supporting the child's choices of activities, education, and career, or using their power to attempt to redirect or create barriers to the child's choices. Holden's analysis is not a deterministic one because the child is also active in accepting, rejecting, or negotiating parent-initiated pathways. Children's own efforts determine progress on the trajectory and they may choose their own pathway with or without the parents' support.

A question for future research is whether parents take a dialectical perspective on their role as socializing agents. Parents do not always expect exact transmission of messages and exact conformity as outcomes (Goodnow, 1997) and it is possible that when parents give commands or hold forth on values, they have some expectation that their requests will be compromised or transformed through interpretation. In this view, parents who have an inflexible or deterministic conception of future goals may be on a trajectory that is problematic for both parents and children. Having precise goals such as insisting that children have specific beliefs, or that they achieve academically at an unrealistic level, or adopt a narrow range of professions (doctor or lawyer, but definitely not psychologist) may undermine children's confidence or promote resistance in children and a sense of failure in parents.

There is preliminary evidence that parents may have expectations and practices that are consistent with a dialectical perspective on influence. Robson and Kuczynski (2013) found that parents of 8- to 13-year-old children rarely conceived of or enforced their behavioral expectations of children in the sense of clear, inflexible "rules" determined solely by the parent. Instead, flexibility was built into the nature of parental expectations. Flexibility was evident in that parents adjusted their expectations according to the child's emotional state and situational circumstances and allowed leeway in the time frame for the child's cooperative response. Leeway was also inherent in the way parents perceived they implemented their expectations. Parents reported that rules were negotiated during interaction. For instance, parents adjusted their rules based on the child's resistance and the child's persuasive abilities. Resistance was anticipated and often interpreted as a legitimate sign of children's autonomy and parents granted greater leeway as children earned their autonomy by demonstrating responsibility. Thus, parents appeared to have an underlying dialectical conception of their influence both by incorporating leeway for the child's agency in their very conception of rules and in anticipating and accepting novel outcomes during interactions with their child.

APPLIED SOCIAL RELATIONAL THEORY

Although social relational theory is relevant to multiple practical applications concerning interventions in the family, the focus here is on applications in family therapy. When families enter the therapeutic setting, parents, who generally initiate the appointment, often present the problem as noncompliance or unmanageability of the child. Parents are frustrated, angry, powerless, defeated, and define for the therapist the desired outcome, which often is that the child must be changed or must be made to comply. However, the therapist sees other issues beyond the presenting problem of child noncompliance, in particular the therapist sees relational complexities in the dynamics of the family. The child is also frustrated, angry, powerless, and defeated, and other family members, the marital relationship, sibling relationships may also be troubled.

Depending on the therapist's theoretical orientation, there are different directions for choosing where to intervene in a dynamic parent-child relationship system. For the behaviorally (i.e., mechanistically) trained therapist the choice is often to begin with the child's noncompliance and its role in a mutually coercive cascade (McMahon & Forehand, 2003; Patterson et al., 1992). Noncompliance has been described as the foundation for the development of children's aggression and the parents are commonly given a child-management protocol to increase their control over the noncompliance. In this perspective the quality of the parent-child relationship is a secondary goal that, hopefully, will follow improvements in the child's behavior. Contemporary parenting programs that are focused on noncompliance often have a relationship-management component where efforts are made to improve the relationship by adjusting the ratio of positive to negative reinforcements or emotional communication skills (Kaminski, Valle, Filene, Cynthia, & Boyle, 2008). However, relationship management is often added on eclectically and pragmatically and does not stem from a theoretically integrated position on the role of relationships in the assessment of causality in the family.

Some cognitive-behavioral therapists have adopted a more comprehensive relational approach to intervention. Cavell challenged the tight focus on noncompliance, arguing that a strong stance against noncompliance could undermine the affective quality of their relationship (Cavell & Elledge, 2007; Cavell & Strand, 2003). Cavell advocated a broader focus on long-term socialization goals instead of immediate reduction of problem behavior. This approach includes constructing an accepting long-term relationship as a context for children's development and developing a sense of connection and containment within that relationship.

Family therapists, trained in a family systems perspective (Nichols, 2012) understand the family as an organized whole, beyond the individual and beyond the dyad, in which mutual influences between the family members feature the interdependent nature of the system. Family systems theory was influenced by cybernetics and general systems theory (Dallos & Draper, 2000). Both theories offered a comprehensive paradigm to understand the individual family member within the dynamics of the family context, but differed in their approach about the nature of the system. Cybernetics takes a mechanistic perspective in which families are approached as closed systems driven by basic principles as feedback, homeostasis, and circularity. In the mechanistic perspective, systems resist change and psychopathology of an individual family member is assumed to have the function of restoring homeostasis when the family equilibrium is upset. On the other hand, in the general systems perspective, systems are open and consist of living organisms that constantly coact with their environment (Overton, 1975; von Bertalanffy, 1968). Within this organismic perspective systems are also seen as self-organizing, self-regulating sets of processes that actively maintain internal stability, as well as creatively adapt to the external environment. In the organismic systems metaphor the psychopathology of an individual family member is considered to reflect the failure of the family as a system to adapt to internal and environmental changes (Minuchin & Fishman, 1981). Because of this holistic approach to humans' individual and relational functioning, the target of intervention is more often the relationship. However, family therapists are hampered by insufficient conceptual tools for understanding relationship dynamics and for intervening at the relationship level.

Social relational theory is not a psychotherapeutic model or protocol, but a theory about family dynamics offering ideas and concepts that focus on meaning construction within family relationships and other social contexts. The theory's dialectical assumptions has a potential to inform clinical practice with troubled families because it offers a reframing of troubled relationships that builds on strengths within the family. Its core examples from research on well-functioning, or nonclinic, families, indicating that child resistance, conflict and opposing perspectives, intimacy, flexibility, and uncertainty have positive functions in the family reframe similar ideas that have had an exclusive negative connotation in studies of clinic families. The focus on agency, the relationship context, and dialectical change suggests directions for a positive action-oriented approach that contrasts with the problem-focused interventions.

Concepts such as equal agency, which draws attention to the agency of not only the parent but also the child and the dialectical tensions between both agents, the relationship as context embedded within cultural contexts, and the dialectical nature of interpersonal influence, can help the clinician to understand (and do something with) the complexity of the process of reconnecting the agents to the relationship.

Addressing the agency of individuals is central to a strengths-focused approach in which the focus is on the positive capacities of parents and children, including positive goals and resources that they can develop, rather than on their problems and deficiencies (R. M. Lerner, Almerigi, Theokas, & Lerner, 2005; Saleebey, 2013). Focusing on strengths connects agents as a constructive future perspective on their relationship becomes more visible (Berg, 1994). Most psychotherapy models agree that progressive change can only be obtained by addressing constructive human dimensions, for example by encouraging parents to use positive reinforcement of appropriate behavior not just punishing noncompliance. However, although attention has been paid to the resilience of children in the family (Walsh, 2006), an agentic strength perspective is almost absent in research on child psychopathology. The traditional focus on children with ADHD, autism, obsessive-compulsive disorders, oppositional-defiant disorders, and conduct disorders is on the deficits of these children and how the environment, in particular the parents, have to deal with it. Almost no research has focused on what these children add to the relationship and how the environment can build on these constructive aspects in social interactions with these children. Instead, clinical concepts such as "noncompliance" infuse children's attempts to express their autonomy with the idea of defiance (Kuczynski & Hildebrandt, 1997). Similarly, constructs such as "parentified child" and "role reversal" attribute victimization and passivity to actions that alternatively may be viewed as the child acting as competent or resilient actor stepping up to promote mutual goals on behalf of the family (Chee, Goh, & Kuczynski, in press).

Focusing on the agency of the child is consistent with evolutions in family therapy in which the child is perceived as an agent of change (Wilson, 2012). Children bring novelty, unpredictability, and creativity into the family therapy session that the therapist can welcome to induce change. Wilson argues that the family therapist has to leave his safe position and move to a "zone of discomfort," a zone that is not controllable for the therapist due to the agency of the child in the therapy session. Treating parents and children respectfully and equally does not mean agreeing with them all the time. Change includes dialectical interventions from the clinician whereby the appropriateness of parents' and children's positions, beliefs, and goals are challenged. This active attitude includes the clinician not being able to know in advance which meanings and behaviors are appropriate for the system because these are coconstructed within the therapeutic process.

Isolated Versus Connected Agents

An implication of the social relational perspective is that the dialectical process of opposing forces between parent and child actions as agents can only be constructive for development when both feel connected to the relationship. The inevitable contradictions that exist between parents and children, which are necessary for development, become obstacles when parent and child agents no longer feel connectedness to the relationship. When contradictions can only be felt and understood as mutual rejections, positive moments of synthesis are impossible and parents and children become alienated from the relationship.

The basic therapeutic premise that follows from this perspective is that family members who visit clinical practice are feeling and behaving as *isolated agents* and not as *connected agents*: Family members have lost or are losing their connectedness to the relationship. At the beginning of a psychotherapeutic process, parents and children tell stories about their being hurt, misunderstood, rejected, teased, denigrated, and assaulted by others. They experience these feelings in an overpowering and undifferentiated way. The basic feeling is one of disadvantage or being badly treated by others. The core issue is that family members seem to have lost a sense that they have significance and make a difference in their relationships.

Children can be said to differ in their sense of connectedness in supportive relationships. Relationally connected children have a history of involved, responsive, and intimate relationships and have a relatively high stake in their relationships with parents and others in their social networks. As connected agents, they are more likely to have their expression of agency constrained by a desire to protect their valued relationship. They are more likely to have a mutually responsive orientation (Kochanska, 2002) and, when they resist, they are more likely to do so in a way that accommodates the relationship. In contrast, relationally isolated agents have a history of uninvolved, unresponsive and nonintimate relationships and a corresponding low stake in personal relationships with caregivers. This dynamic is likely for children in neglecting, abusive, and insecure relationships.

Baumrind (2012), citing Bakan (1966), argues that optimal development requires a balance within the individual of the competing drives of communion and agency:

> *Communion* is the drive to be connected and of service that manifests itself adaptively in pro-social conduct, including friendliness with peers, and cooperation with just authority; *agency* is the drive for independence, individuality, autonomy, and mastery that manifests itself adaptively in self-efficacy, initiative, assertiveness, and resistance to what are perceived as unjust demands. Agency unmitigated by communion is self-centered and exploitive resulting eventually in reciprocated harm; communion unmitigated by agency is self-abnegating and subservient, inviting exploitation. (p. 46)

Thus, Baumrind cautions against the extremes forms of both isolated and connected agency. Reinterpreting this from a relational perspective, what is required is a relationship context that fosters both autonomy and interdependence. This means a relationship where the agency of each member is acknowledged, where difference can coexist with connection, and each member recognizes existentially that they have influence in the relationship.

Reconnecting Agents to the Relationship

A direction for application is that any professional change agent, including the therapist can construct with the parent and the child moments of shared and cocreated meanings in their relationship. The therapist can begin to connect parents and children by pointing to the fact that they took the trouble to visit clinical practice as evidence that the relationship matters to them. Furthermore, the concept of the relationship as a systemic whole, including a past, a present, and a future can inspire parents, children, and the clinician in their joint search for moments of shared meaning (Oliphant & Kuczynski, 2011; Weingarten 1991). Joint recognition of moments of intimacy reconnects the isolated agents to the relationship. By identifying past and present moments of shared meaning the parent and the child can each recognize that the ability to engage in shared meaning belongs to their relationship and not just conflict. However, the construction of the relationship cannot be solely an individual activity. Mutual moments of intimacy are necessary to connect the agents and to create the possibility for constructive dialectics in the relationship. Moments of intimacy do not reflect fusion of the agents: Difference between the agents and acceptance of difference is necessary for positive development.

The agency of the family member reflects the meaning or significance of the family member within the relationship and consequently implies the existential nature of being an agent in the relationship. Because the sense of being an agent is constructed within the relationship, a family member is dependent on acts of recognition of other family members for the development and construction of his or her sense of agency. When the parent and the child can feel again that they make a difference toward each other, they can be reconnected to the history of their relationship.

Promoting the Idea of Dialectical Influence

The idea of "making a difference" in the relationship pertains to the dialectical construct of relational influence discussed earlier. An important goal in reconnecting isolated family members to the relationship is that family members develop a concept of interpersonal influence that is appropriate to interactions among human agents. There are two potential issues, loss of a sense of relational efficacy, and an inappropriate linear conception of the nature of influence in social interactions between human agents.

Relational efficacy is a dialectical elaboration of the existing concept of *self-efficacy* (Bandura, 2006). Despite the importance of the self-efficacy construct for understanding human agency, the original definition of self-efficacy is based on an implicit linear conception of influence, namely, the belief that an agent has the capacity to exert personal control to produce a particular outcome. This sense of *control* is assumed to originate through the experience of contingencies among actions, intentions, and outcomes. However, relational efficacy, or the belief that one can influence another person in a relationship, distinguishes interpersonal outcomes from outcomes such as control over the nonsocial environment. The construct of relational efficacy includes both cognitive and experiential dimensions and stems from an individual's experience of making a difference in the relationship (De Mol & Buysse, 2008a). Relational influence captures the person's existential being in the relationship, where what the person does or does not do has consequences for the other person in the relationship.

A sense of relational efficacy develops from an individual's history of transactions in specific relationships. Children report that their sense of influence in the family derives from a mutually responsive parent-child relationship context (De Mol & Buysse, 2008b). Similarly, Cummings and Schermerhorn (2003) proposed that parental sensitivity and responsiveness promote children's beliefs that they can influence family interactions. For instance, Cummings and Schermerhorn argued that secure and insecure attachment patterns could be interpreted as children's beliefs that their bids for comfort in stressful situations will be met with success. De Mol and Buysse (2008a, 2008b) found that children recognize their influence on parents but often do not perceive this influence to be strategic or intentional. This suggests that children derive their sense of relational influence from the way their parents respond to their actions. The influence children have on their parents tells children something about their agency in the relationship. Because of their position in the relationship, which is less bounded by cultural obligations in comparison with the parents' position (e.g., parents have a social and financial responsibility, which children do not have), children can feel and describe the dialectical nature of interpersonal influence. This is much more difficult for parents because they may be constrained by illusions of control because of dominant unilateral discourses in our society.

Relational efficacy has two components. First, a sense of relational efficacy develops from the awareness that one's influence emerges from a history of transactions in the relationship and that one exerts one's own influence in a bidirectional ←→ context that includes the influence of the other. Second, a realistic sense of relational efficacy requires awareness that influence is dialectical in nature and that the outcome has the potential for novelty. Assessing the other's response always entails uncertainty because the other's response contains external behaviors that one can objectively see as well as internal responses that one cannot see. Grusec and Goodnow (1994) argue that the success of the parent's influence attempt depends, cognitively, on the child's accurate perception of the message and, motivationally, on the child's acceptance of the message. However, the parent never knows for certain if the message has been accurately perceived or accepted.

A sense of relational efficacy is built up of one's experience of both cooperation and resistance, formed during the history of the relationship. Because of the transformations that occur during transactions, an expectation of having a deterministic control over social outcomes is unrealistic and potentially maladaptive because the agency of each family member is ignored (White & Epston, 1990). However, even if a child does not comply, or comply exactly, to a parent's request, a sense of relational efficacy may emerge from perceptions that the parent has been heard, that they matter (Marshall & Lambert, 2006), or that they have made a difference in the relationship.

When agents lose their sense of relational efficacy, the relationship is no longer a constructive power resource that can support them as agents of influence. And when constructive power resources disappear, only coercive power remains (De Mol & Buysse, 2008a). Cummings and Schermerhorn (2003) argued that when children have little sense of agency in the relationship they tend to express their agency in extreme controlling ways or may act in an excessively self-reliant manner. Similarly, Bugental, Lyon, Krantz, and Cortez (1997) found that mothers who experience a loss of influence act in a threatened manner and resort to coercion to restore their power. The problem with coercive power is that coercion can never change the relationship in constructive way because individual agents become further alienated from the relationship.

Another implication for clinical practice is that isolated agents may have an inappropriate expectation that their influence in interpersonal relationships should be linear and direct. The assumption that parents and children are equally agents implies that one relationship partner cannot mold the other or cannot influence the other in a way that the other becomes a person as desired by the relationship partner who exerts influence.

To develop a sense of efficacy in the relationship, parents and children need a dialectical conception of what influence means. Namely, because of the meanings generated by each of the interacting partners during the processes of internalization and externalization, their effects include qualitative change or novelty (see previous discussion of relational influence). Without this dialectical conception of influence, the other's responses of nonexact accommodation, reinterpretations, and negotiations cannot be perceived as positive outcomes of influence. The metaphor of developing and *experiencing the inside* (as a result of internalization) and *dialoguing via the outside* (as a result of externalization) can be used to translate the abstract scientific metaphor of internalization and externalization into a form that can be used in clinical practice.

Each person in a transaction influences the other in a two-stage process: their inside private experience and their outside public communication. The inside consists of cognitions and felt emotions about the other and the relationship and what one would like the other to do. Individuals disclose their inside to others through their outside via overt behavior, verbal messages, and nonverbal communication such as facial expression, tone of voice, and body posture. Within social interactions individuals can see others' outside but not their inside. It is by means of their outside that individuals affect the other person, which means that the other person will interpret the individuals' outside. Based on these interpretations and inside experiences, the person will respond with their own outside. Each person in a social interaction interprets the other's behavior, attributes meaning to it and feels something about it, and ultimately responds or externalizes on the basis of that interpretation and feeling. Thus an influence transaction between two people is a dance with four steps: sender's outside to recipient's inside; recipient's outside to sender's inside. The outcome of actions between agents in the dance of relational influence should always be considered to generate something new that reflects the activity of both partners.

Within a clinical context, the child, as full and equal partner of the parents and the clinician can contradict the illusion of direct control and give insights in the complexities of interpersonal influence. Although agency includes strategic action and partners use strategic behavior to influence the other partner in the relationship, strategic action can never unilaterally change the other agent. Consequently, the therapeutic agent has to take this position explicitly, acknowledging the impossibility of imposing change on the parent and the child. However, therapeutic agents do have relational influence in the sense of making a difference in the relationship.

Acknowledging the Cultural Context of Agency

The recognition in social relational theory of cultural influences on the construction of the parent-child relationship also has important clinical implications. Cultural representations complicate the therapeutic scenario at a level beyond dyadic interactions. For example, a strong social representation in Western culture is the deterministic notion that the parent is causally responsible for the development of the child (De Mol & Buysse, 2008b). This social representation is problematic because meanings are constructed about the failing parent and about the child who is victim of the parental failure. The cultural representation that the parent-child relationship is necessarily hierarchical is a barrier to understanding that friendship qualities or intimate interactions that are possible in the relationship. The dominant representation that a real parent-child relationship is a biological relationship is problematic for stepparent-stepchild relationships where there are no cultural prescriptions available for the stepparent and child about how to act in the relationship. For children with ADHD the representation that education can only be accomplished if the child acts beyond their capacity and sits still and attentive for long periods of time is a barrier to understanding the child's limitations for acting agentically within these constraints.

The therapeutic agent can address the barriers posed by cultural representations by offering parent and child the broad cultural framework in which the constraints on their agency acquire meaning. This implies that parents and children cannot change cultural discourses, but by addressing them as full agents they can think how to cope with these complexities and recognize that they have an influence on these discourses, although without changing them linearly. Acknowledging cultural representations allow the clinician to address the reciprocal influences between the various levels of human complexity.

DIALECTICALLY INFORMED METHODOLOGY

The dialectical approach is partially an argument that a broader methodology of theory-driven research is needed for the study of socialization processes. Over the years there have been calls for a conception of science that recognizes a constitutive role of theory construction as an interpretative act in the process of generating scientific knowledge in psychology (e.g., Haig, 2005; Kuczynski & Daly, 2003; Overton, 2002, Chapter 2, this *Handbook*, this volume; Valsiner, 2000). This position means that the field needs to move beyond the neopositivist methodologies that have dominated research efforts. As an epistemology, neopositivism regarded scientific hypotheses as strict inductions drawn from pristine empirical observations and hypotheses were assessed in this same pristine field. This approach demanded that any theoretical concept or broad theory be ultimately reducible to the pristine observations from whence they derived (see Overton, 2006, for a critique of the history of neopositivism and instrumentalism as scientific methodologies). A consequence of neopositivism is that inductive and hypothetico-deductive methods, with an associated focus on the tools of statistics, aggregated variables, and objective measures, are viewed as the hallmarks of the scientific method, a position that marginalizes the role of theory construction (e.g., Haig, 2005; Overton, 2006; Valsiner, 2000).

Valsiner (2000; Branco & Valsiner, 1997) suggests that rather than viewing methodology as a toolbox of ready-made methods for gathering data (observations),

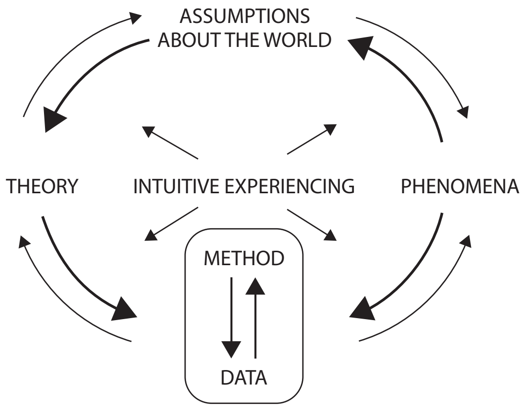

Figure 9.8 The methodology cycle.

Source: From "Changing Methodologies: A Co-Constructivist Study of Goal Orientations in Social Interactions," by A. U. Branco and J. Valsiner, 1997, *Psychology and Developing Societies*, *9*(1), 35–64. Reprinted with permission of Sage Publications.

methodology should be viewed more generally as the whole process of knowledge construction (Figure 9.8). "It entails mutually linked components of general assumptions about the world at large (axioms), specific constructed theories of the given target area, understanding of pertinent phenomena, and—finally—ways of constructing specific methods to transform some aspects of the phenomena into purposefully derived data" (Valsiner, 2000, p. 82). Explaining the phenomenon is the focus of the knowledge construction process and the researcher is the agent who will use whatever methods or concepts it takes to achieve understanding, mainstream or not. Worldviews, metatheory, theory, phenomena, and the production of data are interlinked in a system of ideas observations and procedures in which the researcher, on the basis of personal reasoning, experiences of the real world, and intuitions, makes productive or unproductive choices among various methods in relation to the emerging understanding of phenomena. The following examines the coacting components of the methodological cycle.

Focusing on the Phenomenon

The phenomenon is the central focus of the research endeavor. According to Haig (2005) phenomena are relatively stable, recurrent, general features of the world that researchers seek to explain. Haig distinguishes phenomena from data. Data are pliable and idiosyncratic to particular investigative contexts because data result from the interaction of a large number of factors.

> Phenomena have a stability and repeatability that is demonstrated through the use of different procedures that often engage different kinds of data. Data are recordings or reports that are perceptually accessible; they are observable and open to public inspection. Despite the popular view to the contrary, phenomena are not, in general, observable; they are abstractions wrought from the relevant data, frequently as a result of a reductive process of data analysis. (Haig, 2005, p. 374)

As was outlined earlier in this chapter, socialization, as a phenomenon, is more complex than once was assumed and involves intergenerational change, not just stability and continuity, active agency, not just passive reactivity. This is what needs to be understood. Theory, data, worldviews, experience, therefore, can be regarded as no more than conceptual and procedural tools that aid in understanding the phenomenon.

Worldviews

Worldviews generally refer to metatheoretical ideas regarding ontology, or assumptions about the nature of the world. Ontological assumptions guide the conceptualization of both the phenomenon and its constituent processes. It was argued in this chapter that a dialectical (organismic-contextual or relational developmental systems) ontology is better suited for understanding the phenomenon of socialization in the family than a mechanistic ontology. A dialectical ontology involves assumptions about the active nature of the coacting components, the context in which they coact, the relations between the components and the whole and the nature of outcomes. We also argue, that to make effective use of dialectics as a conceptual tool, one cannot adopt just one idea, such as accepting that children are agents, but retain other assumptions such as a mechanistic conception of influence or regarding context as a variable rather than a constituent process. Comprehensively adopting a dialectical model has implications for the whole system of ideas that are used to understand a phenomenon.

Adopting a dialectical framework is difficult because training in psychology continues to be influenced by a mechanistic ontology (see Overton, Chapter 2, this *Handbook*, this volume). According to Kuczynski et al. (2003) adapting a dialectical framework is especially difficult in the study of socialization because dialectics goes against the grain of "common sense" cultural understandings of the nature of parent-child relationships. Natural language, concepts, aphorisms, and metaphors, which are part of culture, guide the perception of childrearing and as a fundamentally unidirectional, deterministic process. There have been several proposals of steps to be undertaken by a researcher who wishes to take the qualitative shift to dialectically inspired research.

Toomela (2012) addressed the challenge of enabling researchers to abandon habits of partitioning what is a systemic causal whole into discrete linear causes and effects by providing steps for implementing the principle of holism. Citing the work of Vygotsky, Toomela argues that to understand any phenomenon in a system under investigation one needs to know: (a) the component parts that make up the whole; (b) the specific relations between the components or structure of the phenomenon; and (c) development, or how the phenomenon emerges and changes over time.

Overton (2002) outlined three steps that focus on the need to replace traditional epistemological dichotomies of observation versus interpretation, and, theory versus data, with relational bipolar dimensions:

Step 1, *relational analysis—synthesis* replaces split reductionism. This means that analysis must occur in the context of some integrated whole, and the integrated whole operates in the context of its analytic parts (see also Wagoner, 2011).

Step 2, *relational action pattern—conditions* explanation replaces split causes. This means a focus on the systemic conditions associated with change rather than direct causation between isolated elements. This idea invokes Aristotle's formal and final explanations and is similar to Valsiner's (2000) idea of catalytic or systemic causality rather than efficient or linear causality.

Step 3, *abductive logic* replaces split induction and deduction. *Abduction*, also referred to as *retroduction*, was originally described by the pragmatist philosopher Charles Sanders Pierce (1992) as a third mode of inference, along with deduction and induction, and the only mode of inference concerned with the discovery of new ideas. Modern revival of interest in abductive inference is attributable to Hanson (1958) and to Harman (1965), who introduced a conception of abduction known as *inference to best explanation*. The abductive process or abductive inference operates by arranging the observation under consideration and all background ideas (including specific theoretical and metatheoretical concepts) as two spheres of the dialectic relation. The question is then asked as to what must necessarily be assumed in order to have that observation. The inference to what *must,* in the context of background ideas, *necessarily be assumed* then comes to constitute the explanation (or abductive hypothesis) of the phenomenon (Overton, Chapter 2, this *Handbook*, this volume). Theory construction involves three general methodological phases: (1) theory generation entailing the abductive process to generate a system of hypotheses, (2) theory appraisal by assessing the abductively derived hypotheses in varied contexts beyond those used to generate them, and (3) theory development whereby the supported abductive hypotheses become a part of the system of hypotheses to be applied to other phenomena to generate further abductive hypotheses. Each phase requires inferential processes, the very processes that neopositivism disparaged as unscientific (Haig, 2005; Overton, Chapter 2, this *Handbook*, this volume).

Finally, Kuczynski and Parkin (2009) offered a third set of recommendations, this time for implementing a dialectical ontology for the study of parent-child relationships and socialization. First, stop thinking of parents and solely in terms of mindless behavioral reactivity or sets of variables; think of parent and child as equal agents. Second, stop thinking about parents and children as individuals or even individuals engaged in social interaction; think of parents and children as engaging in transactions in an interdependent, long-term relationship context. Third, actively search out processes within the parent, within the child, or between the parent and child that are most likely to be a source of contradiction and disequilibrium, for these are the source of changes in representations that are opportunities for qualitative change. Fourth, challenge linear thinking; think both/and and search for synthesis.

Theory

In the methodology cycle (Branco & Valsiner, 1997; Valsiner, 2000) the researchers' consideration of the phenomenon and the array of ideas concerning worldviews, experience, and data leads to the development of mid-range theory that conceptualizes current understanding of the phenomenon or some aspect of the phenomenon. As can be seen in list of constructs in Table 9.2, the conceptualization of many basic concepts in socialization research was guided explicitly or implicitly by the worldview metaphors of mechanical mechanism and linear causality. Adopting

TABLE 9.2 Socialization Concepts in Mechanistic and Dialectical Metatheoretical Frameworks

Constructs	Mechanistic-Deterministic →	Dialectical-Relational ←→
Bidirectional dynamics	Social interaction Exchange of behaviors Individual dynamics	Social transaction Mutual meaning making Relationship dynamics
Context	Decontextualized dyads	Close relationships
Agency	Unequal agents	Equal agents
Unequal power	Static asymmetry	Interdependent asymmetry
Agency constructs	Self-efficacy, sense of personal control	Relational efficacy, sense of interpersonal influence Isolated and connected agents
Interpersonal causality	Control	Relational influence
Antecedents of change	Control strategies	Contradiction: ambiguity, ambivalence, conflict, expectancy violations
Conformity	Compliance/noncompliance	Willing compliance, accommodation/negotiation
Internalization	Intergenerational Transmission	Construction of working models

a organismic-contextual or a relational developmental systems ontology (see Overton, Chapter 2, this *Handbook*, this volume; Witherington, Chapter 3, this *Handbook*, this volume) interpreted through dialectics provides a means of reinterpreting each of the basic concepts so that they are infused with interconnected assumptions of holism, contradiction, and synthesis. The dialectically reinterpreted concepts in Table 9.2 represent a continuation of the proliferation of new concepts and, indeed, new language, for parent-child relations and socialization processes that has been occurring in the literature on parent-child relations since the "discovery" of reciprocal relational bidirectionality ←→. Examples are "coconstruction," "coaction," "scaffolding," "coevolution," "coregulation," "collaboration," "intersubjectivity," "interpenetration," "shared meaning," "shared affect," "joint activity," "attunement," and "relational dialectics" (Kuczynski et al., 2003). These new concepts represent processes—not mechanical mechanisms—for which there are no natural language terms. Rather than thinking of interaction as a series of discrete turns, exchanges, reactions, or control techniques, the new concepts attempt to aid the perception of the thoughts and actions of one partner as intertwined with the thoughts and actions of the other. Actions of the parent and of the child may be mutually anticipated, interpreted, and adjusted to in a continuous fashion so that it is difficult to think of the products of parent←→child relations, whether they be meanings, childrearing strategies, or social relationships, as individual achievements.

Data ←→ Method

According to Valsiner (2000), methods and data are constructed by researchers on the basis of the way they have personally strategized their study of a phenomenon with regard to the methodology cycle. The data ←→ method process may feed back to the reconstruction of theory regarding the phenomenon. The methodology cycle encourages a flexible and strategic approach to method that defuses debates between quantitative and qualitative research. "Neither quantitative nor qualitative methods per se can be labeled 'objective' or 'scientific' as their status in these valued roles is determined only through their fit with the methodology cycle" (Valsiner, 2000, p. 82).

Given that so much data has been derived from mechanistic, neopositivist approaches, it would seem that there should be more investment in deriving data from an organismic-contextual perspective. In this endeavor, there is a special place for a theoretically guided mixed-methods approach that includes qualitative methods (see Tolan & Deutsch, Chapter 19, this *Handbook*, this volume, for an extended discussion of mixed methods). Qualitative research, including naturalistic observation and its cognitive counterpart, qualitative interviewing, is an interpretive, naturalistic method for identifying, describing, and understanding phenomena. Several features of qualitative research makes it well-suited for the identification and analysis of phenomena from a dialectical perspective. First, the dialectical conceptions of processes, contexts, and outcomes, described in this chapter, entail cognitive, bidirectional ←→ transactions, and qualitative research is directly concerned with data having to do with the research participants' cognitive and emotional experience. Second, qualitative methods are naturalistic methods and have the goal of discovering natural categories (themes) that are grounded in the participants' experiences of the phenomenon. This contrasts with dominant quantitative approaches in which meanings are predetermined, and operationalized beforehand (e.g., preestablished coding systems, rating scales) and imposed on the research participant. Although such methods have their place in testing selected hypotheses derived from existing theory, they do not generate new concepts and theoretical innovation. The most important outcome of qualitative research is to identify and describe new concepts as well as theory about phenomena that takes into account the contextualized and transactional nature of socialization. Qualitative research is also useful for exploring underlying micro processes that underlie measured variables or statistical associations between variables. Finally, naturalistic qualitative research may lead to the construction of new measured variables that derive ecological validity from the extent to which they reflect the natural cognitive experiences of parents and children.

Qualitative research maximally involves the interpretive capacities of researchers in the process of making sense of the data they collect. Kuczynski and Daly (2003) outlined an abductive approach to qualitative analysis of narratives that is designed to promote the discovery of new phenomena from naturalistic data. The strategy requires that the researcher enters the analysis of naturalistic data by first arranging background ideas as *sensitizing concepts*. For example, sensitizing concepts may be the competing behavioral and dialectical models for a phenomenon that are available in the literature as well as ideas available from experience. These sensitizing ideas initially serve to guide the interpretation of data. Thus, sensitizing ideas are analogous to hypotheses, which may or may not be confirmed by the analyses of the data. However, the researcher's ideas are sensitizing and do not determine the final identification or interpretation of themes because the researcher is also alert to ideas in the narratives that contradict or cannot be understood with reference to the background of existing theory. These contradictions are the surprising observations for which a new explanation must be abductively generated. The new inference of a best explanation for a phenomenon can then be assessed against competing ones. Essentially, the approach is a deliberate search for puzzles in the data that fuels the abductive interpretive process in the search for new discoveries.

CONCLUSIONS

It has long been recognized that theories of socialization often provided inadequate models for understanding the phenomenon of socialization. An important advance has been made since the 1970s in the move from unidirectional to bidirectional ←→ models of socialization to capture the inherent bidirectionality that is evident in the phenomenon of socialization. A second advance has been the increasing focus on human agency (Bandura, 2006; Kuczynski, 2003; Sokol et al., Chapter 8, this *Handbook*, this volume; Witherington, Chapter 3, this *Handbook*, this volume) in the complex causal structure of socialization phenomena. The new challenge is consider the larger framework of dialectical systemic assumptions in which relational bidirectionality and agency are embedded. Individual concepts within dialectics—activity, context, qualitative change, contradiction—have long been a source of key metaphors that have fueled theory development in psychology. However, this has often been a piecemeal approach that essentially reduced the various aspects of the dialectical framework to elements rather than components of a whole system of thinking and perceiving phenomena.

The dialectical framework outlined in this chapter is incomplete because the construction of dynamic systems metatheories for developmental psychology is ongoing (Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Overton, Chapter 2, this *Handbook*, this volume; Valsiner, 2012; Witherington, Chapter 3, this *Handbook*, this volume). Moreover, the process of translating between metatheoretical to substantive theory levels of analysis as well as the implications for practice is in its early stages. In any case, conclusions, in dialectics, are always in process.

The transactional model originally proposed by Sameroff (1975a, 1975b) is also an unfinished project. Although the idea of reciprocal relational bidirectionality has taken hold, the dialectical conception of transaction has not. One reason has to do with compromises that result when rich theoretical concepts are subjected to statistical testing. "Although the transactional model originates from a strongly dialectic, organismic orientation, any operationalization requires a mechanistic measurement model, in which dynamic processes are reduced to static scores that can be entered into statistical analyses" (Sameroff & MacKenzie, 2003, p. 617).

Social relational theory builds on the transactional model in two ways: First, when the purpose is to predict selected key hypotheses, improvements can be made in the creation of variables that capture dimensions of parent and child behavior in a more dynamic way and in formulating outcomes so that they reflect the idea of synthesis. Qualitative changes are difficult to detect when measures of outcomes themselves are conceptualized in a deterministic way.

Second, social relational theory provides guidance for exploring underlying micro processes of social transactions. A micro-process model of dialectical causality together with a macro model of transactional nature of human development (Sameroff, 2009) may jointly address the tension between complementary goals of research: prediction, on the one hand, and understanding intervening processes, on the other.

A further challenge concerns application in clinical and other interventions. Advances in applying a dialectical systems perspective requires a new generation of science practitioners who are equally informed in dialectical theory and immersed in the reality of the family lives of their clients and knowledge of what it takes to help them. The promise of an organismic-dynamic-contextual framework for systems is that it offers theory to grasp the continuously more complex nature of families in current society because it embraces complexity and does not try to resolve it using mechanistic concepts.

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CHAPTER 10

Human Development and Culture

JAYANTHI MISTRY and RANJANA DUTTA

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The emergence of new paradigms, metatheories, theories, methods, and data in the field of developmental science has generated an exciting era for integrative thinking about the basis and course of human development (see Overton, 2013, Chapter 2, this *Handbook*, this volume). The integration of culture into the study of human development today is at a particularly promising juncture (Mistry, 2013). The overarching goal of this chapter is to highlight the advances that have been made in addressing the conceptual, theoretical, and methodological challenges in actualizing this integration. Within the broad discipline of psychology, three subfields have made contributions to our current knowledge about human development and culture: cross-cultural psychology, cultural psychology, and developmental psychology. Here, we extend prior syntheses of emergent convergences in these three subfields (Mistry, 2013; Mistry, Contreras, & Dutta, 2012; Mistry & Saraswathi, 2003) to articulate specific conceptual and methodological advances that foster the integration of culture and human development.

Although both the subfields of cross-cultural psychology and cultural psychology have focused on the study of culture in human development, historically they have represented different, often incompatible, theoretical stances (Mistry & Saraswathi, 2003). In search of a culturally inclusive, yet universal psychology, cross-cultural scholars have taken a primarily comparative cross-cultural research stance to explore similarities and differences of human psychological functioning (Berry, 1980; Berry, Poortinga, Segall, & Dasen, 1992; Jahoda & Krewer, 1997). In contrast, in the field of cultural psychology, scholars have focused on understanding culturally constituted meaning systems through which individuals experience their life events and circumstances. Cultural psychologists have given particular attention to the directive nature of shared meaning systems in the lives of individuals and how these meanings are constructed (D'Andrade & Strauss, 1992; Harkness & Super, 1992; Shweder et al., 1998, 2006).

We are grateful for invaluable comments from Willis F. Overton and Richard M. Lerner on previous drafts of this chapter. Our dialogue through the editing process has facilitated and strengthened the integration of perspectives that is represented in the chapter.

Noting that children grow up in specific sociocultural, economic, sociopolitical, and geographic contexts, cultural psychologists contend that contexts cannot be merely conceptualized as environmental influences on individual development. An understanding of context must include the tacit social and interactional norms of the individuals who constitute those settings and whose behaviors and expectations both shape and are shaped by institutional structures (Harwood, Miller, & Irizarry, 1995). The primary goal of cultural psychologists has been to understand the processes by which individuals coconstruct and actively appropriate rule-governed meanings, interpretations, and behaviors of particular contexts in which they participate (e.g., Harwood et al., 1995; Shweder et al., 1998, 2006).

In contrast to both cross-cultural and cultural psychology, the field of developmental psychology has primarily focused on understanding the nature and sources of developmental change. Culture has historically not been a central concern of developmental psychologists. However, when addressing cultural variations in development, developmental psychologists have treated culture as an independent variable, which has an impact on individual development. For example, in Bronfenbrenner's (1979, 1986; Bronfenbrenner & Morris, 2006) influential developmental bioecological model, culture is represented as the outermost layer of context or macrosystem. Although this model has conceptually focused on the interplay among the various layers of the context (i.e., psychological, biological, cultural, historical, institutional), empirically, the specific layers have been treated as split-off independent variables that influence behavior and development as efficient causes. Thus, culture is conceptualized as a feature of environmental or ecological context that exists independent of the person.

Although the three subfields of psychology (i.e., cultural, cross-cultural, and developmental) maintain distinct foci, conceptual, and theoretical perspectives, and methodological traditions, they began to converge in significant ways at the turn of the century (Mistry & Saraswathi, 2003). With this brief introduction, the chapter begins with a summary of initial convergences as well as continuing debates among the subfields (see also Mistry et al., 2012; Mistry & Saraswathi, 2003) in order to provide a context within which the current conceptual, theoretical, and methodological advances toward the integration of culture and human development—the focus of this chapter—can be understood. Following this contextual presentation of initial convergences and debates, the chapter turns directly—first with respect to conceptual issues, and then with respect to methodological issues—to examine advances in the integration of culture and human development. Then two topics in the field of human development are highlighted where the potential for integrating cultural and developmental science perspectives seems promising: cultural neuroscience and the development of ethnic identity.

INITIAL CONVERGENCES AT THE TURN OF THE CENTURY

The late 1990s saw an initial convergence in cross-cultural psychology, cultural psychology, and developmental science with respect to the conceptualization of culture and development (Mistry & Saraswathi, 2003). By the beginning of the 21st century, the three subfields mutually influenced each other's conceptual and methodological perspectives. Scientists who were critical of the culture comparative approach, which had previously defined cross-cultural psychology, led the way to a more socioculturally oriented psychological approach (Jahoda & Krewer, 1997; Poortinga, 1997; Segall, Dasen, Berry, & Poortinga, 1999). Along with these inroads to socioculturally oriented concepts and empirical research, a subgroup of cross-cultural psychologists argued for a paradigm shift (Kim, Park, & Park, 2000; Saraswathi & Dasen, 1997). To integrate the disparate bodies of indigenous psychological literature, these investigators proposed that concepts of human development be drawn inductively from within cultural communities.

Cultural psychology had also begun to make inroads in developmental science research, particularly in the area of childhood cognitive development (Kağitçibaşi & Poortinga, 2000). As a result, the cross-cultural comparative approach to cognitive development seen in the 1960s and 1970s evolved through the 1990s into a culturally enriched substantive body of literature innervated by sociohistoric-cultural perspectives (Rogoff & Chavajay, 1995). These convergences were exemplified in Keller and Greenfield's (2000) vision for the future of cross-cultural psychology, in which "developmental issues and methods will be theoretically, methodologically, and empirically integrated into cross-cultural psychology, thus enabling our field to make significant advance in research and theory" (p. 60).

CONTINUED DEBATES IN THE 21ST CENTURY

Despite cross-disciplinary convergences (Mistry & Saraswathi, 2003), critical differences and debates among the major approaches persisted through the first decade of the 21st century (Mistry et al., 2012). Notwithstanding agreement on the need to situate psychological phenomena in cultural contexts, conceptual and methodological debates continued about *how to integrate* culture with psychological development (Kağitçibaşi, 1996). The main challenge of integrating cultural, developmental, and cross-cultural perspectives arose from (a) underlying assumptions about culture (cast as opposing, split-off, either/or approaches), (b) contrasting methodological approaches, and (c) the different foci of the three fields, as evidenced by different questions of central interest within each subfield.

The question of how to conceptualize culture was debated on two fronts concurrently, but in parallel to each other. The first debate involved *cultural and cross-cultural psychology*. Cross-cultural psychologists such as Segall (1984) and Poortinga (1992, 1997) viewed culture as a set of conditions external to the person and they operationalized culture as antecedent variables influencing human behavior. Poortinga (1997) noted the need to "take cultural context, including ecological as well as sociocultural variables, as a set of antecedent conditions, while behavior phenomena, including attitudes and meanings as well as observed behaviors as outcomes or consequents" (Poortinga, 1997, p. 350). In contrast, cultural psychologists viewed culture and psychological processes as fused phenomena and claimed that the study of development must examine culturally constituted psychological processes, including culturally shared cognitive models and meaning systems (Harwood et al., 1995). As Shweder et al. (2006) argued:

> This insistence in cultural psychology that contexts and meanings are to be theoretically represented as part and parcel of the psychological system and not simply as influences, factors, or conditions external to the psychological system distinguishes cultural psychology from other forms of psychology which also think of themselves as contextual (or situated). (p. 724)

Thus, cultural psychology postulated culture as being inherent in the meaning systems and dynamic processes of making sense of the world. This entailed the presupposition that concepts of human functioning were culturally and contextually situated and, therefore, needed to be understood from an *emic* (i.e., culturally specific) perspective.

A second and similar debate was occurring at the time within *developmental psychology*. This debate was between those influenced by ecological and contextual perspectives (e.g., Bronfenbrenner & Morris, 2006; Lerner, 1991, 1996) and those influenced by sociohistoric and cultural perspectives (e.g., Cole, 1996; Rogoff, 2003; Wertsch, 1991). The issue in this developmental debate concerned the differentiation of the concepts *culture* and *context*. From the contextualist's perspective (see, e.g., Bronfenbrenner's [1979] bioecological model) culture was considered to be an *aspect* of context. Thus, culture was represented as a societal-level causal system that was part of the outermost layer of context (i.e., the macrosystem). On the other hand, those subscribing to the sociohistoric-cultural perspective argued that all contexts are infused with culture. This would mean that all contexts are interpreted through the symbolic lens of cultural beliefs and understandings of making sense of the world (Shweder et al., 2006). This distinction between culture as an aspect of context versus the meaning-making filter through which context is interpreted continued to be debated over the turn of the century.

The different conceptualizations of culture resulted in corollary debates with respect to preferred methods for investigating culture and human development. Cross-cultural psychologists promoted comparison across cultural communities using *common* concepts and measures, whereas cultural psychologists emphasized the *uniqueness* of concepts in each cultural context (Kağitçibaşi, 1996). These methodological debates were cast in terms of the historic *emic-etic* (Berry, 1969; Poortinga, 1997), or *indigenous-universalist* distinctions (Sinha, 1997). A person's actions are *emic*—culture-specific (i.e., indigenous)—to the extent that they represent the perspective of the participant, and can only be understood within that particular cultural context. A person's actions are *etic* or universal to the extent that they are common to all people independent of their cultural background (Kağitçibaşi, 1996; Poortinga, 1997).

Another dimension was added to the cultural versus cross-cultural debate, which entailed proposals for a comparative, decontextualized methodology preferred by cross-cultural psychologists versus a holistic, contextualized methodology preferred by cultural psychologists. The holistic interpretive methodologies—also favored by those subscribing to the sociohistoric-cultural developmental perspective—were tailored to study culturally unique phenomenon from an emic perspective, but these were not acceptable to cross-cultural psychologists, nor to contextualist developmental psychologists who favored conventional neopositivist empirical standards of methodological rigor (Kağitçibaşi, 1996). Similarly, some cultural psychologists (e.g., Greenfield, 1997) found unacceptable culture-comparative methodologies that employed etic concepts in efforts to establish reliable relations among cultural variables and psychological phenomenon.

The conceptual and methodological divide between scientists from the sociohistoric-cultural developmental and the cross-cultural and contextualist developmental fields can be partially attributed to the fact that each pursues a different goal. Cross-cultural psychology aims to extend the knowledge generated by developmental scientists to establish universals. Thus, Segall and colleagues (Segall et al., 1999; Segall, Lonner, & Berry, 1998) argued that the goals of cross-cultural psychology included (a) testing or extending the generalizability of extant theories and empirical findings in psychology; (b) testing or discovering the variation in behaviors using naturalistic variation provided by cultures; and (c) incorporating such variations into a universal psychology applicable to a wider range of cultural settings. In contrast to the cross-cultural goal of establishing lawful relations between environmental variables (as culture and context were often operationalized) and developmental outcomes, cultural psychology argued for understanding the directive power of shared meaning systems in the lives of individuals and their development (D'Andrade & Strauss, 1992; Goodnow, 2010; Harkness & Super, 1992; Shweder et al., 2006).

Leaving aside for the moment the difference within developmental psychology concerning the contextualist, cross-cultural, and sociohistoric-cultural, the study of developmental change within the field itself generally focused on the individual qua individual with the goal of describing, explaining, and predicting intra- and interindividual differences across the life span (Lerner, 2011). Because this goal was framed within a Cartesian-Mechanistic scientific paradigm (Lerner, 2011; Overton, Chapter 2, this *Handbook*, this volume), which understood the person as an additive outcome of independent forces, culture was simply considered to be one of these extrinsic forces.

THE CURRENT TREND TOWARD RELATIONAL INTEGRATIVE APPROACHES

For decades, cross-cultural and cultural psychologists have called for culturally informed approaches to the study of human development (Cole, 1985, 1996; Heine & Norenzayan, 2006; LeVine et al., 1994; Miller & Goodnow, 1995; Mistry & Saraswathi, 2003; Rogoff, 2003; Shweder, 1990; Super & Harkness, 1986; Valsiner, 1989). During the first decade of the 21st century they have been joined by developmental scientists advocating a similar need to expand concepts, theories, and research in order to make developmental science more inclusive (Arnett, 2008; Bornstein, 2010; Damon, 2011; Jensen, 2011; Mistry et al., 2012). The fact that 90% of the developmental literature originates from the United States and is generated by U.S. scholars whereas only 10% emanates from regions of the world that account for 90% of the world's population (Arnett, 2008) has led to serious concerns that the current developmental science literature cannot inform us about what it is like to grow up in the wide ranging circumstances of the world's population (Damon, 2011).

The promise of a culturally rich and fertile developmental science integrating cross-cultural, cultural, and developmental perspectives requires, as Mistry et al. (2012) have argued, overcoming two challenges: (1) resolving the continuing debates about the conceptualization of culture, and (2) framing the central questions for culturally inclusive theories of development in a way that each subfield has something of value to contribute. Overcoming these challenges is contingent on resolving and reframing the debates about culture and human development. If conceptual perspectives are framed as opposing alternatives, they are viewed as irreconcilable, but when framed as complementary and, therefore, equally necessary, they can lead to comprehensive and culturally inclusive accounts of human development. For example, in the forward to Jensen's (2011) book titled *Bridging Cultural and Developmental Psychology*, Damon (2011) notes that although neither perspective—cultural or developmental—on its own can offer a complete vision of human life, the two perspectives have not been easy to reconcile, because they have been separated "by longstanding oppositions between universalism and contextualism, absolutism and relativism, uniformity and diversity, and even the historically charged conflict of nativism versus imperialism" (p. xviii). Emphasizing the need to go beyond these opposing stances, Damon argues that the complexity of human life makes single-factor explanations for human behavior highly unlikely.

Overton's (2006, 2010, Chapter 2, this *Handbook*, this volume; Overton & Müller, 2012) relational metatheoretical framework offers a possible path to such reconciliation between opposing stances. Differentiating between split and relational metatheories, Overton (Chapter 2, this *Handbook*, this volume) argues that questions about development become debates only when cast as opposing dualities or antinomies (e.g., is development fundamentally universal or particular, continuous or discontinuous, biologically based or culturally based). Such dualities in the conceptualizations of development are characteristic of a Cartesian *split and reductionist* metatheoretical framework. In contrast, *relational* metatheoretical frameworks enable simultaneous consideration of both sides of conceptual contrasts. According to Overton (2006) "from an inclusive relational meta-theoretical position, all such debates necessarily evaporate, as the conceptual contrasts become co-equal, indissociable complementarities" (p. 29). Adopting this metatheoretical stance, Mistry et al. (2012) identified two key convergences in the developmental literature that hold promise for an integration of culture and human development: (1) the conceptualization of culture and individual development as mutually constitutive, and (2) the integration of questions central to developmental psychology with those that are central to cultural and cross-cultural psychology. With a focus on the promise of an integrated cultural developmental science, in this chapter both conceptual and methodological issues related to these convergences are examined. As mentioned earlier, first the conceptual issues are explored, followed by attention to the methodological issue of how seemingly contrasting approaches (such as the emic and etic) can be relationally coordinated to serve the general integration of culture and human development.

INTEGRATION OF CULTURE AND HUMAN DEVELOPMENT: CONCEPTUAL ISSUES

Increasing convergence among various conceptual/theoretical perspectives in understanding the relation of individual and culture as mutually constitutive and the integration of the goals of cultural psychology with the goals of developmental science undergird the integration of culture and human development. More specifically, concepts that relationally integrate person and culture are paving the way for empirical investigations that will advance the development of culturally inclusive theories of human development. This trend is represented by many conceptual advances in how developmental processes and changes are conceptualized as situated in and integrated with context. Furthermore, conceptual discussions of how culture and context differ have also contributed greatly to enabling the synthesis of cultural perspectives in the study of human development.

The Relation of Person and Culture

Although discussions of the mutually constitutive or integrative nature of individual development and culture or context were occurring concurrently, nearly two decades ago, among cultural psychologists (e.g., Cole, 1996; Rogoff, 1990) and within developmental science (e.g., Overton's 1997 discussion of the individual as an *embodied active agent*), and in cognitive science (Rowlands, 1999), it appears that scholars were engaged in parallel discussions and *not* in dialogue with each other. To address this dialogical gap, we describe four conceptual advances that have emerged in these parallel discussions and which promote the integration of culture and human development:

1. The first conceptual advance brought attention to the inseparability of individual and cultural levels of functioning and generated a focus on *activity* as the unit of study in empirical research (Cole, 1996; Rogoff, 1990).
2. The second advance was the differentiation of the concept of *mutual constitution* from the concept of *causation* (Rowlands, 2010), and the recognition that efficient causality has been the primary, if inappropriate, focus of empirical research in developmental science.
3. The third advance emerged from Overton's (1997, 2008) introduction of concept of *embodiment* and *embodied action* as a fundamental heuristic for an integrative analysis of person and culture.
4. The fourth advance is represented in current efforts to integrate the goals of developmental science and cultural psychology toward the end of generating culturally inclusive accounts and knowledge bases of human development.

Inseparability of Person and Culture

The first challenge for the integration of culture and human development is to determine how best to conceptualize the relationship between the person and culture. As pointed out earlier, typically, person and culture have been viewed as distinct and separate entities. It has been assumed that the person has a basic set of characteristics and abilities, and these are influenced by cultural variables such as values, attitudes, behavioral norms, and practices espoused by members of a particular group. Behavioral acts are often viewed as the outcome of additive interactions between the person and cultural influences *external* to the individual. Even in approaches that emphasize the study of individuals in bioecological contexts (Bronfenbrenner, 1979; Bronfenbrenner & Morris, 2006), person and context are viewed as separate and discrete *pure forms*. The underlying assumption is that ongoing interactions between the child and adults or peers in key settings represent separable and additive directional influences that relate ecological context and individual behavior.

Dasen's (2003) framework for the cross-cultural study of human development is another, more complex, example of this basic assumption of separable and additive influences. Dasen takes an ecocultural perspective in which theoretical models from developmental and cross-cultural perspectives are integrated into a single, complex model. Like Bronfenbrenner, Dasen uses concentric circles to represent various levels of context and emphasizes that the circle borders should be understood as reciprocal interactions, and uses the traditional symbol (←→) for bidirectional coactions. However, unlike relational developmental system theorists (e.g., Lerner & Benson, 2013; Overton, 2013, Chapter 2, this *Handbook*, this volume) who argue for the fused nature of *coactions*, Dasen's *interactions* are clearly distinct, independent, and separable of each other.

In contrast to the "separate and independent" argument, both culturally oriented psychologists (Cole, 1996; Rogoff, 1990, 2003) and relational developmental systems theorists argue for the inseparability of person and culture/context, though typically the former have focused on the integration of person and *culture*, whereas the latter have focused on person and *context* relations. Ignoring for the moment the differentiation between context and culture, the overarching focus on the inseparability of person and culture/context has been described in various ways by relational developmental systems, sociohistoric-cultural, and functional-adaptive approaches. In relational developmental systems theories, the inseparability of person and context is typically identified through the treatment of the fused, coactive *Person ←→ Context relations* as the basic unit of analysis in human development. In describing the defining features of relational developmental systems theories, Lerner (2006) identifies a central assumption that development occurs through mutually influential connections among all levels of the developmental system, ranging from genes and cell physiology through individual mental and behavioral functioning to society, culture, the designed and natural ecology and, ultimately, history. The character of development . . . means that the integration of actions—of the individual on the context and of the multiple levels of the context on the individual (individual ←→ context)—constitute the fundamental unit of analysis in the study of the basic process of human development (p. 3).

In the exemplars of relational developmental systems theories presented by Lerner, Lewin-Bizan, and Warren (2011), the common underlying focus is on understanding developmental change, and the empirical analysis typically promotes relational units (i.e., fused, coactive, person ←→ context relations) at multiple levels of context as change units.

Sociohistoric-cultural theorists (Cole, 1996; Rogoff, 2003; Wertsch, 1991) have proposed using *individual-in-activity* as the unit of analysis for empirical investigations. Their position originates from Vygotsky's (1978) claim that the behavior of the person is not separate from the activities or actions in which the person is engaged. Using activity as the unit of analysis contrasts with the independent/dependent variable approach that splits individual responses from environmental stimuli. Rather, activity (action) as the unit of analysis consists of people (as active agents) engaged in goal-directed behavior, carrying out actions, using culturally valued tools and mediation means, within a framework of shared cultural assumptions and expectations (Cole, 1985, 1996, 2006; Leont'ev, 1981; Rogoff, 2003; Tharp & Gallimore, 1988; Wertsch, 1985, 1991). The underlying assumption is that human psychological functioning is a result of human activity mediated through the use of tools (physical tools and objects) and sign systems (language, writing, number systems). It is important to note that *human activity* refers to more than human actions—the construct refers to the complex set of human actions that constitute performing or engaging in a socioculturally defined intentional activity, such as writing, having a conversation, playing a game, cooking a meal. In such activities, culture is represented in the goals, scripts, and the symbolically mediated meaning systems shared by a group. Thus, the focus is on functions of individual action in the context of activities, rather than on individual characteristics, as representing individual development.

To differentiate this focus on individual-in-activity from cultural influences as an independent/antecedent variable, Rogoff (2003) presented a series of photographs that move beyond the nested-circles or other models that situate cultural variables as boxes representing an antecedent factor or influence on individuals. Noting the inadequacy of using two-dimensional printed graphic tools to communicate the complexity of theoretical implications of individual-in-activity, Rogoff used a series of vivid photographs (Rogoff, 2003, pp. 53–61). As evident from the series of photographs, it is only when seen in the context of the activity is it possible to conduct a complete analysis of the child's actions and engagement with the context.

The true value of theoretical concepts lies in their heuristic function of guiding empirical study. Detailed and multidimensional analysis of activity has been a long-standing tradition in cultural and cross-cultural psychology as seen in Greenfield's study of weaving (Greenfield, 2004), Lave's focus on sewing in apprentice tailors (Lave, 1990), and Gaskins's analysis of play in Mayan children (Gaskins, 1999). Weisner's (2002) ecocultural approach greatly influenced this focus on the activities and routines of daily life as appropriate for empirical study of children's development. Using this approach, Rogoff and colleagues provide rich documentation of thought processes involved in the culturally situated activity of selling Girl Scout cookies (Rogoff, Baker-Sennet, Lacasa, & Goldsmith, 1995; Rogoff, Topping, Baker-Sennet, & Lacasa, 2002). In so doing they provide invaluable insights into culturally facilitated cognitive processes exemplified in the planning and keeping track of orders using cultural tools (such as order forms, memory and calculation aids).

Functional and adaptation-oriented approaches to human development (Kağitçibaşi, 1996, 2007) represent a related, albeit different, conceptualization of the relation between person and context. Because human actions are assumed to be *functional-adaptive* within specific contexts, any empirically derived account of psychological functioning needs to integrate specific facets of contexts. Thus, although individual behavior and context are assumed to be adapted to each other, assumptions of inseparability are implied but *not* clearly apparent.

Landmark/classic studies of cross-cultural psychology have taken the functional-adaptive approach to document how people adapt to various ecocultural contexts (e.g., Berry, 1966; Segall, Campbell, & Herskovitz, 1966). For example, Segall et al.'s (1966) study of cross-cultural differences in illusion susceptibility, and Berry's (1966) study of cross-cultural differences in psychological differentiation, stimulated considerable empirical research. In addition, these studies have also generated substantive theorizing about the functional-adaptive links between ecological contexts, modes of subsistence, socialization processes, and individual psychological functioning. Kağitçibaşi's (1996, 2007), conceptual approach, which she described as a *contextual-developmental-functional* perspective, integrates both cultural and cross-cultural perspectives. Focusing on the self, social, and cognitive competence as core developmental domains she contends that individual development in these domains is embedded in family and larger societal contexts. Competence is defined vis-à-vis specific contextual demands resulting in self-development as a functional-adaptive response to the specific cultural context, whereas variation in the contextual demands across families and cultures incorporates the cross-cultural dimension. However, in these examples from cross-cultural psychology, despite the clear *individual-in-context* focus, context is still empirically operationalized as separate from individual behavior.

Functional-adaptive perspectives have also been pervasive in developmental science. Individual development has been viewed as adaptation to an ecological context by many developmental scientists. For example, Sternberg and colleagues view cognitive development (e.g., Birney & Sternberg, 2011), as well as the development of expertise (Sternberg, 1997, 2003) as outcomes of adapting to environmental contexts. Sternberg's (2003) *Triarchic* theory of successful intelligence is described as adaptation to, selection and shaping of environments by capitalizing on strengths and compensating for weaknesses. Framing developmental questions from a functional-adaptive perspective has the additional advantage of informing social policy as exemplified by Shonkoff and Phillips's (2000) synthesis of child development research to inform policy. In framing self-regulation as a cornerstone of early childhood development that cuts across all domains of development, Shonkoff and Phillips (2000) highlighted regulatory processes as a fundamental property of all living organisms and claimed that it

> includes physiological and behavioral regulations that sustain life (e.g., maintenance of body temperature and conversion of food into energy), as well as those that influence complex behaviors (e.g., the capacity to pay attention, express feelings, and control impulses). Regulatory processes modulate a wide variety of functions to keep them within adaptive ranges. (p. 26)

Thus, self-regulation as a central domain of development is framed from a functional-adaptive perspective that necessitates an individual-in-context perspective and takes into account environmental context, rather than viewing a developmental domain as simply situated within the person (see McClelland, Geldhof, Cameron, & Wanless, Chapter 14, this *Handbook*, this volume, for an extended discussion of self-regulation). Another illustration of the individual-in-context perspective is provided by scholars who propose that parenting processes be viewed from a domain-specific socialization (Bugental, 2000; Bugental & Goodnow, 1998; Bugental & Grusec, 2006; Grusec & Davidov, 2010; see also Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume, on socialization). In noting diverse approaches and many discrepancies in their extensive review of the knowledge base on socialization, Bugenthal and colleagues suggest socialization be viewed as progressive and mutual adaptation of parenting functions and child behavior in context. Rather than assume cross-context generalizability of socialization, they identified five domains of socialization, each targeting a specific function of parenting:

1. Protection: which represents the caregiving function of ensuring child's safety and well-being.
2. Reciprocity: which represents the caregiving function of engaging in reciprocal relationships in which mutual exchange of benefits and accommodation to each other's needs is accomplished.
3. Control: which represents the parenting function of providing guidance and use of resources to ensure behavior appropriate within accepted societal norms.
4. Group participation: which represents the parenting function of fostering social identity, belonging, and affiliations with members of one's in-group.
5. Guided learning: which represents supporting children's learning and appropriation of the skills and competencies necessary to participate in their daily settings.

The underlying assumption of this model is that different types of caregiver–child interactions mediate the acquisition of different socio-emotional skills and tendencies (Bugental, 2000; Bugental & Goodnow, 1998). Armed with extensive evidence of the specificity of these domains, Bugental and colleagues (Bugental & Grusec, 2006; Grusec & Davidov, 2010) contend that the socialization systems reveal variations in developmental course, regulatory processes (including neurohormonal activation) and the nature of the interplay between the caregiver and child, in the context of the specific socialization functions and tasks involved.

Though not a comprehensive list, the above examples highlight a variety of ways in which scholars have conceptualized and empirically operationalized the inseparability of person and culture/context. However, it is imperative to note that in these various approaches, the relationship between person and context can be *but is not necessarily* conceptualized as mutually constitutive. Conceptualizing culture and individual development as mutually constitutive, as elaborated in the next section, goes beyond claims of the inseparability of culture and individual development or that human action is embedded or situated in context.

Mutual Constitution of Culture ←→ Person Development

Over the past two decades, investigators from both cultural perspectives and from developmental science perspectives have proposed that culture and personal functioning be viewed as *mutually or co-constitutive*. Within cultural psychology for example, Cole (1996, 2006) conceptualized culture and cognitive development as mutually constitutive. His proposition was based on an integration of phylogenetic, historical, and ontogenetic perspectives, rather than framing each of these as separate points of analysis. Cole argued that the "capacity to inhabit a culturally organized environment" is a "universal, species-specific characteristic of *Homo Sapiens*" (Cole, 1996, p. 73). Similarly, Eckensberger (2003) emphasized that psychology should be viewed as a cultural science, and culture should be viewed as a "*constitutive condition* for humans in general" (p. 75).

One implication of the mutual constitution of culture and individual psychological functioning lies in how relations between the person and sociocultural environments are conceptualized. In their proposed integration of cultural and developmental psychology, Shweder et al. (2006) claim that culture and psyche "make each other up" (p. 721); they contend that culture, community, and the psyche instantiate one another and are mutually sustaining. So, what does it specifically mean to state that culture and person development are *mutually or co-constitutive*? And how can this form of relationship be operationalized to guide empirical analysis?

To answer these questions, we need to distinguish mutual constitution from the concept of causation (Rowlands, 1999, 2010). Rowlands (2010) distinguishes between a Cartesian versus a non-Cartesian conception of the mind employed in cognitive science to address questions of how mental processes (such as remembering, perceiving, and thinking) are realized and where they exist. Rowlands begins with the Cartesian premise that these cognitive processes are situated exclusively in the brain and realized exclusively through brain or neuronal processes. However, arguing against the Cartesian premise, Rowlands contends that mental processes are partly *constituted* by wider bodily structures and processes, such that mental processes can be conceptualized as being extended beyond the person into the environment. Rowlands's claim that "Mental states and processes are not just things that happen inside our brains; they are also things that happen, *partly,* in our bodies and even, *partly*, in the world outside of our bodies" (p. 13), is highly consistent with other similar notions, such as *distributed cognition* and *situated cognition* (Rogoff, 2003), as well as *embodiment* (Overton, 2008, Chapter 2, this *Handbook*, this volume) to be discussed later in this chapter. Referring to "cognition beyond the skull," Rogoff (2003) pointed out that "The idea that cognition is distributed across individuals, other people, and cultural tools and institutions may be difficult to consider if one assumes that cognition resides wholly inside individual heads" (p. 271).

Rowlands (2010) provides a cogent and compelling argument for the significance of the notion of mental processes as extending beyond the mind, by illustrating how mental processes are *constituted by, not caused* by what occurs outside the individual mind. In a particularly illustrative example, Rowlands dissects and compares the mental processes that occur when using a GPS system (global positioning system) versus a printed MapQuest map with driving directions. He notes that the GPS directions are essentially situated in that these use the driver's physical location to provide indexical information, through the use of words such as *here* that have meaning linked to the driver's current physical location. Thus, part of the encoding process is *off-loaded* or *distributed* onto the environment (p. 15). However, as Rowlands (2010, p. 67) is quick to note, this off-loading part of the mental processing cannot be interpreted to mean that mental processes are dependent on the environment in the sense that the environment drives or causes the mental process (that is, the Cartesian view). Dependence implies that specific mental processes function only in tandem with specific environmental structures, whereas constitution goes beyond the idea that mental processes are situated in a wider sociocultural environment.

Rowlands defends his thesis of the extended mind, claiming that cognitive processes are "in part, composed of the processes of manipulating, exploiting, or transforming environmental structures" (p. 67). The key point is that the process of manipulating information contained in the environment transforms the mental process itself, thereby becoming a part of mental process itself. Rowlands (2010) refers to examples of such processes that were first discussed by Vygotsky (1978)—such as the use of knots tied in string as a mnemonic process to remember extensive amounts of information. Similarly, Rogoff (2003) provides many examples of how cultural tools are a part of thinking processes. For example, in computing arithmetic problems, such as multiplication of three-digit numbers, the spatial organization of the numbers on paper can be considered symbolic mediation tools that are a part of the process of the mathematical processing we use to solve the problem. The distinction can be aptly summarized as follows: Dependence or causation implies that the person and environment are two distinct entities, whereas mutual constitution implies being a constituent part of each other in a way that they cannot be dissociated.

Having laid the conceptual foundation of mutual constitution, it is now critical to examine how it has been empirically operationalized in the field. The construct of *embodiment* (Overton, 1997, 2008, Chapter 2, this *Handbook*, this volume) is discussed as a heuristically rich construct that enables the synthesis of person, biology, and culture. The construct also facilitates the operationalization of mutually constitutive action and action-context relations to guide empirical analysis of developmental processes.

Embodiment as the Mutual Constitution of Person ←→ Culture

Overton's (2008) concept of *embodiment* is a complex and integrative holistic synthesis of biological, psychological, and cultural systems. In defining the *embodied person* functioning as a *self-organizing dynamic action system*, Overton's conceptualization of the individual is already a fusion of the person and the relational biological-cultural world (2008), and embodiment as a concept bridges and integrates biological, sociocultural, and person-centered approaches to psychological inquiry.

> As a relational concept embodiment includes not merely the physical structures of the body but the body as a form of lived experience, actively engaged with the world of sociocultural and physical objects. From a relational perspective the biological, the psychological, and the sociocultural are indissociable complementarities represented as multiple lines of sight on the same object. The body as form references the biological line of sight, the body as lived experience references the psychological subject (person-oriented) standpoint, and the body actively engaged with the world represents the sociocultural point of view. (p. 3)

This constitutive relational metatheoretical construct of embodiment replaces the reductionist, simplistic, split views of the biological, the psychological, and the sociocultural as discrete pure forms affecting each other. The notion of the body as a form of lived experience is a particularly clear illustration of the inseparability of the biological, psychological, and sociocultural lines of sight. Building on Boesch's (1991) clearly articulated employment of embodiment in a developmentally oriented cultural psychology, Overton (2008) notes that the body is the medium of our actions, because it is with our body that we act. Embodiment therefore is "*the body as lived experience actively engaged*" (p. 6) with the physical and sociocultural world. But what does this statement mean and how does it represent the integration of person, biology, and culture? It means that the dynamic body, with its anatomical features and physiological processes, acts, and in so doing, both constructs and is constructed by the world. Thus, action is a core and central construct that is embedded in the notion of embodiment and provides further elaboration of how biology, person, and culture operate in a relationally integrated fashion.

Action

As Overton (2008, p. 9) explains, two of the functions of action are the *expressive* and the *instrumental* functions. In its expressive form, action entails the embodied projection of person-centered meanings into a world of physical and sociocultural objects, thus participating in the transformation of the objective physical and sociocultural world into an *actual* world of lived experience (that is, one that is known, felt, desired). However, in a reciprocal fashion the objective physical and sociocultural worlds simultaneously coact with the projected embodied expressions of meaning, thus forming a constitutive feature of this lived experience. Thus, biology, person, and the socioculturally referenced environmental world are all incorporated into a relational matrix through the construct of action. The second, instrumental function of action also addresses the inseparability of person and culture in the developmental process. In this case, the embodied action constitutes the fundamental microscopic process of developmental change. The person acts (i.e., performs a goal-oriented action, which is itself defined as *experience*) in a physical and sociocultural world. To the extent the act fails to achieve its goal, negative feedback to the organism leads to further variation in acts ultimately resulting in the desired goal. The effect of feedback loops, both negative and positive, between embodied acts and objective physical and sociocultural world, results in changes in the person's functioning, hence development.

Considering human acts as the unit of analysis requires recognition of intentionality, reflectivity, and agency, along with the constitutive context within which acts occur. Cross-cultural psychologists have also called for action-oriented theories as a means to construct contextualized or context-inclusive theories of human development (Eckensberger, 1979, 1995, 2003). For example, Eckensberger explains how the act of writing is constituted by/comprised of the scripts of the language, the culturally shared schemas for writing, and the culturally constructed interpretations that are integral to the person's action and intent in writing.

Although the study of intentionality of actions has a long historical tradition in philosophy (Eckensberger, 2003), this focus on action—exemplified in Overton's construct of embodiment—is relatively recent in the conceptual discourse of developmental science.

Another focus on action is evident in the writings of Brandtstädter (1998, 2006). Brandtstädter's contribution to the study of action is valuable because it not only conceptualizes action as an interpretive construct, but it also delineates action as the unit of analysis representing the relation between person and contexts. Although Brandtstädter does not specifically use the term *culture*, it is clear that meanings and interpretations of context are an integral component in his conceptualization of action. Brandtstädter (2006) makes clear that actions, though typically defined with reference to intentional states of the person, are constituted and constrained by social rules and conventions as well as *the person's representation of these conventions*. This latter statement underscores the importance of culture as the source of meaning-making processes whereby actions are interpreted. Hence, action as defined by Brandtstädter (1998, 2006) is a construct that integrates the biological individual and culture as well. It is through *action* that mutually constitutive dialogic relationships are established between individuals and their contexts resulting in change, adaptation, and development. In the next section, the focus is on how this process unfolds.

Experience and Action as the Source of Developmental Change

The heuristic richness of Overton's (1997, 2008) construct of embodiment is evident in that it also includes a conceptualization of developmental processes. The embodied person developmentally transforms his or her own expressive and adaptive functioning, as well as the world itself, through transactions with the biocultural world. Overton (2008) claims that "a *body actively engaged in and with the world* necessitates that not only cognition and learning, but all emotions and motivations and all psychological functions are co-constituted by the sociocultural and environmental context" (p. 5). Once again the term *co-constituted* is highlighted, denoting both the inseparability and the mutual constitution of the biological, person, and sociocultural standpoints. Similarly, as Lerner et al. (2011) also emphasize from a relational perspective, the question of how nature and nurture are related can best be answered in terms of dynamic coaction or fused action of indissociable complementary processes.

To understand how experience or actions result in developmental change, it is imperative to have a common understanding of what comprises development. As Lerner et al. (2011) note, change and development are not equivalent. Changes that can be labeled as developmental must have a systematic, organized character, and they must be connected to prior changes. From a relational developmental systems perspective (Lerner, 2006, 2011; Overton, 2006, 2013, Chapter 2, this *Handbook*, this volume; Overton & Lerner, 2012), developmental processes are viewed as changes in individual ←→ context relations, thus adding another dimension to developmental changes. The situated nature of developmental processes is explicitly acknowledged by including context. From a cultural perspective, developmental processes are assumed to occur through an individual's participation in culturally situated activities and contexts and include appropriation of mental tools and symbolic systems (Bruner, 1990; Cole, 1996; Rogoff, 2003; Wertsch, 1991; Vygotsky, 1978), or mentality-practice complexes (Shweder et al., 2006). An integration of the two perspectives can be fully achieved if context is recognized as being cultural in nature, in that environmental (both physical and social) context is always interpreted through meaning-making processes and meditational means that are cultural by nature.

Conceptual discussions regarding the nature and processes of development provide a comprehensive description of different dimensions of development, clearly articulating how transactions with the sociocultural world (i.e., both the physical and social world) are integral components of the developmental process. Overton (2006) argues that a developmental theory must address two crucial questions regarding development. The first question focuses on the nature of developmental phenomena (the "what" of development), and the second focuses on the nature of transitions or change (the "how" of development). To address the first question, as mentioned earlier, Overton (2006) delineates two dimensions of behavioral development: the *expressive–constitutive* dimension of an act (i.e., the underlying pattern or structural organization of actions) and the *instrumental–communicative dimension* (i.e., strategies and means of adapting to the sociocultural world at each organizational state). Both these dimensions are considered coequal, essential, and complementary characterizations of the nature of developmental phenomena. Taking the example of attachment behaviors, Overton suggests that proximity-seeking behavior in attachment theory may be considered as expressive–constitutive when it is assumed to represent an underlying attachment organization. But proximity-seeking behavior can also be studied as an instrumental behavior that represents a way of coping with separation fears.

The instrumental–communicative dimension by definition focuses attention on the strategies and means of adapting to the sociocultural world; thus, here the second function of embodied action delineated by Overton (2008) comes to the fore. Overton's discussion of how the meanings through which action is interpreted get constructed and adjusted in a dynamic co-constructive and relational to-and-fro system between the person and context clarifies how, as mentioned earlier, action is the fundamental developmental process. This idea is similar to Brandtstädter's (2006) description of the dynamic relational interplay of action in context, as when actions in context encounter resistance or feedback, the feedback gets incorporated in newly constituted meanings of both the actions and context. The integration of intentionality and personal agency in terms of the selection of particular behavioral options, and the use of actions to change relations with context, are heuristically valuable dimensions of actions in that they represent the dynamic, interpenetrating nature of the relation between individual and context as the source of developmental change. The key here is that individual action in context is itself the fundamental microscopic process of development.

But can we specify the role of action as integrating the individual and sociocultural levels of analysis in transformational developmental transitions (Overton, Chapter 2, this *Handbook*, this volume)? For example, Lerner has characterized developmental transitions as changes and transformations of self-organizing dynamic systems (Lerner, 2006, 2011). Lerner notes that a transformational transition is viewed as developmental if it represents a change in structure or organization of a system. Furthermore, because relational developmental systems represent person ←→ context relations, developmental transitions should represent transformations of person ←→ context relations, not just transformations of the structural organization of internal mental components. Lerner's (2011) discussion of irritability, adaptation, and action in ontogenetic development is instructive here, in that the actions of the organism must be integrated with the actions of the context, and this can be in both structural and functional terms. As Lerner notes:

> Irritability means that an organism can alter itself in reaction to stimuli or events in its world, e.g., it can change its form, shape, or organization (these are structural changes) or it can alter things such as its rate or direction of change (these are functional changes). (p. 35)

The focus when studying development should be on change in relations—not change in individuals. However, the individual remains at the center in serving as the agent of developmental regulation (Brandtstädter, 2006).

Sociohistoric-cultural theorists and cultural psychologists have been discussing similar notions since the 1990s. Developmental transitions and transformations are characterized as representing the integrative or fused relation between individual and the sociocultural world. For example, Rogoff (2003) conceptualizes development as transformations in the person's participation in cultural activity, thereby highlighting individual activity and participation in the sociocultural world as the nexus of developmental transitions. Rogoff focuses specifically on reconceptualizing human development as the process of "*people's changing participation in the sociocultural activities of their communities*" (p. 52). She argues that people develop as they participate in and contribute to cultural activities that themselves develop and are reconstructed with the involvement of people in successive generations; a position that closely aligns with Lerner (2006) and Overton (Chapter 2, this *Handbook*, this volume). Conceptualizing development as a "transformation of participation perspective," Rogoff asserts that the "personal, interpersonal, and cultural aspects of human activity are conceived as different analytic views of ongoing, mutually constitutive processes" (p. 52). From this perspective, studying developmental processes must include an analysis of individuals' participation in the activities of their cultural communities. Rogoff elaborates this notion, stating that "In referring to cultural processes, I want to draw attention to the configurations of routine ways of doing things in any community's approach to living" (Rogoff, 2003, p. 3).

In addition to advocating the use of activity as the unit of analysis, sociohistoric-cultural theorists have also operationalized the mutually constitutive nature of person and context through their emphasis on *person-in-activity* as the appropriate unit of analysis (Rogoff, 2003; Werstch, 1991). Rather than conceptualizing people as "having abilities and skills," the focus is on the "person-acting-with-mediation-means" as the appropriate unit of analysis (Wertsch, 1991, p. 119). The centrality of meditational means in this conceptualization is derived from Vygotsky's (1978) assumption that it is the use of culturally produced tools and sign systems that fundamentally changes the nature of human psychological operations. For example, it is through the use of physical tools, such as writing implements and paper, that the human activity of writing triumphs over the constraints of direct or face-to-face communication and enables communication between individuals across time and place. On the other hand, through psychological signs (e.g., knowledge of the varying genres of written texts; expository text versus narratives), humans mediate internal or mental activity aimed at mastering the ways in which thoughts are communicated. Thus, Vygotsky (1978) accorded symbolic actions a specific *organizing* function that penetrates the process of tool use and produces fundamentally new forms of behavior. It is through symbolic actions, that is, through the use of meditational means that have been culturally constructed and through which the individual acts in goal driven activity that the cultural construction of the mind occurs.

Thus, sociohistoric-cultural theorists argue that integration of person and cultural context is enabled in empirical research through including culturally constructed or derived meanings as integral or constitutive features of action as the unit of analysis. For example, Shweder and colleagues (2006) claim that "contexts and meanings are to be theoretically represented as constitutive parts of the psychological system and not simply as influences, factors, or conditions external to the psychological system" (p. 724). Translating these notions as guides for empirical research, Shweder et al. (2006) described the *custom complex* as an integrative construct in which culture and psyche constitute each other. The custom complex combines sets of related behavioral practices and their underlying symbolic meanings into an integrated unit. Accordingly, delineations of customary practices, along with underlying beliefs, values, sanctions, rules, motives, and satisfactions that are associated with these, represent a partial fusion of individual behaviors and culturally constructed belief systems.

Within developmental science, Baltes, Lindenberger, and Staudinger (2006) have argued that the regulation by individuals of their relations with their complex and changing physical, social, cultural, and historical context is the key problem for analysis of developmental processes. In a similar vein, but within a more specifically relational perspective, Lerner et al. (2011) assert that relations between individual and context must be depicted as fusions among variables from multiple levels of organization that comprise the ecology of human development. Although the levels of organization range from the biological through individual and social functioning to societal, cultural, physical, ecological, and historical, the key is that the relations among these levels are conceptualized in a "truly *interpenetrating* manner" (Overton, 2006, p. 34). The notion of interpenetrating relations is a critical, core tenet.

Summary

To this point, several conceptual advances drawn from contemporary cultural and developmental science have been highlighted that are promoting an integrative relational understanding of culture and human development, and are serving as a base for empirical research. These conceptual advances consist of (a) a recognition of the *inseparability* of person and cultural levels of functioning, along with a focus on *activity* as the basic unit of analysis, (b) an understanding that person and culture are *mutually or co-constituted*, (c) the introduction of *embodiment and embodied action* as a fundamental heuristic for an integrative analysis of person and culture. In the following sections we explore the fourth conceptual advance, which entails contemporary efforts being made to construct culturally inclusive accounts of human development.

The Contemporary Integration of Culture and Human Development

As mentioned earlier, developmental scientists have added their voices to those of cultural and cross-cultural psychologists who have raised concerns about the inherent bias in research questions grounded in the context of the United States (Arnett, 2008; Bornstein, 2010; Damon, 2011; Heine & Norenzayan, 2006; Jensen, 2011; Mistry et al., 2012). Fortunately, an increasing effort to integrate cultural perspectives in research questions of interest to developmental scientists represents a promising trend toward the development of culturally inclusive knowledge bases in human development (Mistry et al., 2012). Here we elaborate two trends in the integration of cross-cultural and cultural perspectives with developmental science: (1) the inclusion of cultural variations in empirical studies of human development; and (2) the inclusion in human developmental research of culture as the meaning-making processes through which people interpret their environmental context.

Culturally Inclusive Knowledge of Human Development

The primary task for a culturally integrated account of human development entails going beyond merely documenting the range of variation found in different domains of human functioning. What is needed is the inclusion of systematic variations (Rogoff, 2003) into the existing knowledge base of core domains of human development. The primary challenge here is to consider how best to approach this task. Historically, in the subfield of cross-cultural psychology, the question of variations across cultures has typically been approached by beginning with empirically observed behavior patterns among United States or European samples (Henrich, Heine, & Norenzayan, 2010). These have then been assumed to be the normative patterns against which cultural variations are to be documented. To counter this approach, cultural psychologists have deliberately started from the vantage point of non-Western cultural communities to highlight alternate models of human development that facilitate shedding our ethnocentric frameworks (e.g., Gaskins, 1999; Greenfield, 1999; Lancy, 1996; Shweder et al., 2006). However, the problem with both of these approaches is that once behavioral patterns are documented as normative within a specific cultural community, then variations in behavioral patterns noted in another community are invariably viewed from the frame of reference of the patterns initially documented as "normative."

Fortunately, serious attempts to provide an integrative relational and culturally inclusive human development knowledge base have emerged over the past decade. In comprehensive reviews of the literature on specific domains of human development, investigators have offered conceptual integrations of systematic cultural variations, thus providing information of relevance to a worldwide audience. Further, there is an increasing interest in the United States in incorporating international perspectives into developmental science. Although these trends may not have yet achieved the goal of providing integrative accounts of human development, the progress made by including the knowledge of human development in various regions of the world is a step in the right direction. Conceptual issues and challenges underlying these trends are discussed in the following sections.

Conceptual Integration of Systematic Cultural Variations

A particularly promising approach to the conceptual integration of systematic variations in the existing human development knowledge base has been offered by Rogoff (2003), who has championed the importance of examining *regularities in variation* noted amid the diversity of human actions, practices, and traditions empirically observed across worldwide regions and communities. For Rogoff (2003), examining regularities in variation (i.e., patterns of variation) requires identifying similarities and differences in patterns of human action and practices among diverse communities, and, further, describing the basic processes that generate these patterns. Failure to identify patterns of variation and the basic processes that generate these can lead to the empirical literature derived from different cultural communities becoming inundated with a seemingly infinite range of idiosyncratic variations in practices.

Further, the focus on establishing the basic processes that generate systematic variations addresses yet another difficult conceptual issue: the tendency to categorize differences as a reflection of regions or ethnically defined groups (e.g., Western, or Eastern, or Asian, or Hispanic). For example, consider the well-documented variation found in studies of independence and interdependence, and of collectivism and individualism (Kağitçibaşi, 1996, 2007; Kim & Choi, 1994; Landrine, 1992; Markus & Kitayama, 1991, 1994; Triandis, 1989).

Frequently cultural communities and even nations have been categorized as being either collectivist or individualistic (Park & Huang, 2010), which has then established these constructs as independent variables (antecedent conditions; efficient causes) that affect behavior. In contrast, in reviewing the collectivist/individualistic literature, Greenfield, Suzuki, and Rothstein-Fish (2006) argued that, based on consistent variations in cross-cultural studies on the individualistic-independent and the collectivist-relational-interdependent self, independence and interdependence appear to be alternative developmental pathways. The empirical task then is to examine the co-occurrence of interdependence (or conversely independence) as an overarching socialization script/parenting context and the emergence of a relational-interdependent self (or conversely an individualistic-independent self).

Thus, the pattern of relations or intersecting transactions between specific parenting/socialization contexts and emerging behavior in particular groups/samples becomes the focus of investigation, rather than merely noting the existence of differences in behavior based on cultural, ethnic, or national membership. Accordingly, as Lerner (2011; see also Lerner, Lerner, Bowers, & Geldhof, Chapter 16, this *Handbook*, this volume) has suggested, from a relational developmental systems theories-framed perspective, researchers should ask what facets of individual and contexts, interrelating during what portions of ontogeny and under what conditions of the proximal and distal contexts, result in what indicators on independence and what indicators of interdependence across what subsequent portions of the life span?

The distinction between identifying the underlying processes that generate patterns of variations versus attributing specific patterns of behavior to particular cultural communities is analogous to the distinction between the *idiographic filter* (Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume) and the approach taken by traditional methods of psychology to identify patterns. In the approach of traditional differential psychology, typically, common patterns are extracted by initially aggregating individual level information and extracting generality from it in the form of average tendencies, and the common patterns then get attributed to, and associated with, membership in the specific cultural community being studied. In contrast, the idiographic filter (IF) involves identifying invariant (across individuals or in this case, across cultural communities) nomothetic relations at the latent level while explicitly recognizing idiosyncratic features of the manifest (observed) indicators of the latent constructs. The objective of IF analysis is analogous to Rogoff's (2003) notion of abstracting regularities in variation (or consistent patterns of variation) across cultural communities, such that the focus is on the latent constructs derived from first order factors and their loadings on the manifest variables. The emphasis on the higher-order patterns of variation and the underlying processes that generate these variations avoids the tendency to attribute particular patterns to particular groups. The alignment of these concepts of higher-order patterns (regularities in variation and the IF) that are derived from two quite different methodological approaches to developmental science is elaborated on later in the chapter.

Although evidence of alternate developmental pathways or coherent links between socialization contexts and behaviors may initially derive from culture comparative research, the primary significance of this research lies in the extent to which the underlying processes or the mutually constitutive relations that are the basis for these variations is articulated and documented. For example, an ethnographic examination of childrearing practices among the Gusii in Africa and a community in northeastern United States, LeVine et al. (1994) provided an example of contrasting cultural models of early childcare that documented patterns of systematic variation in caregiving practices during early infancy. LeVine et al. (1994) labeled the Gusii model *pediatric*, because its primary concern was with survival, health, and physical growth of the infant. They labeled the U.S. model *pedagogical*, because its primary concern was with behavioral and educational development of the infant. The theoretical significance of this example is that the pattern of variation noted is not attributed to particular cultural, regionally based, or ethnically defined groups. Rather the focus is on characterizing *varying patterns of mutually influential relations between individuals and contexts* (e.g., primacy of survival concerns), including practices and their underlying interpretive norms, in shaping immediate and long-term trajectories of developmental outcomes that are reliable and coherent. Moreover, because these complex relations between individuals and context are embodied (Overton, 2013), and thus mutually constitutive at multiple levels of analysis, they can be discussed in regard to several levels of organization, for instance, between caregiving contexts and practices, as well as between parental caregiving and emerging infant behaviors.

Rogoff, Mistry, Goncü, and Mosier (1993) provided yet another example of a cultural comparative study that documented variational patterns that, through an analytic process akin to the Molenaar and Nesselroade's (Chapter 17, this *Handbook*, this volume) idiographic filter, can have applicability beyond the communities they examined. In this study of interactions between toddlers and their caregivers, the investigators documented contrasting, yet culturally coherent models of how learning opportunities are structured for infants. They selected four cultural communities (a Mayan peasant community in Guatemala, a tribal village in India, a middle-class community in Turkey, and a middle-class community in the United States) that represented variation in the extent to which children are segregated from adult activities.

Rogoff et. al.'s (1993) observations of the four communities revealed two patterns of learning that were consistent with variations in whether children were able to observe and participate in adult activities. In communities where children were segregated from adult activities, adults took on the responsibility for organizing children's learning by managing their motivation, by instructing them verbally, and by treating them as peers in play and conversation. In contrast, in the communities in which children had the opportunity to observe and participate in adult activities, caregivers supported their toddlers' own efforts with responsive assistance. Toddlers appeared to take responsibility for learning by observing ongoing events and by beginning to enter adult activity (Rogoff et al., 1993). Learning occurred through active observation and participation. Toddlers and caregivers often maintained simultaneous attention to several ongoing activities and were responsive to each other, often through nonverbal means. Within each community there was a *coherence of patterns* demonstrating the mutually constitutive relation between features of cultural context (i.e., segregation from adult activity, parental goals for children's development, differential responsibility for learning), and the interactions between caregiver and toddlers.

Perhaps the most critical conceptual point is that included in the examples just presented is the relation between the idea of regularities or patterns in variation found in Rogoff's (2003) work and the "commonality at a latent-variable level" described by Molenaar and Nesselroade (see Chapter 17, this *Handbook*, this volume). As already discussed, in differentiating between manifest and latent levels of variation, the Molenaar and Nesselroade concept of the idiographic filter helps developmental scientists explain how commonalities across a range of variability can be discerned by a second-level analysis, which in effect yields latent variables that cluster into group patterns with comparable systematicity. Although Molenaar and Nesselroade apply their notion of the IF at the individual level of analysis, it is statistically applicable to work seeking to derive regularities in variation across cultural communities. In arguing for the conceptual significance of IF, Molenaar and Nesselroade (Chapter 17, this *Handbook*, this volume), explain that each entity of developmental analysis (e.g., person or cultural community) shows a phenotypically unique trajectory of intra-entity change, thus creating a situation where science cannot move beyond an idiographic analysis. However, the IF allows each entity (e.g., person or cultural community) to manifest such individuality but, at the same time, be linked at a second-order, latent variable level to differential or nomothetic (clusters) of entities showing comparable individuality (this methodological approach to understanding the links between the idiographic and nomothetic is discussed later in the chapter).

The significance of this conceptual convergence between the notion of regularities in variation (Rogoff, 2003) and the nomothetic analysis through which quantitative methodologists working from a relational developmental systems perspective derive second-order latent commonalities cannot be overemphasized. The convergence not only highlights the promise of theoretical integration of perspectives, it also paves the way for recognizing the complementarity of different methodological paradigms (this is discussed more at length later in the section on methodological issues). The difference between developmental methodologists and cultural psychologists may be in terms of their focus on different levels of analysis (i.e., the level of the single individual in a developmental study or the level of the single group living at a particular time and place). Nevertheless, both scientific groups recognize that despite the need for idiographic analysis that respects the features of the single person or the specific group (e.g., cultural community), more nomothetic analysis is also possible through both quantitative methods (e.g., the IF presented by Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume) or qualitative analysis (using Rogoff's frame of searching for regularities across variations).

Regardless of methodological approach used, the integration of culture and human development can be best accomplished when the vast array of cross-cultural variations in specific domains of development is synthesized to document conceptually coherent regularities in variation. This synthesis leads to the next logical question: To what extent has this integration been accomplished in the developmental science literature?

Cultural Inclusivity in Knowledge of Human Development

The most culturally inclusive accounts of human development can be found in the work on language development by MacWhinney (2010) and Wagner and Hoff (2012). MacWhinney (2010) framed language development within a relational developmental system as an emergent process charting the components and processes of language development in the six subsystems of language development (audition, articulation, lexicon, syntax, mental models, and conversation). In doing so, the author integrated the emergence of language across multilayered time frames (from phylogenetic to interactional), and more importantly included cultural variations seamlessly without treating them as a separate focus. For example, MacWhinney argued that acquisition of first language could be better explained by developmental emergence rather than by nativism by citing cross-cultural evidence countering the nativist view that the use of grammatical structures such as relative clauses enables the construction of an infinite number of sentences. In fact, in hunter-gatherer communities of South America, people communicate effectively without relying on recursive syntactic devices (MacWhinney, 2010). Examining biological and contextual underpinnings of auditory perception, MacWhinney challenged the well-established view that infants lose the ability to hear the contrast not represented in their native language. Instead, MacWhinney concluded that full flexibility of hearing contrasts is maintained among infants growing up in a bilingual world, whereas for those growing up monolingual, flexibility in processing is gradually traded off for quickness and automaticity. Thus, by incorporating variations across bilingual and monolingual contexts, MacWhinney presented a more inclusive and complete account of auditory perception than is typical, which furthered developmental science.

Wagner and Hoff (2012) achieved a similar integration of theoretical perspectives on language development that included cultural variations. Instead of framing the theories as debatable alternatives, Wagner and Hoff presented them as integrative and complementary contributions to a comprehensive portrayal of language development while seamlessly integrating cultural variations in their discussion. For example, in lieu of a survey of cross-cultural differences in language input to children, Wagner and Hoff noted that there are consequences of whether children have language directed to them or learn it by hearing others speak it—a well-documented regularity in variation across cultures—on emergence of language development (Wagner & Hoff, 2012).

Another well-documented regularity in cultural variation involves priority given to work or play activities for children. In nonindustrialized communities where children are embedded in the world of adults, the boundaries between work and play are not as clearly marked as they are for children in industrialized, urban communities (Gaskins, 1999; Lancy, 2008; Rogoff, 2003). This cultural variation had concomitant implications for how children learn. For example, Lancy (2008) noted that children in rural communities were typically free from adult control for play when contrasted with industrialized urban communities, where adults intervened to accelerate preparation for formal schooling. Among children in rural communities, if there is any attempt to intervene to accelerate development, it is more likely to be in areas of development that hasten interdependence on others. For example, adults may explicitly teach children to learn proper etiquette and kin terminology so as to promote the child as a good candidate for shared nurturing (Lancy, 2008).

Digressing somewhat, it is interesting to note that evidence for contrasting patterns of person ←→ context relations in rural and urban settings is emerging from the nascent field of human social genomics. Summarizing studies that demonstrate that more than 50% of differentially expressed genes were attributable to living in rural versus urban environments, Slavich and Cole (2013) highlight how social-environmental conditions can trigger broad shifts in gene expression, which have implications for disease risk and longevity. Slavich and Cole emphasize "the previously unappreciated fact that environmental factors such as geographic location can regulate the expression of approximately 10 times as many genes as genetic factors" (p. 333).

The examples of how cultural variations are incorporated in culturally inclusive accounts of human development highlight the fact that empirical evidence generated from emic and indigenous perspectives can indeed be integrated into the existing knowledge base of developmental science. Furthermore, the focus on regularities in variation highlights the integral role of culturally constructed meaning systems and frames of reference that mediate the mutually constitutive connection between cultural contexts and children's development. More importantly, empirically establishing the underlying processes or mutually constitutive person-context relations that generate regularities in variation not only guards against claims of infinite variation in cultural practices or extreme cultural relativism, it also avoids the tendency to essentialize and decontextualize cultural differences.

Increasing interest in representing international perspectives in developmental science represents another attempt to generate culturally inclusive knowledge of human development. This trend is apparent in the number of books and handbooks devoted to integrating cultural and developmental science perspectives (Bornstein, 2010; Jensen, 2011; Kitayama & Cohen, 2007) or to incorporating internationally inclusive scholarship on topics in human development (Adler & Gielen, 2003; Brown, Larson, & Saraswathi, 2002; Daiute, Beykont, Higson-Smith, & Nucci, 2006; Gielen & Roopnarine, 2004; Kitayama & Cohen, 2007; Penn, 2005; Roopnarine, Johnson, & Hooper, 1994). Although there is considerable variation in the extent to which these publications do, in fact, accomplish the integration of the cultural psychology and developmental science, at the least they have brought attention to contributions made by international scholars to the knowledge base of developmental science.

In spite of these advances, the challenge of integrating cultural and developmental perspectives cannot be understated. This challenge is, for example, apparent in Bornstein's (2010) *Handbook of Cultural Developmental Science*. In this text the dual focus of culture and development is described as "charting relations between cultural variation on the one hand and, on the other, developmental variation in physical, mental, emotional, and social development in children, parents, and cultures" (p. x).

Although this framing of a dual focus continues to treat cultural variation and developmental variation as separable topics, the chapters in the first part of the book do provide integrative discussions of the range and nature of cultural variations in specific domains of development (e.g., language, motor skills, cognition). For example, Worthman (2010) situates a worldwide perspective on child health in demographic and epidemiological data collected by international agencies to highlight the persistent child health risks and disparities that exist across the world. Worthman (2010) notes the consistent association between poverty and neonatal mortality in both affluent, industrialized regions as well as in the developing world, and the role of preventable diseases in mortality risks after the infancy period. In a noteworthy example of a conceptually integrative portrayal of development, Werker, Maurer, and Yoshida (2010) contend that the perceptual processing underlying language development is situated in the range of variations in fundamental properties of the world's languages (e.g., that the languages of the world fall into different rhythmical classes). The second part of Bornstein's (2010) text has a contrasting structure, in that each chapter, authored by an array of international scholars, consists of an overview of childhood and caregiving as it occurs in varying countries or regions of the world.

Although inclusion of region/country specific chapters in a single book may not represent an integration of perspectives, this approach can broaden the ethnocentric bias that is otherwise inherent in developmental science. As one example of the benefits of providing an international perspective on a specific topic, Brown et al. (2002) present a comparative analysis of a contextualized description of adolescence in different regions of the world. The authors provided an overarching framework (Brown et al., 2002) of developmental tasks of adolescence such as developing competencies to form and maintain adult relationships in family/work contexts, establishing a family, and to becoming economically productive and independent. Such a framework identifies educational, occupational, and health care opportunities available to youth to participate in a global youth culture (e.g., through media, access to technology) and situates these opportunities in key societal institutions (i.e., schools, employment related institutions, the job/labor market) pertinent to this phase of life.

Furthermore, the specified framework provided to international authors standardized the format and helped to situate adolescents in the sociohistorical and economic context of that country. Many illustrations reveal how the characteristics of adolescence in each country/region are situated in the interplay among different definitions of adolescence, differences in the key societal institutions with which adolescents engage, the key individuals who are part of the lives of youth, and the particular societal changes that are occurring within a country or region.

In an explicitly stated effort to bridge cultural and developmental science, Jensen (2011) invited a selected group of internationally based authors to present the synthesis of the two perspectives in their respective areas of scholarship. Invited authors were asked to offer a synthesis of the two perspectives by addressing three questions: (1) How best can the oppositional stance between the "one-size-fits-all" perspective and the "one-theory-for-every-culture" relativistic perspective be synthesized? (2) To what extent does the distinction between structure and content adequately capture the insights from both developmental and cultural psychology; and what other plausible alternatives might there be? (3) Does bridging developmental and cultural psychology offer new and helpful alternatives to these old but persistent issues of universalism and relativism? Chapters are organized to integrate the study of culture and developmental domains (e.g., memory, moral development, and learning), culture and developmental contexts (e.g., family contexts, peer relationships, and communities), culture and developmental selves (e.g., identity development, self-acceptance, individual purposes), and culture and developmental phases (perspectives on African life stages, Hindu life stages, and adulthood). As might be expected, the extent and nature of the synthesis of cultural and developmental perspectives varies across the chapters.

Though designed to foster integration between developmental and cultural psychology, most chapters in Jensen's text (2011) treat culture as a factor that influences specific behaviors or developmental outcomes, even though interaction between cultural and developmental factors are viewed as an ongoing interplay. For example, Phinney and Baldelomar (2011) describe identity development as situated in multiple cultural contexts, and argue that an identity is formed as a result of the actions and decisions of an individual in response to both developmental needs (e.g., to resolve questions of purpose and goals in life and achieve a coherent sense of self) and the actual and perceived opportunities and affordances in the cultural community in which he or she lives. The study of identity formation addresses the interplay of developmental pressures and cultural factors.

Similarly, in her focus on memory development, Leichtman (2011) organizes her review of the literature around three questions that are framed to examine the impact of *cultural effects on memory* in general, as well as on specific functional memory systems (e.g., working memory, procedural memory, semantic, episodic, and representational systems). In contrast, Saraswathi, Mistry, and Dutta (2011) emphasize the inseparability of the individual and social world, as reflected in the Hindu conceptualization of the human life cycle. They describe the four stages of the Hindu life cycle to illustrate the underlying dialectic process of development in which individual action and agency intersects with duty to the structured social world within which one is embedded. They argue that the underlying structure or organizing principle of the Hindu stages constitutes transformations in social relations—that is, in relations between individual and social world. The cyclical and repeating transformations (induct–embed–detach) guide an individual through an ever-widening social world, with dissolution at each level leading to a birth into a higher level of synthesis with the social world.

Despite these many promising trends, the challenge of integrating cultural and developmental science cannot be underestimated. In the commentary on Jensen's (2011) edited text on bridging cultural and developmental psychology, Shweder (2011) raises the critical question: "So, is it possible to do developmental psychology and do cultural psychology at the same time?" (p. 304). Shweder argues that although we have made much progress in documenting the existence of plural norms for ontogenetic change, the question of developmental change in potentially plural developmental trajectories has as yet not been addressed. A fundamental question then is how to integrate developmental change and processes with insights concerning the culturally situated nature of human development offered by cultural psychologists? We argue that this requires a shift from focusing on cultural variations in developmental domains to a focus on culture as the interpretive and meaning-making processes that individuals utilize in the process of acting in, with, and on their environments. We argue that, *this process of acting in, with, and on the environment through culturally interpreted meanings itself represents the developmental process*.

Culture as Interpretive and Meaning-Making Processes

The critical notion of culture as a meaning-making and interpretive process is articulated in Overton's (2008; Chapter 2, this *Handbook*, this volume) construct of embodiment (discussed earlier in this chapter). In highlighting action as the means whereby biology, person, and the sociocultural world are synthesized in the construct of embodiment, Overton (2008, p. 9) explains that in its expressive form, "action entails the projection of person-centered meanings, thus transforming the objective environmental world into an 'actual' or lived experience (that is, one that is known, felt, desired)." Thus, culture as interpretive, meaning-making processes is highlighted and has implications for conceptualizing how context functions in the developmental process.

Scholarship in cultural psychology and in developmental science appears to be converging, both in terms of paying attention to developmental processes as culturally and contextually situated phenomenon, as well as in terms of empirical investigations about how context functions in individual developmental processes and trajectories. In this regard, the influence of Bronfenbrenner's bioecological model (1979; Bronfenbrenner & Morris, 2006) in facilitating an increased awareness (among both developmental scientists and policy makers) of the multiple layers of context that can affect individual development, cannot be underestimated. However, it must be remembered, as mentioned earlier, that Bronfenbrenner's model treats culture as an independent variable, which has an impact on individual development. Consequently it is important to differentiate this *bioecological model* from sociohistoric-cultural perspectives, such as Weisner's (2002) *ecocultural perspective*, Rogoff's (2003) *sociocultural perspective*, or Shweder et al.'s (2006) *cultural psychology perspective*. The ecological and these several sociohistoric-cultural perspectives represent individual-in-context processes and go beyond the bioecological model to emphasize that individual behavior is mediated through culture as the meaning systems, symbols, and practices through which people interpret experience.

The contributions of these sociohistoric-cultural perspectives and the associated empirical literature they have generated hold great promise for a true synthesis of culture and human development. In this context, Nicotera's (2007) distinction between neighborhoods as *environment* and *place* illustrates how the conceptualization of community context can include both environmental circumstances as represented in bioecological models, as well as the meaning-making processes through which individuals interpret their circumstances.

Nicotera distinguished between *environment* as a static context that most people experience in the same way, and *place* as the socially constructed history of individuals' lived experience of an environment over time (p. 27). Interestingly, evidence for the significance of the subjective experience of events and environments is emerging from research in *human social genomics* (Slavich & Cole, 2013). In a review of social genomics research mentioned earlier, Slavich and Cole noted that

> Changes in the expression of literally hundreds of genes can occur as a function of the physical and social environments we inhabit. Moreover, it appears as though these effects are often more strongly tied to people's subjective perceptions of their surrounding social environment (e.g., feeling lonely) than to "objective" features of those environments (e.g., being single). (p. 331)

Once again, consistent with the relational metatheoretical frame, both the subjective and objective dimensions of ecological circumstances should be analyzed concurrently. To take an example, features of community context, such as economic and demographic characteristics (e.g., population density, racial/ethnic composition of neighborhoods) represent shared environmental circumstances that can be assessed as static snapshots of community contexts. However, the socially and culturally constructed meaning attributed to these contexts, and the processes or strategies developed in response, need to be examined at the family and individual level to represent what Nicotera (2007) referred to as the *place* aspect of community context. Thus, for example, ethnic stratification at the community level (i.e., ethnic composition and ethnic enclaves) is the environmental backdrop against which ethnically underrepresented families construct culturally grounded belief systems or ethnotheories through which they interpret the experience of being an ethnic minority. Both environmental and interpretive dimensions of context are thus germane to understanding the developmental process.

Another example of how both subjective and objective dimensions of context can be viewed as complementary is provided by Cooper, García Coll, Thorne, and Orellana (2005). They illustrated how static, demographic categories of immigration, ethnicity, and race are instantiated and made more or less salient in the institutional practices of schools. For example, "schools' institutional use of pan-ethnic categories such as Hispanic or Asian highlighted certain distinctions while muting others that were more meaningful to some families" (p. 196). Similarly, documentation of bilingual programs in schools revealed that bilingual class labels such as *Spanish bilingual* and *English only* accentuated some identity labels while muting others: The Spanish bilingual program reinforces a sense of unity among Spanish-speaking children despite varying immigrant origins while accentuating their separation from African American and European American children in English-only classes. In each of these examples, static demographic characteristics (such as racial or ethnic composition of the school's population) are given interpretive salience and directive force for action by the institutional practices of labeling, which children made sense of and interpreted in navigating and responding to and negotiating these practices.

The significance of understanding how context functions cannot be understated for any serious attempt at integrating developmental and cultural perspectives. Toward this end, Goodnow and Lawrence (Chapter 19, this *Handbook*, Volume 4) combined the terms *cultural* and *contexts* to underscore the relevance of cultural contexts to all analyses of *development in context*. Further, recognizing that it is first and foremost critical to specify the particular features of context that are the focus of analysis, Goodnow (2010, 2011) delineated four ways of specifying contexts that offer a promising guide for empirical research that integrates developmental and cultural foci of interest. Perhaps the most common way of *specifying context in developmental science* research has been to *delineate and document cultural context as the ideologies, values, and norms* that are shared by members of a group. These ideologies are often considered to represent modal patterns in that they are shared by members of a group and they are applied across a variety of experiences, situations, or judgments. However, the danger of representing cultural context in terms of specific ideologies is the tendency to treat these as single-factor determinants of individual outcomes. Instead, as Goodnow (2010) suggests, the integration of questions of developmental processes into this specification of context could focus on how particular ideologies or expectations and norms become modal through the collective action of individuals, or at times devalued and perhaps actively dismantled as individuals negotiate the norms.

A second commonly used *specification of context is in terms of the practices, activities, and routines shared by members of the group* (Goodnow, 2010, 2011). In this case, the focus is shifted from ideologies to individual or collective actions (what people do) or how individuals participate in particular contexts. These practices, activities, and routines are considered to be cultural in that their underlying interpretations are shared, and in that these are recurring, repeated patterns or scripts for carrying out everyday activities. Integrating developmental analysis into the focus on practices and routines could focus on how individuals enter, selectively participate, and in doing so transform these routines and practices over time.

Two other specifications of context delineated by Goodnow (2010, 2011) are less frequently considered in developmental science research. Goodnow notes that *specifying the heterogeneity of context* has been the focus of anthropological analyses where there has been a shift from regarding cultures as integrated and stable sets of meanings to recognizing the presence of conflict and contest. This focus on cultural contexts in terms of multiplicity and contest is just beginning to appear in developmental science research. For example, in research on ethnic and racial socialization investigators are not only documenting the heterogeneity or homogeneity of neighborhood contexts (Benner & Graham, 2009), but also examining how parental socialization practices and actions intersect with the multiplicity of contexts within which their children exist. Questions such as how parents and children navigate, negotiate, and sometimes contest competing messages and how identities are formed through these processes of engaging with the multiplicity of contexts are now beginning to be addressed (a brief synthesis of the literature on ethnic identity formation is presented later in the chapter). Similarly, the fourth *specification of context focuses on analysis of paths, routes, and opportunities afforded to individuals within the contexts of individual development*. This specification of context forefronts analysis of how individuals move through school, paid work, or relationships in terms of having access to opportunities or facing barriers. An integration of questions of developmental change would include a focus on mapping pathways and trajectories. For example, Cooper, Dominquez, and Rosas (2005) document how, for underrepresented minority youth, coming to know the opportunity structures and learning to see various steps as part of a future self are ways of introducing change in the interpretive meaning making of youth about whether to stay in school or drop out.

To conclude this section, we reiterate that contexts are always interpreted by individuals as they act on or function within the contexts. Hence, both environmental or ecological features of context and the ways individuals interpret and give meaning to features of context must be considered complementary and preferably be analyzed simultaneously. But how to conduct such complementary analyses concurrently is challenging at best and leads to a consideration of relevant methodological issues.

INTEGRATING CULTURE AND HUMAN DEVELOPMENT: METHODOLOGICAL ISSUES

The field of developmental science has focused on the description, explanation, and optimization of developmental change (Baltes, Reese, & Nesselroade, 1977; Lerner, Easterbrooks, & Mistry, 2012). Historically, description and explanation of developmental processes was typically framed in dichotomies such as the classic nature versus nurture debate or whether development is continuous or discontinuous. The discipline has since progressed beyond such dichotomies and expectations of single or simple causal factors as explanations for development. However, the rich and complex theoretical view of development as a mutually constitutive process involving embodied epigenetic processes creates methodological challenges for empirical research. To avoid the trappings of dichotomous contrasts it is important to maintain a relational metatheoretical stance (Overton, 2014, Chapter 2, this *Handbook*, this volume) toward methodology. Contrasting methodologies may need to be bridged, integrated, or be considered complementary to investigate the mutually constitutive nature of culture and individual development.

There are two critical methodological implications generated by the theoretical stance proposing the mutuality of individual development and sociohistoric-cultural context in the study of development. The first set of methodological challenges derive from the need to integrate investigation of both the objective environmental world within which an individual acts, with the person-centered meanings and frames which transform the objective environmental world into a lived experience. The challenge of integrating both objective dimensions of the environment as well as the subjective meaning-making process through which individuals interpret the environment requires a synthesis of methods that have historically been cast as opposing methodological approaches, such as the emic-etic distinction (i.e., the insider versus outsider perspective). The second set of methodological challenges arise from the need to study development as an epigenetic process, involving mutually constitutive, multilevel, and dynamic relations between the person and context that change over time. Addressing these challenges requires not only the integration of contrasting approaches, but also sophisticated analytic methods to synthesize multilayered data, and to analyze complex relations that change over time and therefore need to be investigated longitudinally. The need to integrate assessment of both subjective and objective dimensions of the external world and to investigate development as an epigenetic process is well illustrated in the newly emerging field of human social genomics (Slavich & Cole, 2013) described earlier in this chapter. Summarizing evidence from research on susceptibility to disease, Slavich and Cole (2013) illustrated how subjective perceptions of external social conditions (e.g., if the environment is perceived as friendly or hostile) trigger neural and endocrine responses that regulate gene expression, which in turn shape a person's risk for health-related disorders and disease. Slavich and Cole (2013) contend that evidence demonstrates that subjective perceptions of the physical and social environment are more critical than the objective indicators of the environments in the relation between person and context.

Despite the methodological challenge of investigating integrative and dynamic processes, the task of empirically examining development as embodied, epigenetic processes has already been undertaken and is well represented in the two volumes of *Advances in Child Development and Behavior,* edited by Lerner and Benson (2013). Innovative methodological approaches to the study of integrated, systematic, and successive change across ontogeny and phylogeny are presented in these works. For example, Molenaar and Lo (2013), present a class of mathematical models of biological growth to demonstrate the variations in morphogenetic structures that originate through diffuse self-organizing forces in development. Several authors review existing empirical evidence to illustrate the integration of biology and experience in epigenetic developmental processes. For example, Müller, Baker, and Yeung (2013) integrate empirical evidence on stress, social interaction, and interventions to document that individual differences in executive functioning of the brain are dependent on experience.

A comprehensive review of various methodological approaches designed to integrate objective and interpretive dimensions of individual actions in cultural context and to study epigenetic processes of development as situated in context is beyond the scope of this chapter. However, two promising methodological trends are highlighted to illustrate that it is possible to address the challenges in empirically investigating the integration of person ←→ culture and individual development. The first trend is the integration of emic and etic perspectives through mixed-methods approaches (see Tolan & Deutsch, Chapter 19, this *Handbook*, this volume). The second trend is the development of methods specifically designed to examine the interpenetrating interface between individual and context, as this occurs at multiple levels of analysis.

Mixed Methodological Approaches

Debates on appropriate methods to study human development are rooted in historically rival epistemological stances. Despite this oppositional stance, developmental researchers are increasingly receptive to the use of mixed methodological approaches to empirically investigate human development. In fact, the dynamic nature of human development *requires* integration of methodological approaches (García Coll, Szalacha, & Palacios, 2005; Weisner, 2005; Yoshikawa, Weisner, Kalil, & Way, 2008). For instance, it is increasingly common to see research studies use quantitative (information is reduced to numeric form such as counts, scores, and ratings) *as well as* quantitative data (elaborate information such as open-ended responses, narratives, and field notes) to address the same questions. Four major types of mixed-methods research designs seen in developmental science (Creswell & Plano-Clark, 2007) are:

1. Triangulation designs that obtain different but complementary data on the same topic.
2. Embedded designs in which more often than not, qualitative data are used to provide supplementary data in a study based primarily on quantitative data.
3. Explanatory designs in which qualitative data are utilized to provide explanations or to elaborate on initial quantitative results.
4. Exploratory designs that are typically used to explore a phenomenon for which there are no prior instruments or theory.

The combination of methods that are rooted in contrasting philosophical orientations (e.g., interpretive and positivistic approaches) presents a major methodological challenge. This is apparent when considering a few of the contrasting approaches that have historically been cast as opposing stances. The contrast between interpretive and neopositivistic methodological paradigms goes beyond the typical qualitative—quantitative distinction. Interpretive and neopositivistic approaches are rooted in opposing philosophical assumptions about reality (Overton, Chapter 2, this *Handbook*, this volume). Neopositivistic approaches are rooted in the ontological and epistemological assumptions that there is an objective *mind independent* reality and that this reality can yield pristine noninterpreted data through the observations of a totally neutral observer. Interpretive approaches, on the other hand, are rooted in the sociohistoric-cultural constructivist philosophical assumptions, which assert that perception is an active process of mind and that as such acts of perception participate in the construction of the world as known. Thus, for the sociohistoric-cultural constructivist there can be no "mind independent" knowledge. Thus, the interpretation of participant perspectives becomes a critical dimension in investigations conducted within the interpretive methodological approach (Guba & Lincoln, 2008). Athough in their most radical forms these stances are irreconcilable alternatives, when cast into a relational metatheoretical framework they form an integrated *identity of opposites* (Overton, 2006, Chapter 2, this *Handbook*, this volume). For example, Overton's (2008) construct of *embodied action* entails the projection of person-centered meanings onto a physical and sociocultural world, thus transforming what from an external point-of-view constitutes the objective environmental world into an actual, lived, or known world. Therefore, depending on the assumed point of view, it is reasonable to maintain both the constructed (internal person-centered) reality and the objective (external object-centered) reality.

In a related vein, in the field of cross-cultural psychology methodological debates about the preferred research orientation have historically been cast in terms of the emic-etic distinction (Berry, 1969; Poortinga, 1997), or the indigenous–universalist orientation to research (Sinha, 1997). Behavior is *emic*, or culture-specific, to the extent that it can only be understood within the cultural context in which it occurs; it is *etic*, or universal, in as much as it is common to human beings independent of their culture (Kağitçibaşi, 1996; Poortinga, 1997). Typically, culture-comparative methodologies utilize etic constructs to establish lawful relations between cultural variables and psychological phenomenon. However, these methods have been criticized as not sensitive to cultural context (Greenfield, 1997). The contrasts between emic and etic approaches are often cast as oppositional alternatives, related to the question of how culture or cultural context should be conceptualized and operationalized in psychological research. Should culture be conceptualized as an independent variable (e.g., a set of antecedent conditions) in relation to behavior and development? Or should it be conceptualized as culturally constituted meaning systems? Should the focus be on finding lawful relations between environmental (antecedent) variables (as cultural context is often operationalized) and behavioral outcomes, or should the focus be on understanding how culturally constituted meaning systems are constructed in given contexts?

From a relational metatheoretical stance, it becomes clear that these questions need not be framed as oppositional alternatives. The more fruitful approach would be to focus on understanding both contexts (external object-centered) and the culturally constituted meaning systems embedded in various contexts (internal person-centered) as complementary points of view. If the focus were to be exclusively on culturally constituted meaning systems, there would be the danger of relying solely on culturally specific explanations for variations that may not be applicable across communities (Kağitçibaşi & Poortinga, 2000). If meaning systems were the exclusive focus, then important social-structural (external object-centered) factors such as social-class standing, poverty, and educational levels would be overlooked. On the other hand, an exclusive focus on contexts as "social address" variables (Bronfenbrenner, 1986) could reinforce past assumptions that processes of development are similar across groups, and that variations can be fully accounted for by differential exposure to external causal agents or conditions, and equally non-person-centered biological predispositions. Clearly, emic and etic approaches can and must function as complementary points of view (see Tolan & Deutsch, Chapter 19, this *Handbook*, this volume).

However, despite the need for integration of complementary approaches, designing empirical investigations that combine approaches is no easy task. A coherent integration of complementary methodological approaches requires deliberate attention to underlying metatheoretical assumptions and explicit statements of how these are being treated. Fortunately, trends in the use of multiple methods in empirical studies, and particularly the use of mixed methods designs are promising means of conducting research grounded in a relational metatheoretical stance. Discussions of mixed methods approaches (Creswell & Plano-Clark, 2008; Teddlie & Tashakkori, 2009; Tolan & Deutsch, Chapter 19, this *Handbook*, this volume) offer detailed descriptions and conceptually grounded categorizations of various types of mixed methods research designs. Other discussions offer examples from the existing literature that illustrate particular combinations of mixed methods (Yoshikawa et al., 2008).

The significance of beginning an empirical research agenda that employs both approaches in an integrated fashion is well illustrated in a study of family engagement in education among Latino parents in Head Start classrooms (McWayne, Melzi, Schick, Kennedy & Mundt, 2013). Recognizing that existing measures of family engagement, developed primarily with European American families, might not actually represent what family engagement meant to their sample of Latino families, McWayne et al. (2013) began with an emic approach to first develop the construct of family engagement from the participants' perspectives (person-centered). In a series of studies, McWayne et al. (2013) first sampled 113 parents from 14 Head Start programs to identify domains of family engagement and to co-construct with the parent participants items to assess these domains. The second study, with 650 caregivers was designed to establish the construct validity of the measure, followed by a further validation of the measure through the use of teacher reports of family involvement and parent reports of satisfaction with their experiences in Head Start.

To summarize, mixed methods approaches can facilitate the integration of complementary perspectives. First, emic and etic perspectives can be jointly employed in mixed methods designs to ensure that interpretations of human actions being investigated are based on concepts and measures that yield reliable and valid data reflecting the added value of both perspectives. Second, idiographic and nomothetic perspectives can also be integrated in mixed methods approaches to address the seemingly intractable problem of documenting the unique features of specific cultural communities while simultaneously deriving the manifest variation that may cohere at a second-order level to reveal systematic regularities or general patterns across cultural communities. As Kluckhohn and Murray (1948) noted, nomothetic, differential, and idiographic features of development are applicable to all human beings, and arguably to groups or cultural communities as well.

In addition to the synthesis of complementary perspectives (such as emic and etic approaches), the integration of culture and human development also requires integration across multiple levels of analysis. Advances in methodological techniques offer the promise of achieving this task, and a few techniques are presented in the following section.

Integration of Multiple Levels of Analysis

The methodological challenges that arise from viewing developmental processes within a relational metatheory are particularly difficult to address as these require the integration of multiple levels of analysis. This notion has been discussed within varying conceptual perspectives. Within cultural psychology and sociohistoric-cultural perspectives the focus on multiple levels has been proposed in various ways. It is exemplified most explicitly in Cole's (1996, 2006) discussion of the integration of phylogenetic, historical, and ontogenetic levels of analysis in understanding cognitive development, and by the focus on studying individual actions in the context of the activity settings within which they are embedded. It is at the level of activity settings that phylogenetic, historical, and sociocultural levels of analysis are integrated through the meaning-making processes that individuals engage in while interpreting the activity contexts.

In relational approaches within developmental science as well, there is a shift to including person-oriented analytic models and time series designs (see von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume; Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume), rather than relying on between-subject cross-sectional designs. In fact, the hallmark of the relational developmental systems approach is a focus on intraindividual variability (Nesselroade & Molenaar, 2010). Furthermore, conceptual discussions of how the individual's actions are integrated with the actions of the context (in both structural and functional terms) are offered by Lerner's (2011) discussion of irritability, adaptation, and action in ontogenetic development, and Overton's (2008) description of how the embodied act constitutes the fundamental microscopic process of developmental change. Actions, as goal-directed acts, are enacted in the world, and they encounter resistances and succeed or fail to various degrees in achieving the goal. The encountered resistance provides feedback to the system, which uses this feedback as a resource to change or transform the system, which in turn produces revised action (Overton, Chapter 2, this *Handbook*, this volume). This cycle of transactions between the embodied action and the physical and sociocultural world constitutes the development process.

Despite the prevalence of conceptual discussions of the dynamic nature of developmental processes, empirical research is often limited to cross-sectional designs and questions regarding developmental sequence, milestones, and factors that either facilitate or hinder development. There is limited focus on investigations of developmental processes per se, perhaps reflecting difficulty of actually studying developmental processes in real time. The complexity of examining microlevel developmental processes, employing analytic tools necessary to examine the intricate, dynamic, and fused nature of individual actions and context, as these operate over time is challenging at best. However, advances in methodology, both statistical and qualitative, have facilitated investigations of emergent and microgenetic processes. Investigations conducted through qualitative and interpretive approaches tend to focus on in-depth analysis of a few cases of individuals (Raeff, 2011; Rogoff et al., 1995) or collectivities (Rogoff, 2011; Saxe, 2012a). In investigations that involve large samples, statistical techniques such as dynamic factor analysis and IF techniques enable intensive analysis of individual longitudinal data to examine developmental processes (Molenaar & Nesselroade, 2012; Nesselroade & Molenaar, 2010). A few illustrative examples from both approaches are presented as follows.

Qualitative Analysis of Epigenetic Processes

The microgenetic process of an individual's action-coaction within a culturally situated activity is illustrated in Raeff's (2011) analysis of Rogoff et al.'s (1995) study of Girl Scouts participating in cookie sales. Rogoff et al. (1995) documented detailed case studies of four girls to illustrate how developmental change involved moving from peripheral participation to being primarily responsible for selling the cookies. In illustrating how the girls transformed their responsibilities and understanding in the process of acting with others to achieve the task, Rogoff et al. (1995) documented how through their actions, the girls stretched their own thinking to understand the action and ideas of others as they worked to accomplish tasks together during their participation in the activity at hand. Raeff's (2011) purpose in using Rogoff et al.'s (1995) case study data was to illustrate how the integration of the principles of organismic-developmental theory with sociohistoric-cultural perspectives facilitates the often-neglected investigation of developmental processes. As Raeff (2011) notes, "once a developmental goal is explicated in terms of the organization of action constituents, the next analytic step involves discerning the current organization of an individual's functioning with respect to the action constituents under scrutiny" (p. 19). Raeff offers a detailed and valuable example of such delineation in her analysis of the Rogoff et al. (1995) study. Raeff's analysis is offered here in some detail to illustrate her description of the microgenetic process. Through a hypothetical extension of the Rogoff et al. (1995) analysis, Raeff's describes the nature of such analysis as follows:

> More specifically, such analyses would first involve identifying some developmental endpoints or goals for selling Girl

> Scout cookie sales responsibly, such as planning sales routes, filling out the sales form correctly, keeping track of deliveries and payments, interacting appropriately and effectively with customers, and identifying with the Girl Scout role. Next, each of these goals can be defined further in terms of constituent and sub-constituent parts. In another presentation of the Girl Scouts research, keeping track of deliveries and payments is analyzed in terms of four constituents, each of which is defined further in terms of two subconstituents (Rogoff et al., 2002). For example, "keeping track of delivery progress and deliveries yet to be made" involves "checking off the order once a delivery was made," or "prompting tracking by someone else by reminding someone to check off completed deliveries, or requesting someone to recap the completed deliveries or to describe upcoming deliveries" [Rogoff et al., 2002, p. 278]. These constituents represent different possible means for keeping track of deliveries. Once particular aspects of selling cookies are chosen for investigation, and defined in terms of specific constituents, investigations of development can proceed. Observations would involve tracking differentiation and integration within and between constituents. (Raeff, 2011, pp. 21–22)

As Raeff (2011) describes, such investigations at the microgenetic level require carefully delineated differentiation of constituent actions and analysis of dynamic processes in naturally occurring experiences and contexts.

Similar analysis can also be conducted at the level of a cultural group. However, analysis of multileveled epigenetic (*qualitative discontinuous* or *emergent*; Gottlieb, 1996; Lerner, 2002; Lerner & Benson, 2013; Overton, 2010; Werner, 1957) processes and transformations and newly emerging collective practices that occur in historical times require in-depth analysis of single communities and would be invisible in cross-cultural comparisons of practices. An example of sociogenetic analysis of community level change over historical time is provided by Rogoff's (2011) unique biography of a midwife in a small Mayan community. Although focused on the life of the midwife over a period of over 40 years, Rogoff's analysis includes the lives of San Pedro children and families, and tracks the dramatic changes and stabilities around birth and childrearing practices, revealing the interrelatedness of individual lives and community history.

Another example of co-constructed developmental change processes at the level of cultural groups is illustrated in Saxe's (2012b) study of the adaptation of an indigenous numerical system used by a cultural community in Papua New Guinea. This study illustrates the epigenetic process as it unfolds at the cultural level—in other words, the cultural community is the unit of study in this research. Based on fieldwork conducted in 1978, 1980, and 2001 in the Oksapmin community of Papua New Guinea, Saxe (2010b) uses the community's historical changes over time as a central organizing construct and documents the dynamic interplay between individual and collective activity in the use of an indigenous number system as it is transformed over time.

Through careful ethnographic observations and analysis of the Oksapmin people's use of indigenous representational forms, like their 27-body-part counting system, Saxe documented historical changes in organization of their activities of daily life. He carefully documented how the adaptations to the representation system emerged to serve newly emerging arithmetical functions as collective practices changed with the advent of formal schooling. What is particularly striking is that the adaptations in the body-part counting system were the children's own constructions as they engaged with new kinds of arithmetic problems in the classroom. Furthermore, Saxe's (2012b) detailed analysis reflects a form of microgenetic emergence of transformations at the sociogenetic level.

Statistical Techniques for Analysis of Epigenetic Processes

Although the focus on intraindividual variability and the analysis of individuals in context is not new in developmental science, advances in statistical modeling have resulted in the emergence of new analytic procedures designed to explore the role of multivariate features of human development (e.g., Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2010; Ram & Grimm, Chapter 20, this *Handbook*, this volume; von Eye et al., Chapter 21, this *Handbook*, this volume). Despite the complexity of examining microlevel developmental processes in large samples of individuals, analytic tools necessary for the exploration of the organization of constituent actions and hierarchical integrations of constituent subcomponents, as they operate over time, as well as to examine dynamic processes have been developed. Notably, and as discussed earlier in regard to the work of Molenaar and Nesselroade (Chapter 17, this *Handbook*, this volume), Ram and Grimm (Chapter 20, this *Handbook*, this volume), and von Eye et al. (Chapter 21, this *Handbook*, this volume), developmental methodologists have constructed many procedures to work with interrelational data and overcome typical issues such as nonnormal distributions, which characterize many of the ordinal and nominal variables of value to developmental science (e.g., see the discussion of configural frequency analysis in von Eye et al., Chapter 21, this *Handbook*, this volume). Advances in estimation of missing data have also furthered the ability of researchers to test complex conceptual models of development in context (e.g., Laursen, Little, & Card, 2012), using robust estimates for longitudinal and cohort-sequential panels (Little, 2013). The challenge for statistical analysis of developmental processes is to be able to model the properties of *dynamic processes,* rather than as static relations between input and output variables (Nesselroade & Molenaar, 2010). Taking the example of a protracted phenomenon such as socialization, Nesselroade and Molenaar (2010) note that despite tremendous variability in the interactions between children and caregivers, both over time, and across individuals, it is reasonable to assume that there is a common underlying pattern of relations. They argue that "conceptualizing process as a latent mechanism with possibly different manifestations for different individuals opens the door to a considerably more general kind of lawfulness" (p. 214). More specifically, Nesselroade and Molenaar (2010) propose merging idiographic filter measurement with dynamic factor analysis to model process. They delineate the two-step process, with dynamic factor analysis as the first step, which takes into account lagged relations between factors and observed variables. "The lag structure extends latent variable modeling to include temporally highly organized change patterns, a hallmark of an ongoing process" (p. 212). The second step of applying the IF (ideographic filter), enables identifying nomothetic relations at the latent level, that is, to identify process as latent entity across individuals, while recognizing that it can manifest itself somewhat differently in different individuals at the observable level.

Along with autoregressive and latent growth models, which have become increasingly sophisticated in handling covariation as well as changes in mean-levels of variables over time (e.g., Molenaar, 2010; Nesselroade & Molenaar, 2010), investigators have become highly competent at modeling the multilevel ecological system variables and dynamic, bidirectional reciprocities (e.g., Molenaar, Lerner, & Newell, 2014; Molenaar & Newell, 2010). The cascade model derived from dynamic systems theory perspective represents one example of modeling and testing theoretically derived sequentially progressive pathways (Dodge, Greenberg, & Malone, 2008; Lewin-Bizan, Bowers, & Lerner, 2010; Masten et al., 2005). The general purpose of these models is to examine the interrelations among human functioning in multiple domains and in multiple levels of contexts to identify transactional, interpenetrating, proliferating and cascading effects.

In one such example, focusing on psychological adjustment and academic achievement, Masten et al. (2005) examined a cascade model of externalizing symptoms (aggression, delinquency) that appear in childhood and are associated with poor academic performance during school years, while in turn this academic performance was hypothesized to amplify current internalizing problems/symptoms such as depression, fearfulness, and anxiety. Extensive multimethod and multiinformant data were used with multiple indicators at each age to cover a 20-year longitudinal span to address the complex relation between the three domains of academic achievement and externalizing and internalizing behaviors. SEM procedures in the versatile Mplus software allowed them not only to test their hypothesized model against a null model of basic autoregressive continuity and stability in these three domains, but also alternative nested models including an ingenious model controlling for IQ, parenting quality, and SES that could potentially account for these relations. Such sophistication in the simultaneous specification of elaborate recursive and nonrecursive path models over time, implicating multiple domains and contexts in addition to measurement models that can be tested on subgroups such as gender or culture and with modest sample sizes because of imputed data bodes well for developmental scientists going forward in exploring individual-context interplay.

A similar articulation of a dynamic cascade model is seen in Dodge et al.'s (2008) prospective inquiry of precursors of serious violence and antisocial behavior in 754 adolescents from 27 schools representing four geographic locales. In their study, they modeled seven predictor domains encompassing individual and contextual variables, which act sequentially, each one influencing the next uniquely as well as partially mediating the effects of the prior domain, thus culminating incrementally into violent behavior. These predictor domains were (a) adverse social-context, (b) early harsh and inconsistent parenting, (c) social and cognitive readiness for school, (d) child's externalizing problems, (e) school-related social and academic failure, (f) communication and monitoring of child as an adolescent (after Grade 4), (g) deviant peer associations (after Grade 7). Each of these domains was derived from multiple measures and informants that were weighted using Partial Last Squares (PLS) routine in SAS. Having established the measurement models, they proceeded to test the structural nested models of cascading influence from one predictor to the next using SEM in Mplus to predict adolescent violent behavior in Grades 10 and 11. Each predictor domain was tested as a mediator of the relations between the immediate prior domain and the outcome variable of serious violence. The researchers successfully demonstrated that adverse social contexts in early childhood predicted adolescent violence and that thereafter each subsequent predictor domain at each of the following ages incrementally predicted adolescent violence (ultimate outcome variable) controlling for the impact of the previous predictor domain in the theorized chain of predictors. Gender differences in means and developmental paths were also evaluated by relaxing the constraints of equality of developmentally cascading paths across gender group and interesting differences in mean levels and developmental paths to serious violence were noted for boys and girls.

In a similar vein, Lewin-Bizan et al. (2010) attempted to identify and incorporate a cascade of person ←→ context relations and pathways that promote thriving and Positive Youth Development (PYD) as a conceptual alternative to the typical deficit model of adolescence. Going beyond negative events like bullying, violence, depression, or unsafe sex, they defined thriving as presence of positive attributes, one of which was contribution to society, pursuing the question as to what attributes of the adolescent and context lead to flourishing during the period of adolescence. Accordingly they articulated a model with cascading influence of positive youth-parent relationships (maternal and paternal warmth and monitoring), leading to attributes of intentional self-regulation in youth (ability to select, optimize, and compensate and thus regulate goal pursuit), which in turn would lead to positive youth characteristics (competence, caring, confidence, character, and connection) and thus to the final outcome of contribution to society. Using Zellner's (1962) *Seemingly Unrelated Regression* (SUR), they conducted a series of regression analyses with four waves of longitudinal data testing this sequential cascading model of influence while controlling for current levels of predictor variables. Thus, contributory behavior at Grade 8 was predicted by positive youth characteristics at Grade 7 while controlling for stability in contributory behavior at Grade 7; positive youth characteristics at Grade 7 were predicted by intentional self-regulation at Grade 6 over and above stability of positive youth characteristics at Grade 6, and intentional self-regulation at Grade 6 was predicted by parenting at Grade 5 while controlling for intentional self-regulation at Grade 5.

Although those substantively interested in adolescent violent behaviors or positive youth contributions and thriving can follow up the details of developmental trajectories and gender differences by perusing the specific articles, the purpose here is to draw attention to these investigations as exemplars of how the complex and incremental person ←→ context relations are being addressed analytically and paving the path for future context and culture-inclusive developmental research. There is still considerable room for improvement in these and other similar analytical models, which derive from better articulated theoretical relations such as the appropriate lag between when a predictor variable might be expected to have an impact on the outcome variable, or which processes to include as precursors to development, or which alternative or nested models to test. However, these are questions that will stimulate future advancement of better finessed and culturally nuanced inquiry about human development.

To this point we have discussed the integration of culture and human development from both a conceptual and methodological perspective. These perspectives are critical in providing us with powerful tools for scientific inquiry. However, their power is realized only when they lead to theoretically based empirical investigations yielding useful scientific findings. Thus far, we have presented selected examples of empirical research that illustrated how the theoretical and methodological challenges of examining person and context as interpenetrating relations have been addressed in empirical research. Progress in advancing this relational program lies in using the concepts and methods to construct and test empirical research programs across the broad range of culture ←→ human development. Toward this end, we have selected two specific topics of research in the field of human development where the integration of cultural and developmental science perspectives appears to be most promising. These two topics are the emerging field of cultural neuroscience, and integrative research on socialization and ethnic identity development.

INTEGRATING MULTIPLE LEVELS OF ANALYSIS: CULTURAL NEUROSCIENCE

In the earlier section on conceptual issues, the inseparability of individual and culture was highlighted both from cultural psychology and developmental science perspectives. The inseparability was established either through constructs that integrate both within a single unit of analysis, or through framing individual development within embodied action or action-oriented conceptualizations. The underlying assumption is that individual action occurs within specific contexts. Further, the centrality of action as an organizing and framing construct for human functioning enables the inclusion of lived experience or interpreted experience, which highlights culturally constructed interpretations and meaning making, which cultural psychologists have insisted needs to be theoretically represented as part and parcel of the psychological system (Shweder et al., 1998, 2006). These notions are consistent with the relational metatheory position that person, biology, and culture operate as relational, interpenetrating, or fused systems. As Overton (Chapter 2, this *Handbook*, this volume) notes, the psychological development of the person-agent entails the epigenetic stance that novel forms emerge through the coconstituting actions of the target system, as well as the resistances the target system encounters in both the actual and objective sociocultural and physical environment.

Perhaps somewhat surprisingly, evidence for the inseparability of individual and culture has been emerging gradually from the explosion of interest in linking brain development and behavior. Within the field of cultural psychology there were initial concerns that the interest and weight given to neuroscience-based research in psychology would revert to debates about the relative contributions of biology versus environment, with biology being equated with universalism and cultural studies being equated with relativism (Chaio & Ambady, 2007; Losin, Dapretto, & Iacoboni, 2010; Norenzayan & Heine, 2005). However, evidence of the centrality of activity-dependent processes of brain development has not only allayed this concern, but has, in fact, led to the emergence of a new field of research defined as *cultural neuroscience* (Ambady & Bharucha, 2009; Chaio & Ambady, 2007; Losin et al., 2010; Miller & Kinsbourne, 2011; see also Marshall, Chapter 7, this *Handbook*, this volume, for a discussion of sociocultural neuroscience).

The inseparability of individual and experience is bolstered by evidence from developmental neuroscience, which demonstrates that neural processes arise from routine, recurrent activities and experience (Johnson, 2005). This is especially well established for basic perceptual and linguistic processing. Both *experience-expectant* and *experience-dependent* mechanisms (Black & Greenough, 1986; Greenough & Black, 1992) are recognized as core neural-activity-dependent processes through which brain development occurs. Research within the field of cultural neuroscience has extended this focus to other domains of psychological functioning in which varying forms of culturally constituted activities are observed to give rise to varying forms of neural processing. For example, the emergence of distinctive neural patterns of functioning have been observed as arising from activities entailing mathematics (Ambady & Bharucha, 2009), attention, contextual processing, categorization, and reasoning (Park & Huang, 2010).

Marshall (2009, Chapter 7, this *Handbook*, this volume) discusses the centrality of the concept of the embodied brain in all subfields of neuroscience, including sociocultural neuroscience. Thus, *embodiment* is a bridge concept that integrates body, mind, and culture within a relational metatheoretical paradigm. As Marshall points out in his conclusions concerning embodiment "pursuing this intriguing approach to reuniting the study of mind, brain, body, and culture will move us toward a more integrative, and hence more collaborative, approach to the relations between psychology and neuroscience" (2009, p. 122). Chaio and Ambady (2007), while not recognizing the centrality of embodiment, make a related point in their discussion of the mutual constitution of culture, brain, and genes. They claim that this broadens cultural psychologists' typical focus on mutual constitution of culture and mind to focus on bidirectional coactions among culture, genes, and the brain.

Perhaps the most valuable contribution being made by research in cultural neuroscience is that relations between biological and psychological processes are now being examined through multidirectional models that emphasize constant dialogue in gene–epigenome-environmental coactions as they have an impact on human development (Meaney, 2010; Sameroff, 2010). Describing the integration of biology and culture as biocultural co-constructivism, Li (2003) offered a framework that highlights the coactive, dynamic, and across-level nature of the integration. Li described the framework as follows:

> The effects of a series of interconnected feed-downward (culture- and context-driven) and feed-upward (neurobiology-driven) interactive processes and developmental plasticity at different levels (hence, *cross-level*) are continuously accumulated via the individual's moment-to-moment experiences (hence, *dynamic*) so that, together, they implement concerted biological and cultural influences (hence, *biocultural coconstructivism*) in tuning cognitive and behavioral development throughout the life span. (p. 171)

However, the challenge of finding appropriate methods to examine and establish the mutually constitutive processes through which development occurs has not yet been overcome. Although the integration of epigenetics into developmental psychobiology has had a major impact on understanding mutually constitutive processes, the need still exists for the further integration of the methods of biological sciences with the methods that have been privileged in many areas of developmental science. As Meaney (2010) notes, the functional links between genome and environment or between the biology and culture cannot be established through statistical associations.

For the biological scientist, genotype–phenotype relations are defined by the actual physical operation of a genomic region in relation to the proximal cellular events that directly mediate the behavioral variation as well as the more distal influences that regulate the relevant cellular signals (Meaney, 2010).

Further, if we are to adequately integrate sociocultural dimensions of the environment as well, then as Sameroff (2010) argues, we need to include constructs from sociology to represent the structures of societal hierarchies and the meaning-making constructs from anthropology. In closing, it is useful to remember that promising syntheses, consolidation, or integrative frameworks to guide systematic analysis of the developmental process can emerge from the dialogue among scientists drawn from many disciplines.

INTEGRATING INDIVIDUAL AND CONTEXT: ETHNIC IDENTITY DEVELOPMENT

Self and identity are multidimensional constructs meant to represent a core feature of human development (Côté, 2009). Identity typically refers to "the sameness and continuity of the person's psychological functioning, interpersonal behavior, and commitments to roles, values, and beliefs" (p. 3). On the other hand, self is characterized as "a self-organizing, interactive system of thoughts, feelings, and motives that characterizes an individual" (as defined by the *International Society for Self and Identity*; Côté, 2009, p. 4). Both constructs are recognized as being socially situated and, hence influenced by the social context (Erikson, 1968). Because self and identity are recognized as socially situated domains of development, there has been greater receptivity to incorporate cultural perspectives in the study of their development. Further, over the past three decades, research on self and identity has been broadened to incorporate research projects that focus specifically on ethnic identity development. Hence, empirical investigations on the development of ethnic identity offer promising exemplars of the relational status of cultural and developmental science perspectives. Here the conceptual frameworks that undergird research on ethnic identity development are first discussed and then some exemplars of research that reflect integrative perspectives and designs are presented.

Conceptual frameworks on the development of ethnic minority children emphasize that the experience of minority status by bicultural children forms the backdrop against which socialization within family, school, and community settings is situated and experienced. Rather than treating race and ethnicity as the static attributes of individuals, new conceptual frameworks treat ethnic/racial minority status as a particularly relevant feature of living in a socially stratified society (García Coll et al., 1996; García Coll & Szalacha, 2004). García Coll and colleagues specifically frame race, gender, social class, and immigrant status as representing social position variables that indirectly affect children's development through the various mechanisms of racism, prejudice, and discrimination. For example, a family's social position can result in residential, economic, social, and psychological segregation and differential access to quality institutions such as schools, neighborhoods, and the health care system, all of which can indirectly affect children's psychosocial and academic outcomes.

Similarly, it is argued that demographic features of neighborhoods, such as lack of ethnic and racial diversity, are evident in the immediate settings and activities of a child residing in such a community and these can have a relation to developmental outcomes. For children from ethnic minority backgrounds, it may mean that the lived experience of being a minority is highlighted. Markers—such as physical features, dress, or accent—that accentuate the salience of being different from the majority of others in the environment can become symbols imbued with meaning that have to be interpreted, navigated (understood and planned for), and negotiated (managed or dealt with) by the child and family (Mistry & Wu, 2010). These interpretive processes are the mediating constructs through which environmental circumstances have specific meaning for children and families.

What are the unique socialization processes that have been conceptualized as facilitating the development of bicultural or ethnic identity among minority children and adolescents (see Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume, for an extended discussion of the socialization process)? This question was highlighted in a special issue of the 2009 volume of the journal *Cultural Diversity and Ethnic Minority Psychology* titled "Racial-Ethnic Socialization, Identity, and Youth Outcomes: Excavating Culture." In this issue (Rodriguez, Umaña-Taylor, Smith, & Johnson, 2009) a conceptual model was proposed that delineated the linkages between racial-ethnic socialization, the self-system, and child psychosocial development and adjustment among children and families of color. The model conceptualized the components of familial adaptive culture regarding race and ethnicity that are deemed to be critical for the development of ethnic minority children, with a particular focus on academic outcomes. In the model, two specific socialization processes have been identified as critical for children from minority backgrounds: ethnic/cultural socialization and racial socialization. These socialization processes are considered components of the adaptive culture that families create in response to living as underrepresented ethnic/racial minorities in the context of the larger society. Cultural/ethnic socialization refers to the messages and practices through which families promote affiliation, a sense of belonging, and pride in the family's cultural heritage. Racial socialization, on the other hand, refers to the messages and practices through which families promote increased awareness of racism and discrimination, and preparation for coping with such experiences. These socialization processes are assumed to affect child/adolescent outcomes through the mediating process of strengthened self-system processes. Racial/ethnic socialization are expected to promote child adjustment and psychosocial outcomes by strengthening self-system processes such as self-esteem and ethnic and racial identity, which, in turn, facilitate academic performance through various mediating processes, such as buffering the psychological impact of racism, and by incorporating successful academic performance as an integral component of self-identity.

However, the question arises as to why racial and ethnic socialization are, in fact, critical for bicultural and ethnic minority children? García Coll and colleagues contend that because it is crucial to include the experience of racism and its derivatives of prejudice, discrimination, and oppression as "normative" experiences for immigrant and ethnic minority children, it follows that socialization within various childhood settings (home, school, peer group, neighborhood) must include a focus on coping with these negative experiences (García Coll et al., 1996; García Coll & Szalacha, 2004). The empirical studies reported in the Special Issue are grounded in these experiences and serve as tests of various dimensions of the conceptual framework formulated in the issue.

Increasing recognition of the situated nature of children's development has led to calls for research that includes institutional or community-level constructs and analysis (García Coll & Szalacha, 2004; Mistry & Wu, 2010; Syed, Azmitia, & Cooper, 2011). In a review of interdisciplinary perspectives on the relation of ethnic identity and academic success in ethnic minority children, Syed et al. (2011) specifically noted that this relation must be understood conceptually as the need for "integrating individual, relational, and institutional levels of analysis" (p. 442). For example, in highlighting the role of the school context, Syed et al. (2011) argue that when children are ethnic minorities in their schools, they are likely to face negative stereotypes about their achievement potential, which can undermine their self-esteem, and lead them to disengage from school, thereby negatively affecting their academic performance. At the institutional/community level, sociocultural circumstances that provide the context for experiencing minority status are of particular relevance for ethnic minority children and families. As García Coll et al. (1996) noted, societal level features, such as segregation, social position, and pervasive racism are the circumstances that are relevant for minority children, because they heighten the salience of being marked as "different" or the "other." The process of being marked as different (Bhatia, 2007) and the process of racialization represent processes through which ethnic identities may become salient.

However, not all individuals from underrepresented ethnic minority groups experience being a "minority" to the same extent. For example, immigrants to the United States from Latin American countries whose ethnic heritage is European may not be visible as minorities, unless their accent marks them as foreigners or "outsiders." Furthermore, even among immigrants who are underrepresented minorities in their host countries, their minority status does not in and of itself imply challenges for school achievement. Research highlighting the *immigrant paradox* is a case in point. This refers to the counterintuitive finding that some immigrants, who are often underrepresented minorities in their host countries, have better psychosocial, school adjustment, and achievement outcomes than their native born peer, especially among first-generation immigrants (Suárez-Orozco & Suárez-Orozco, 2002).

Bhatia (2007) describes the multidimensional nature of the process of being marked as "other"; the variety of markers used (appearance, dress, accent, artifacts, and so on), whether the marking as other is assigned by members of the ethnic majority or by the individuals themselves, and the affective underpinnings of being marked or made visible as a minority. For some ethnic minorities, this process of being marked as different is often not a choice and as Phinney (1996) suggests it reflects experiences associated with one's group status in society. Phinney argues that in the United States, ethnic minority status implies less power and status, and is often coupled with experiences of prejudice and discrimination. These experiences increase the salience of ethnicity in the lives of ethnic minorities. As Cross (2005) describes, ethnicity often gets racialized: "The racial part of the identity is often forged by experiences with discrimination, while the rapprochement with ethnicity is, in part, a reaction to being labeled as racially different" (p. 174). As such, being marked as a member of a racialized group induces a psychological experience fueled by the sociocultural nature of race within the context of the United States, and one's ethnic identification is often a reaction to this racializing experience (Pufall-Jones, 2011). These circumstances that heighten minority status must be dealt with and families create adaptive processes and practices in response. Familial socialization processes, such as racial and ethnic socialization, are family-level responses to prepare children for the experience of minority status, and the experience of discrimination and racism (or the potential for facing discrimination). These adaptive processes are typically targeted to strengthen culturally based affiliations and identities that can buffer the negative aspects of the minority experience while also serving as resources to support academic achievement.

The critical question here is: How does context matter in understanding how familial socialization and self-system processes come into play in the development of ethnic minority children and adolescents? Rather than conceptualizing context as having a direct impact on outcomes of identity development processes, the assumption is that individuals respond to specific aspects of contexts, and that the relation between contextual-level constructs and familial- as well as individual-level processes and outcomes, are mediated through interpretative and meaning-making processes through which individuals negotiate and navigate these specific aspects of context (Mistry & Wu, 2010). In light of this, to identify which aspects of sociocultural context must be included in research on ethnic minority status, the critical question is: What features of sociocultural context make ethnic/racial minority status more or less salient? By definition, the primary feature of sociocultural context that is likely to increase salience of minority status is the extent to which one is a minority within immediate social settings (e.g., neighborhoods, schools, peer groups). The assumption is that ethnicity becomes salient for individuals who are underrepresented in their social contexts, when they have to interact with individuals from the ethnic majority in their day to day lives. However, representing the diversity or heterogeneity of community settings is an important specification of context that has been largely neglected in developmental psychologists (Goodnow, 2010). In addition to diversity of settings, societal-level racism and discrimination is another critical aspect of sociocultural context because an individual's experience of being of minority status becomes more salient in contexts where he or she is likely to experience discrimination and prejudice.

The line of reasoning thus far begs the question: Why is the salience of minority status within communities of relevance to the development of children from ethnic and racial minorities? Some have begun to specify how contextual characteristics intersect with the dynamic socialization and ethnic identity processes that have been documented as crucial for some, if not all, ethnic minority children (Byrd & Chavous, 2009; Cooper & Davis, 2005; Syed et al., 2011). For example, the need for identity processes to serve as a buffer against prejudice and stereotyping experiences may be exacerbated or attenuated depending on the extent to which ethnic minority status is salient in the context of the diversity of neighborhoods and schools. In a similar vein, the extent to which ethnic minority children experience a sense of belonging to school or display achievement motivation can also be exacerbated or attenuated depending on the prevailing sentiment of larger society or community groups. In the literature on African American achievement motivation processes, Smalls, White, Chavous, and Sellers (2007) describe how the "racial identity-as-promotive" conceptual perspective is rooted in the larger context of the community's context and history. They claim that within the African American community, the focus on promoting a racial identity consonant with high engagement and effort in school is situated in and emerges from this community's historical context of being denied opportunities for educational and occupational mobility due to race.

Ethnic and racial diversity of neighborhoods and school settings also becomes implicated in terms of the opportunities or constraints it creates for inter- and intraracial contact and friendships: These contacts and friendships can promote a sense of belonging to the school, or through access to social support and mentors can provide the instrumental guidance, and ethnic identity support that facilitates motivation, effort, and academic behaviors (Syed et al., 2011). Finally, school settings as institutional contexts also create their own set of opportunities and constraints that have to be navigated and oftentimes negotiated to prevent them from becoming barriers to academic success. For example, barriers to specific programs, or institutional processes such as tracking, can limit options for underrepresented minority students and therefore become challenging environments that these students must negotiate. In a similar vein, institutionalized processes whereby ethnic categories are imposed on children in specific programs (e.g., bilingual programs) can create attributions and category assignments that become constraining (Cooper & Davis, 2005).

Although there have been calls for research to examine how community/school constructs and familial socialization processes intersect in their impact on child/youth identity and academic achievement (Mistry, Contreras, & Pufall-Jones, 2013), such studies are complex and difficult to conduct. Despite this, there is emerging research that has examined how neighborhood and school settings moderate the relations among racial/ethnic socialization, self-system processes, and academic achievement. Perhaps the most complex, yet conceptually coherent studies of how community context, familial socialization, self-system processes, intersect in generating varying pathways to academic success, have been those that have been conducted over extended periods of time, have used mixed methods, and have been theoretically driven. García Coll and Marks (2009) study of the children of three immigrant communities illustrates such a conceptually driven, comprehensive approach. The researchers' primary objectives were to understand the processes underlying academic pathways and outcomes among children from three immigrant communities (Cambodian, Portuguese, and Dominicans) in a city in the northeast. Using a mixed methods approach, the researchers gathered extensive data on the multiple contexts that the children inhabited (community, school, and familial). For each of these contexts, the researchers used multiple data collection methods (e.g., publicly available data, participant interviews and questionnaires, and data collected through ethnographic methods); and multiple data sources (children, parents, community members, school personnel). Although the complexity and nuances of the findings cannot be adequately summarized here, a contribution of the study is that the researchers first used theory-predicated analyses within each immigrant group before they examined similarities and differences in patterns across groups. Furthermore, the comparisons across groups revealed the complex and nuanced nature of how immigrant, school, and family contexts matter in whether and how ethnic identity and acculturation are important factors in the academic achievement of children. For example, the researchers noted the similarities between the Cambodian and Dominican groups, in that ethnic identity components such as pride and centrality were significant predictors of academic achievement. However, the ways and contexts in which ethnic identity related to academic achievement varied greatly between the two groups (p. 170).

CONCLUSIONS

The primary focus of this chapter has been to highlight important advances in both concepts and methods toward the integration of culture and human development. In extending prior syntheses of emergent convergences across varying disciplinary perspectives (Mistry, 2013; Mistry et al., 2012; Mistry & Saraswathi, 2003), here the parallels between sociohistoric-cultural perspectives and relational development science perspectives are brought to the fore. In particular, we call attention to four key convergences: (1) the relation of person and culture as embodied or mutually constitutive, (2) the integration of meaning making as part of context, (3) action and epigenesis as the source and process of developmental change, and (4) the simultaneous focus on both idiographic and nomothetic levels of analysis.

Discussions of the mutually constitutive or integrative nature of individual development and culture or context were occurring concurrently, more than two decades ago, among sociohistoric-cultural theorists (e.g., Cole, 1996; Rogoff, 1998); developmental scientists (e.g., Overton, 1997), and cognitive scientists (e.g., Rowlands, 1999). The inseparability of person and context, elaboration of mutually constitutive relations, and embodied action as a valuable heuristic are particularly promising convergences of perspectives toward the integration of person and culture. The second key convergence is the critical notion of culture as a meaning-making and interpretive process. This is articulated in Overton's (2008) construct of embodiment in which the projection of person-centered meanings on the objective environmental world and the corrective feedback from that world creates *lived* experience. Scholars oriented toward cultural perspectives have similarly been arguing that individual behavior is mediated through culture as the meaning systems, symbols, and practices through which people interpret the world (e.g., Rogoff, 2003; Shweder et al., 2006). The integrative focus on the both the environment as context, as well as the meaning-making processes through which people interpret context, thus represents a significant convergence in integrating person and culture.

The third key convergence among relational developmental scientists and scholars taking a cultural perspective is reflected in the shift from focusing on cultural variations in developmental domains to a focus on culture as the interpretive and meaning-making processes that individuals utilize in the process of acting in, with, and on their environments. The critical significance of this shift is that in addition to clarifying culture as the interpretive processes through which we understand context, *this process of acting in, with, and on the environment through culturally interpreted meanings itself represents the developmental process*. Thus, in both cultural and developmental science perspectives, culturally constructed or derived meanings are considered integral or constitutive features of action, and thereby integral in the developmental process itself (Brandtstädter, 2006; Cole, 2006; Overton, 2006; Rogoff, 2003). In fact, the process of epigenesis whereby individual action is constructed, interpreted, and adjusted in a dynamic co-constructive and relational to-and-fro system between the person and interpreted context is the microscopic process of development.

The fourth key convergence is represented in the conceptualization of regularities in variation that emerge from synthesis of cross-cultural research (Rogoff, 2003) and the "commonality at a latent-variable level" as described by Molenaar and Nesselroade (see Chapter 17, this *Handbook*, this volume). In differentiating between manifest and latent levels of variation, Molenaar and Nesselroade explain how commonalities across a range of variability can be discerned by a second-level analysis, which in effect yields latent variables that cluster into groups patterns with comparable systematicity. The significance of this conceptual convergence between the notion of regularities in variation (Rogoff, 2003) and the nomothetic analysis through which quantitative methodologists working from a relational developmental systems perspective derive second-order latent commonalities cannot be overemphasized. The convergence not only highlights the promise of conceptual integration of perspectives, it also paves the way for recognizing the complementarity of different methodological paradigms. The difference between developmental methodologists and cultural psychologists may be in terms of their focus on different levels of analysis (i.e., the level of the single individual in a developmental study or the level of the single group living at a particular time and place). Nevertheless, both scientific groups recognize that despite the need for idiographic analysis that respects the features of the single person or the specific group, more nomothetic analysis is also possible through quantitative methods (e.g., the IF presented by Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume), qualitative methods (e.g., using Rogoff's frame of searching for regularities across variations) and mixed models (e.g., Tolan & Deutsch, Chapter 19, this *Handbook*, this volume).

The convergences highlighted in this chapter can pave the way for developing theories of human development that are culturally inclusive and relevant globally. The need for such a global orientation stems from the state of science and technology that situates us in an interconnected world bringing diverse people together on scientific, economic, and social fronts. In this climate of interconnectivity and coexistence of diverse peoples, we call for greater dialogue and discourse as a critical process for the development of culturally inclusive theories and knowledge of human development. Hopefully, the emerging convergences delineated in this chapter will promote the dialogue that can promote integration and synthesis of perspectives.

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CHAPTER 11

Emotional Development and Consciousness

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This chapter is about the development of emotional life and the importance of the rise of consciousness in children's emotional development, for any theory in which the term *feeling* can be used requires us to consider the meaning of consciousness. Here I try to be quite specific in what I mean by the use of the terms *emotion, feeling*, and *consciousness*, appreciating that although consciousness is central to any theory of development, its meaning and measurement is elusive. Thus, I try to make clear how I approach these problems.

Consciousness is a fundamental problem in development, especially theories of development that have *constructivism* as one of its central tenets. Any theory of development requires an understanding of the adaptation to the environment—the central proposition offered by Darwin and a central proposition of contemporary relational developmental systems models (Lerner & Overton, 2008)—and thus recognizes the environment as an integral part of how development occurs. However, for the human organism, development entails active reciprocal bidirectional (←→) coactions among biological and environmental systems, which underlie the child's growing emotional life as well as his or her knowledge of the world. The self-system, which emerges from the coactions includes the child's knowledge of itself as well as others and things. It is the growth of knowledge about the self that not only gives rise to emotional life, but is the beginning of mentalism. Historically, the understanding of this dual knowledge of the self and other was the basis of the early work on social cognition (Chandler, 1978; Lewis, 1980, 1983).

In the next section of this chapter I take up more specifically the topic of emotional development. The theory of emotional development, which is presented in more detail elsewhere (Lewis, 2014), utilizes what I have called, after Darwin, *emotional action patterns*, often what are called the early or basic emotions. These early action patterns, evolutionarily derived, are themselves transformed by the development of consciousness. However, when I state "evolutionarily derived" it is implied that evolutionarily derived is not itself independent of the coactions throughout early epigenesis of the fetus's coactions of these tendencies with environments. This view requires acceptance of the idea that biological processes are a form of information that requires coaction with other processes and with the environment of the developing child (see Jablonka & Lamb, 2005; Johanson & Edey, 1981; Levins & Lewontin, 1980). The model of development occupies the central focus of this section.

GENERAL ISSUES IN THE STUDY OF EMOTION AND CONSCIOUSNESS

Some general considerations are helpful in setting the stage for what is to follow. First, I state an explicit definition: An emotion is made up of thoughts about our evolutionarily derived *action patterns* that occur in the context of particular events in the physical-social world. Emotions become shaped during development by the coactions of the child's social niche and the child's temperament. This definition includes the term *thoughts about*. The consideration of *thoughts about* leads to another major theme in the theory of development found here. *Thoughts about* itself has a developmental course and the most important feature of human emotional development involves the emergence of thinking about the self as measured by self-referential behavior. This development of self-referential behavior, which is a measure of *thoughts about self*, I call *consciousness*. Although some have used *self-consciousness*, I argue that self-consciousness is redundant because consciousness is always about the self. Thus, it is not any thought about action patterns-in-context that are emotions, but thoughts about the self as distinguished from the object.

The second feature of the definition of emotion is the *action patterns-in-context* (action pattern ←→ context). As I try to show, the human infant, at birth and soon after, exhibits highly specific actions in the world, these actions, in coaction with particular features of the physical-social world are necessary for survival and have evolved. An essential feature here is that these action patterns are open to the influences of the infant's social niche.

Emotions are real stuff; they exist in our actions and the units of language (Barrett, 2012). We think about thinking and we think about emotions. But what is it that is meant when using the term *emotions?* The infant does not possess symbolic thought or language and, hence, how can they have what have been termed *primary emotions*: anger, contempt, fear, disgust, happiness, sadness, and surprise? These are action patterns that engage the child's social and object worlds, shape these worlds, and are shaped by them. Not until the child has the capacity to have thoughts about itself do these action patterns become emotions. Such a definition of emotion was made popular at the turn of the 20th century by William James in his classic work on psychology. This dual meaning of emotion fits with both bodily sensations, or what I call *action patterns*, as well as ideas about ourselves. Our emotions are created out of how we think: I am proud when I am able to help someone by giving them money and I am disgusted and outraged by the random killings of innocent civilians in ethnic strife. Thus, beside action patterns, emotions require the ability to think about one's self.

The task in studying emotional development is not only to find ways to observe action patterns-in-context and to measure them, but of equal importance, to study children's thoughts about themselves. Darwin, in his classic book, *The Expression of the Emotions in Man and Animals* (Darwin, 1872), suggests this definition as he saw these action patterns as having external as well as internal states that he found in the expressions in the face, voice, and posture of humans and beasts. In everyday life we seem to accept this belief that facial expressions and emotion are likely to go together. When someone cries at a funeral, we tend to assume that they are sad. Yet, we humans are more complex and are capable of masking our behavior; we sometimes laugh at a joke we do not really think funny because we do not want to hurt the joke teller's feelings. Deception of facial and bodily expressions is as real a feature of emotional life as are expressions that reflect what we are really thinking. Although internal changes as part of action patterns may exist, the history of them over the past 100 years reveals that we have not been able to measure them well (Bard, 1934; Cannon, 1927; Lewis, 2011). This lack of measurement has led to the belief that there are no physiological components to action patterns and that all there is are only thoughts (Ortony, Clore, & Collins, 1988). It is argued that action patterns and thoughts are both necessary for the emotional life of humans and that development involves both.

In the theory of development to be presented, Darwin's examination of action patterns as shared by many animals, including humans, is utilized. However, these biological systems—which themselves function and develop according to processes of *probabilistic epigenesis* (Gottlieb, 1997; Gottlieb, Wahlsten, & Lickliter, 2006; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume;

Overton, Chapter 2, this *Handbook*, this volume)—coact with consciousness in specific cultures and only for humans. Consider the example we call sadness. Sad behavior over loss seems likely evolutionarily derived or readily learned. However, to feel sad means that we have awareness of—at the level of thinking about—this action pattern-in-context. It is likely, however, that one child may have more sadness than another as a function of his or her temperament and/or environmental coactions, which lead to differences in the strength of the action pattern and ultimately to individual differences between children in how sad they feel.

The problem of the nature of an emotion also makes its study that much harder. For example, do children have the same emotions as adults? Does Maron's sadness over his mother leaving him at the babysitter's represent the same sadness of Maron's mother when she leaves? The same question can be asked for adults. For example, when I say I am fearful of a hornet stinging me while I sit on my porch, do I mean that I have the same emotion as when I say I am fearful that there is someone following me down a dark street? Is fear in one situation the same as fear in another? These questions lead to my belief that my experiences of myself and my interpretation of events, as well as my action patterns, are only loosely related and that the same action pattern may be experienced differently depending on my interpretations and my experiences of myself. I assume that our consciousness, thoughts about our action patterns-in-context, is not the same as the action patterns themselves. Thus, my experience of my fear is likely to be different as a function of the context in which it occurs.

I argue that emotional life is made up of a set of three features. The first is emotional *affordances* (i.e., opportunities for action; see Gibson, 1979; Good, 2007; Overton, Chapter 2, this *Handbook*, this volume; Sanders, 1999), which some have called elicitors—events in the world. The second feature is the action patterns including expression that have evolved and that are located somewhere in the body. The third is the ability of the child to experience or be aware of its action patterns, or consciousness. By dividing the term emotion into these features, my belief is that using these different terms may make more sense out of the development of emotional life. Consider the following example:

I am driving along the highway at 60 miles an hour when suddenly my left front tire blows out. For the next 30 seconds, my attention is directed toward bringing the car to a safe stop at the side of the road as I am attending to the movement of the wheel, the sound of the tire, the cars going past me, all of which capture and maintain my attention. It is an outwardly directed attention. Having successfully reached the side of the road, brought the car to a safe stop, and turned off the ignition, I start to attend to myself and notice that I am shaking and my heart is racing, and at this moment I experience (or feel) what I label as fear because it fits my knowledge about this action pattern-in-context. It is likely that this action pattern existed earlier, and if we had electrodes we could probe those parts of the body likely to be markers. However, it was not to my adaptive advantage to pay attention inward to myself, for my attention was needed elsewhere in order to safely bring the car to a stop. Although I was likely showing a specific action pattern, and may have even shown a fear face, I certainly was not experiencing myself as fearful until the car was safely brought to rest. This example raises a number of issues that will lead to strong disagreement unless we can come to terms with the problems to follow. Simply stated, the problems involved are the meaning of the terms *experiences* and *feelings*. They can be both bodily experiences and feelings or ideas about myself. Bodily experiences exist in humans, animals, and even infants. Ideas about myself develop and are likely seen only in older humans, not infants nor animals. We all use the term *feeling* in describing our emotions. I can say to you that I am feeling fearful and because of both our common language and because of *mentalism*, that is, my knowledge that you and I share internal states such as thoughts, desires, motives, and the like, that you can find in you what I say I am feeling. In fact, others' feelings of fearfulness may make me feel fearful. But what then does feeling fearful mean? The terms feelings, thoughts about myself, or experience of me, and consciousness all speak to the process which asserts something about me, but are likely to mean different things about myself.

What Kind of a Thing Is an Emotion?

To begin with, there is probably no advantage in using the common term *emotion* because the term has a surfeit of meanings. Arguments are bound to ensue when we do not carefully articulate what we are referring to. The debate that occurred between Zajonc and Lazarus in the 1980s might not have taken place had they not appreciated that while one was referring to action patterns, the other was referring to cognitive evaluation (Lazarus, 1982; Zajonc, 1980). In *Children's Emotions and Moods* (Lewis & Michalson, 1983), we deconstructed the term emotion into several of its component parts such as affordance contexts or elicitors, action patterns including expressions, and experience (see also Frijda, 1986).

Thus, *action patterns* are evolutionarily derived acts in the sense that they find their roots in evolutionary processes and develop in accordance with processes of probabilistic epigenesis (Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume). Action patterns are adaptive behaviors designed for action in the context of specific environmental events or contexts, these events I call *affordances* or *affordance contexts*, which, as stated earlier, refer to opportunities for action. Although in earlier works (Lewis, 1992a) these have been referred to as *elicitors*, affordance and affordance context is more appropriate in that we study living organisms that are inherently active self-organizing systems (Lewis, 2010; Overton, 2010, Chapter 2, this *Handbook*, this volume), and, thus, do not *react to*, but *act in* the context of *external factors*. Because evolutionarily derived actions in the context of an affordance are inherently relatively plastic (see Bateson, Chapter 6, this *Handbook*, this volume; Johanson & Edey, 1981; Lerner, 1984, 2006; Overton, 2010, Chapter 2, this *Handbook*, this volume, for extended discussions of human plasticity), they are open to individual differences in children's temperaments, their concurrent environmental conditions, and the cultural rules we call social. Because of this inherent flexibility, the difficulties in finding a close association between an affordance and an action pattern should not be taken to negate the assumption that such evolutionarily derived actions exist given the large amount of evidence for these patterns of action (see Lewis, 2014, for details).

In addition to this inherent flexibility, two other difficulties exist that make the association between a context and action pattern even more difficult to observe. The first has to do with the nature of the context itself. For the most part the affordances used in emotional research in infants to date are likely to be made up of multiple features. For example, holding down an infant's arms and restraining them is made up of multiple contexts including sudden movement toward the child, physical contact, smiling, and unexplained action which is not in keeping with the preceding events. Because multiple contexts are involved, the association between them and a single action pattern is difficult to observe. One solution to this problem might be to select very carefully the affordances to be presented. In our work, to be described later, the use of the affordance context, which is the blockage of a learned response to a desired goal, can be used to study anger, because from Darwin on it has been argued that such a blockage should elicit anger, which is just what we observed in infants as young as 2 months old (Harmon-Jones, 2003; Lewis, Alessandri, & Sullivan, 1990). When careful choices of affordance contexts are made we are more likely to find greater association between them and specific action patterns.

However, another issue that is likely to prevent our ability to closely examine evolutionarily derived actions to particular events is the real possibility that multiple action patterns, even in a specific context, are more likely the rule than single ones. At least our adult sense suggests that at the funeral of a friend we may likely experience both sadness and fear, or at the wedding of a daughter, both joy and sadness (Lewis & Michalson, 1983; see, e.g., Larsen, McGraw, & Cacioppo, 2001, for a similar finding). The nature of emotional life may be made up of a fugue, the flow of action patterns and thoughts entwined so that multiple emotions rather than *an* emotion may be what our lives are made up of. It is only when we try to study them in the laboratory that we break the flow apart.

However, if we reject the idea of an evolutionarily derived and prenatally adapted action in a specific context, we are left with the unanswered question of how action patterns including facial and bodily expressions as well as physiological responses are organized. The idea that they are socialized or that they are learned—these complex coherences—is difficult to imagine and there is no direct evidential support that they are acquired in this way. It is only the difficulty in finding specificity between facial expression and contexts that moves us toward accepting the postnatally acquired theoretical viewpoint. At the moment, we need to accept that action patterns such as fear, joy, and sadness, and so on, are an evolutionarily derived part of the human condition although these action patterns are inherently flexible. Like language acquisition, the structure or procedural rules are available at birth but are so plastic so as to be open to the pressures of the infant's coactions with its environment.

In speaking of consciousness we must also be aware that consciousness itself develops. If we consider consciousness by levels, then following Damasio (1999) we can think of the very early level of consciousness as core *consciousness*, which is marked by an attention to external objects, which is focused and extended, and spontaneous behavior that has a purposeful quality to it. I think of this as action patterns similar to what James, in his interest in attention, refers to as a kind of automatic behavior. For Damasio (1999), core consciousness is followed by *extended consciousness*, which begins as the infant first differentiates itself from external objects. Differentiation of the self from other is a basic biological process even found in T cells, so are not likely extended consciousness, but rather part of the infant's ability to act in its world. For me, the level of consciousness focused on entails the child being able to *think* about himself, *think* about other objects, and *think* about the relations between himself and other objects. This latter level, called *social cognition* by some, I will call *consciousness*, and it is this level that influences emotional life. It is this level that is meant when I say consciousness throughout the chapter. Although the infant cannot utter the words, nor symbolize, nor think "I am feeling happy," caregivers often say that the baby is happy. If the infant could utter the sentence, "I feel happy," it seems that the access to her feeling would be dependent on her ability to know at least that the feeling is hers. It is not the event out there, it is not someone else's, it is private and not known by anyone else unless the child tells them, although if she acts in a certain way in a particular context someone else might guess what her emotion might be. The child's ability to access her bodily states and her thought about herself is dependent on her ability to be able to know about herself; first, that there is a self, a me, and second, some unique combination between her action patterns-in-context and her ability to self-reflect. It is this self-referential ability that is talked about and for which the term *consciousness* is used. Consciousness is not about the *aboutness* of what is accessed, the content, but it is the *process* itself of accessing.

When discussing the idea of consciousness, we need to keep in mind the confusion with several terms that are used. Feelings and experiences are used and are often assumed to be representations of the level of consciousness that I refer to, that of thinking about the self. Certainly, feeling and experiencing do not have to have the same level as the mental representation of me. Let us examine feeling as an example. Let me suggest that there are two meanings of the term, which reflect two different levels of consciousness. Consider that I am at the dentist's office and he wants to fill a cavity. He gives me a shot of Novocain and after a moment or two he pricks my gums and asks, "Do you *feel* this?"—meaning does it hurt. My answer is that I do not *feel* it. He then begins to perform a procedure. If I had a meter that was capable of measuring pain at the pain receptors in my gum or along the neural pathway from the receptor to some central region, it would register as pain. From a physiological perspective I have pain, but I do not *feel* pain. It does not mean that the body does not experience the pain in some way, nor does it mean that much pain will not have a powerful effect later in life. What it does mean is that I am not conscious of the pain; I do not feel it.

Perhaps another example can be found to make this point that does not involve pain, as some might say that pain is a special case. Here is an example from the research of Gazzaniga (1988). A patient with her corpus callosum severed because of her epileptic attacks is asked to haptically finger a wooden number under a blanket so that she cannot see her fingers move nor see the number, and by raising her fingers, she tells the experimenter what number she felt, a question that she can answer easily by raising several of her fingers, keeping them under the blanket. However, when the experimenter asks her to tell out loud what the number is, she cannot tell him; "I don't know," she says. She clearly knows because she raised her fingers correctly but yet she does not know what it is that she knows. But is this what we mean by consciousness? The phenomenon of blindsightedness is another example of these different levels or consciousness (Weiskrantz, 1986).

Our bodies have a life of their own; they know many things that we, our consciousness, do not know. Our body knows that when we eat too much sugar, that it needs to secrete insulin. This is something known by ourselves, that is our body, but not known by our consciousness. We cannot readily access many things that are happening in us. In all these examples we can see that some part of us, our body, is experiencing something which enables other parts of our body to act. But we, our conscious or self-referential self, does not know of it.

My claim, therefore, is that before we can think about ourselves, before there is self-referential behavior and, therefore, before this level of consciousness, the infant may have or be in a particular state as a consequence of a particular affordance context, however, the infant is not able to think about or experience that state as we adults do. Thus, if we restrict feeling to the body, then we can say a newborn feels pain. But if we mean that the infant can access this bodily state and know that it is her pain, then no. The infant does not have the privilege of the first person, reflected in the statement, "I am in pain." To avoid the problem with the word *feeling,* the terms *self-referential* or *consciousness* to speak not of bodily action, but of ideas about the self, will be used.

The Issue of Consciousness

The issue of consciousness plays an important role in the theory of emotional development that I explore later. I have made much use of the development of consciousness in the theory of emotions and therefore in trying to find ways to measure it. Looking at self-referential measures, such as touching the marked nose, enables us to know that the child knows that the image *there* in the mirror is located *here* in space, the same here in which he stands; this is also demonstrated in self-referential language such as in the use of personal pronouns like me and mine, and in pretend play where the child reveals that she knows that something she is doing is not literal (Lewis & Ramsay, 2004).

When I speak about consciousness I am not making reference to a consciousness that is not conscious because in effect this is what Freud tried to do. I do not see the mental processes as a struggle between the conscious and the unconscious. What then is there that the consciousness struggles against? When I say that I am not going to eat dessert and then I do so, or when I say that I will finish painting the wall but do not do it, what is my conscious desire struggling against? It has for some time been our common belief and a firmly embedded one at that, that there must be something there inside us that is preventing us from doing that which we desire to do. This something we assume to be the unconscious, some kind of wild beast with a will of its own. It would appear that this puzzle has always been with us; the Greeks had a word for it, *akrasia*, and later, it was the devil in Western belief, and now for the past century, it has been the unconscious.

However, if we stop for a moment and think about all the different things we do that we are not conscious of, from solving a problem to rote physical activity, from speaking sentences without knowing what will come next to suddenly remembering, it seems clear that there is something in there, and that something is likely to be sets of processes, habits, and the like. Some who are interested in this problem have called the thing inside *procedural rules*, others *action patterns*, and still others, *instincts* and *innate releasing mechanisms*. This thing or things are not considered unconscious but rather not conscious and will be referred to as *the system of the self*. This system is a highly organized complex evolutionarily adapted set of processes that control both the internal workings of our bodies and much of our commerce with the outside world. It is evolutionarily derived but highly plastic and capable of being influenced in its social and physical worlds.

I believe that when we are not conscious of ourselves we are not unconscious. The interpsychic conflicts we have are between our conscious self and the system of the self, a system that we most of the time have very little knowledge about and until this past century we knew almost nothing about. In fact it is our consciousness that has allowed us to learn about this system. Interestingly we still do not know a great deal about what it is. Is it a modular system made up of many parts, which are organized in some fashion or some highly coactive system in which the activity of the whole system is what determines the outcome. Both of these possibilities—a modular or highly coactive system—find support in the research on the topic. The point to be made here and which I try to do throughout the chapter is that this consciousness exists but is a distributive system, and that once developed, one which when used can be rewarding but at the same time highly disruptive. I do not want to think about myself when I am involved in a task but do want to think about myself to define the task or when the task is completed or when I have failed. I want to think about what I want to do, that is to plan, but during the execution of the plan it is probably better not to think about myself.

So when does this level of consciousness emerge in the human child? To ask this question is to suppose that there is a way to measure consciousness. I have proposed and tried to show that there are measures of something that is close to consciousness, and that is what I have called *self-referential behavior*. The ability to make reference to oneself is about as close to consciousness as I can get and have suggested that it can be measured by self-recognition in mirrors, in the use of personal pronouns, as well as in pretend play. Although not going into the argument here, I spend some time later doing so; however, the coherence between these measures and the subsequent development of the self-conscious emotions such as shame and embarrassment suggest that these self-referential measures are a good approximation of what is meant by consciousness. As discussed later, studies suggest that consciousness develops in the human infant and that somewhere after 15 months of life it can be seen in the self-referential behaviors. The rise of this level of consciousness has a profound effect on the development of a child's emotional life.

People have claimed that consciousness is only an idea and that for other cultures this consciousness either does not occur (Keller et al., 2004) or that it is a collective consciousness (Markus & Kitayama, 1991). However, such an argument has to do with the aboutness of consciousness and that is not what is referred to here. The aboutness is a cultural artifact; however, consciousness, the self-referential ability, is more likely a function of the nature of the embodied human brain (see Marshall, Chapter 7, this *Handbook*, this volume, for an extended discussion of the embodied brain). Shweder (1985) has shown that in some cultures there is a we-self aboutness. However, even in we-self cultures there is no question that when a woman is menstruating and, therefore, considered to be polluted, it is the woman herself that is not touchable. It is not anyone else in her family. Even in we-self cultures the idea of a person bounded and separated from other such selves plays some role.

I suggest that with consciousness the major challenge is to maintain our identity in the face of change. The function of the self-concept is to construct identity; that is, to maintain the idea that all of this is *me*. Sometimes it means adding pieces together, sometimes it requires a separation of parts. Sometimes the elimination of one or more parts and sometime the distortion of parts or even a distortion of the composition of the whole is necessary. All of the thoughts about ourselves are designed to maintain the idea of *me*. The idea of me consists of at least two features; unity, that is, I am one person, and continuity, that is, I am the same person over time and that what happens now will have consequences for me in the future (Lewis, 1997).

Consciousness transforms the human infant because it is the first of the emerging ideas and as such allows for and aids in the transformation of the child's action patterns or procedural rule into mental thoughts, both about itself and through that to thought about others and finally into thoughts that connect the past, the present, and the future. Consciousness is the most powerful of human features, the ability to be both in the present and at the same time to be somewhere else.

The Meaning of Behavior

For some time, I have been thinking about the complexity of the developmental process where the challenge of the meaning of an action over time is a particular problem (Lewis, 1967). This is a serious problem because the equivalence of an actions across age causes all sorts of difficulties. We often observe that a very young infant can perform some action that when performed at an older age would be considered to represent some complex mental state. The example of the newborn imitating the action of another, in particular, a tongue protrusion, on the surface seems no different than a 2-year-old imitating another child's play with a toy. It could be claimed that there is no difference between the two types of imitating and thus give to the newborn all sorts of mental states, or alternatively, which is more likely the case, that the same action can be in the service of different processes.

This problem of equivalence of actions has interacted with the history of the study of infant action over the past 50 years. The studies disproved the belief in the incompetent infant who could not see well, learn easily, or remember, what William James (1890) called a bundle of confusion, to contemporary research, which demonstrates that infants can be shown to have almost limitless capacities, and because of this the infant is often now considered to be more like a scientist in the crib (Gopnik, Meltzoff, & Kuhl, 1999). The number of competencies that now have been demonstrated are quite amazing and seems to reflect the wide range of evolutionarily derived action patterns of which the very young are capable. Although some have recognized that these competencies are not predicated on mental states, others, especially those interested in the infant's commerce with its social world have attributed unrealistic abilities that include such claims as the infant knows its mother and has the concept of itself as a good or bad infant (Legerstee, Ellenbogen, Nienhuis, & Marsh, 2010; Reddy, 2010). I will not dwell on all of the attributes that the 3-month-old infant is given because this is covered later, but make sure that it is understood that the same action can result from many different processes. Some of these early infant actions reflect evolutionarily derived action patterns, while later actions are the result of thoughts. Without this understanding we are readily forced into the conclusion that there is no development at all because the infant can do everything at the beginning of life or soon after. In the study of emotional development we need to understand that the early action patterns are not the result of mental processes, whereas later in development these same action patterns can be the result of mental processes. A sad face in the 4-month-old can be due to a physical-social context such as the cessation of a coaction either with people or while operating on an object, whereas a sad face at 24 months can be due to a thought about the cessation of a coaction not yet begun.

Individual Differences

The emotional life of different children differs for at least two reasons. To understand the development of emotional life requires that we consider these reasons. The two reasons have to do with temperament, which coacts with preadaptive action patterns so that when the infant is older something that might set a condition for joy for one infant might set a condition for fear in another. The second reason has to do with the child's experience in its social and nonsocial world. The diversity of the infant's social and object worlds are a function of the reciprocally bidirectional action of person ←→ context. This context includes the diversity of the immediate family, the diversity of the culture and history. Socialization for some implies a process involving action on a passive child by others who surround him. What is referred to here is a broader idea of an active child and an active world (Lewis, 2010). In many contemporary system approaches this is referred to as the *relational reciprocal bidirectionality* of person ←→ context (Lerner, 2006; Lerner, Lerner, Bowers, & Geldhof, Chapter 16, this *Handbook*, this volume; Overton, 2006, Chapter 2, this *Handbook*, this volume). In our own analysis the findings lent support to the idea that the child is, indeed, both acted on and is acting on (Lewis & Rosenblum, 1974; see Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume, for an extended discussion of a related perspective on socialization). The child participates in the creation of its known world. As suggested by Bronfenbrenner's bioecological systems perspective (Bronfenbrenner & Morris, 2006) the child's active construction occurs in an ever-widening context from family to neighborhoods to communities. The family and family circumstances has a significant impact on other contexts that the child will be exposed to and these will affect the kind, frequency, and intensity of the child's action patterns. Even climate and temperature form a part of the broad ecological context to say nothing of the type of dwelling the infant lives in and the temperature during the day and night (Golder & Macy, 2011; Hannak et al., 2012). When we include the number of people in the child's social nexus we can understand the complexity these have on individual differences.

Now these two factors, temperament and socialization, will have profound impact on individual difference and because they are interactive, they produce large numbers of possible permutations. The factors have an impact on the infant's early emotions and they have an impact on the self-conscious emotions. That we can find any general pattern is surprising because these individual differences make the mean value nonrepresentative of any one child. To say, for example, that the response to blocking an infant's learned responses to a goal is an anger action pattern is to forget that for 10% to 15% of the infants, sadness not anger, is the response, and for others it is a combination of both, or even no reaction.

The possibilities that arise from the coaction of so many varied social events as they coact with temperament differences is so large that, between individuals, there is at best only weak coherences. Individual differences in wariness of the stranger is not correlated with wariness of the visual cliff; the threshold to respond to pain is not correlated with the ability to dampen a response once it occurs (Lewis & Ramsay, 1995; Ramsay & Lewis, 1994). Physiological responses such as heart rate or cortisol release are only weakly correlated with action. Individual differences swamp our findings (see Lewis, 2011).

INTENTION, AGENCY, AND ACTION PATTERNS

To start the discussion on intention, agency, and action patterns, it is necessary to describe in some detail the studies my colleagues and I have conducted (Alessandri, Sullivan, & Lewis, 1990; Lewis et al., 1990; Lewis & Ramsay, 2005; Lewis, Sullivan, & Brooks-Gunn, 1985; Lewis, Sullivan, Ramsay, & Alessandri, 1992; Sullivan & Lewis, 1988, 2003; Sullivan, Lewis, & Alessandri, 1992). We examined how infants learn and what happens when the rules are changed. The basic premise that will underlie this discussion is that *all goal-directed systems are intentional*, but that different *levels* or *types* of intention may be useful in understanding animate, inanimate, phylogenetic, and ontogenetic differences in agency.

The experimental paradigm was intended to examine whether young infants could learn a simple task and, once they had learned the task, what would happen when the rules changed. Because the learning consisted of pulling a string to obtain a reward, their motor actions were observed to assess learning. In addition, their faces were continuously monitored to measure their emotional expression. A simple operant-conditioning task was used. A string connected to a Velcro wristcuff activated a microswitch. A pulling movement of the string triggered a brief presentation of a color slide showing an infant's smiling face, accompanied by a recording of children's voices singing the *Sesame Street* theme song. Arm-pulling responses were recorded and each child was videotaped.

Each experimental session included a 2-minute baseline during which we were able to determine the baseline or ongoing rate of arm movement for each child. Infants then received a learning phase of contingent stimulation in which the audiovisual stimuli were activated by each arm pull. All infants learned the task within the first 3 to 4 minutes. When learning was achieved, a 2-minute extinction phase occurred where the arm pull did not result in an outcome. This was followed by a second 3-minute control phase where the learned response could again produce an effect.

Rates of arm pulling throughout the session were computed as the total number of arm pulls per minute.

Facial movements were coded from videotapes of the infants using the Maximally Discriminative Facial Movement Coding System (MAX; Izard, 1979). Coders sampled the videotape segments of each infant using a frame-by-frame analysis of the videotape for each of three facial regions: brows, eyes, and mouth. After coding each component, facial expressions were identified by MAX formulas and their frequency tabulated for each minute of the session. Described here in detail are mostly three, joy, anger, and sadness, which could be coded with more than 90% agreement between judges.

At each age (2, 4, 6, and 8 months), infants were assigned to an experimental and yoked-control condition. The experimental subjects' arm pulls resulted in the event occurring, whereas the control subjects received the same amount of the event as did the experimental subjects, but it was not related to their arm-pull behavior. For them, there was no possibility of associating a cause and effect (see Lewis et al., 1990).

Look first at the arm-pull data for each age group (see Figure 11.1). Notice that control subjects showed no change from the base period to the learning, extinction, and second-learning phases. Not so for the experimental subjects: To begin with, the infants who could cause the event to go on significantly increased their arm-pull behavior. Of particular interest are the subjects' responses once the association between arm pull and event ceased to work (extinction). Notice that when the arm pull no longer caused the event, arm-pulling behavior significantly increased rather than declined over the period of disassociation. In fact, in this study, during the disassociation phase, there was about a 150% increase in arm pulling over the learning phase and more than a 350% increase over the base phase. Once the extinction phase was over, the infants returned to the rate of arm pulling they showed during the first learning phase. These differences were all highly significant. Now let us turn to the emotional acts.

There was little joy during the base phase and no change for the control subjects (see Figure 11.2). The subjects who learned showed increases in joy during the initial learning phase, a decline during extinction, and renewed joy once the second learning phase began. Angry expressions follow a reverse pattern (see Figure 11.3). There is little anger during the base or during the initial learning phase. Anger increased markedly once the association between action and outcome was broken and declined as rapidly once the second learning phase began.

Age effects reveal that 2-month-olds behave in the same manner as do 8-month-olds. Notice that arm-pull action patterns do not vary by age. Although arm-pull rates, over all phases, are greater the older the infant, there are no interactions between age and phase. In other words, 2-month-olds show proportionally the same increases as

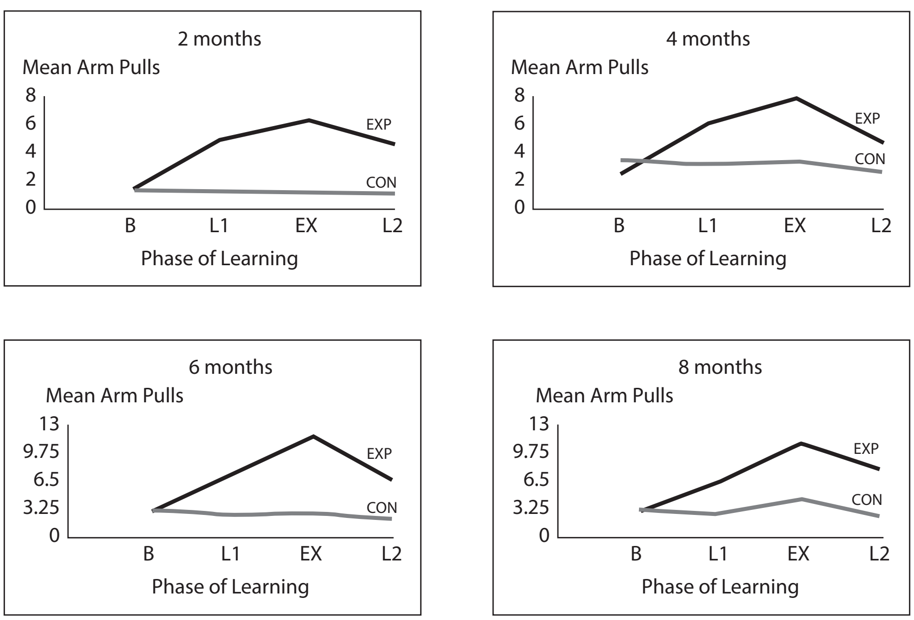

Figure 11.1 Arm pulling by condition as a function of age.

Source: Adapted from data in "Violation of Expectancy, Loss of Control, and Anger Expressions in Young Infants," by M. Lewis, S. Alessandri, and M. W. Sullivan, 1990, *Developmental Psychology*, *26*(5), pp. 745–751.

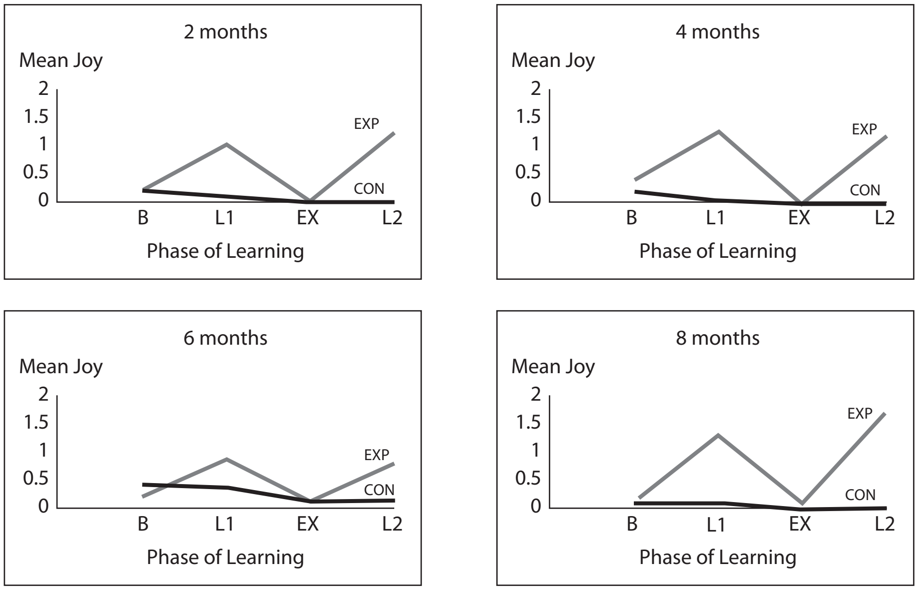

Figure 11.2 Facial expression of joy by condition as a function of age.

Source: Adapted from data in "Violation of Expectancy, Loss of Control, and Anger Expressions in Young Infants," by M. Lewis, S. Alessandri, and M. W. Sullivan, 1990, *Developmental Psychology*, *26*(5), pp. 745–751.

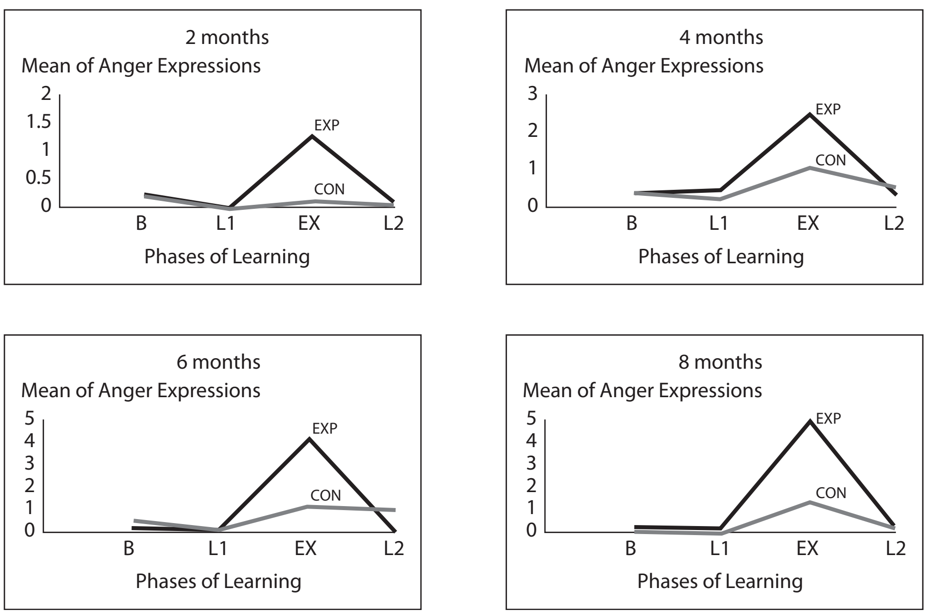

Figure 11.3 Facial expression of anger by condition as a function of age.

Source: Adapted from data in "Violation of Expectancy, Loss of Control, and Anger Expressions in Young Infants," by M. Lewis, S. Alessandri, and M. W. Sullivan, 1990, *Developmental Psychology*, *26*(5), pp. 745–751.

the oldest infants (344% for 2-month-olds and 393% for 8-month-olds from base rate to extinction).

The emotional data reveal the same findings. Again, overall amount of expression demonstrated increases with age but there are no age by phase interactions. Thus, even for 2-month-olds, the construction of an association between an action and outcome is accompanied by increases in positive affect, and the disassociation between them results in the appearance of anger which declines once the association is restored. It should be pointed out that the original design called for a second disassociation (extinction) and a third association (learning) phase, but too few subjects were able to finish all seven parts. The 40% that did, showed an increase in arm pull and anger and a decrease in joy during the second disassociation, and increase in joy and decrease in anger and arm pull once the association was restored.

It is also important to note that there was a significant relation between arm-pull rate during the disassociation and angry faces. One more finding is necessary before asking what this all means. We measured the activity in each of the child's arms and found that although movement in both was present to begin with, during the learning of the association only the arm or hand pulling the string increased in activity; the hand not pulling, decreased. More important, when arm-pull rate increased as the angry face appeared, it was only in the arm associated with the response. The response to the disassociation, even in the 8-week-olds, was not a generalized activation, but a highly specific response to a learned association.

Let me try to summarize the results of these observations. To observe how children in the first year of life learn, and what they do when what they have learned changes, we created a situation where an arm pull resulted in some unusual event. I say unusual because from our perspective we have no reason to believe that the child, prior to our manipulation, has ever experienced an association between an arm pull and the appearance of pictures and sounds. Certainly it is possible that the children, in their cribs, learned that moving their arms produced some effect such as the shaking of the mobile above them, but pictures and sounds, are unlikely.

Regardless of whether it was an unusual association, the children, even as young as 8 weeks, demonstrated that they could learn, and learn quickly, that the arm movement would increase the occurrence of this event. Moreover, as they learned this response they showed an interested face as well as joy and surprise. All infants regardless of age learned this association. We cannot tell if they wished to learn this response, because we made the connection or association for them by our electronic/mechanical contraption. However, once attached to it, they did appear interested and happy when they made it work.

Piaget (1952/1936) would argue that they neither desired nor were interested in engaging in this task. Once in the situation, the infant continued in it because the event (our outcome of face and voice) led to its continuation. It was not the child who desired but the outcome that controlled their action. This is how Piaget avoided imparting to the 8-week-old the mental property of intentionality. Having learned this association between arm pull and the event, the event suddenly stopped. The arm pull no longer resulted in the onset of the visual stimulus. The infants' joy disappeared, they became angry; however, 10% to 15% of the infants showed sadness instead. Notice now what occurred. The response that led to the event did not work and so infants increased their response level and at the same time appeared mostly angry. Moreover, we know the increased effort to produce the effect and the angry face are related to the disassociation between action and outcome because *as soon as* the association is restored, the anger disappears, arm-pull frequency declines to the original learned level, and the joy response returns. These children, even the 8-week-olds, appear to be angry when they do not get what they expect to get. Moreover, like the angry adults who bang the soda machine when they lose their change, because it did not work, the increased action directed at causing the event disappears once the event returns. We also measured the activity of the arm not attached to the string. This arm did not show an increase in arm pulling as a result of the frustration. Because of this, it is difficult to argue that the increase in arm pull was part of a general response.

Let me try to apply a simple associational or learning perspective. From such a mechanistic view, the positive reinforcement of *A* (the arm pull) with *B* (the picture and sound) should result in an increase in the rate of *A*. So far, so good. Now, the reinforcement stops. One might expect *A* to stop if it was controlled by *B*. *A* continues and we explain this continuance as a habit, or something learned. Exactly what this habit is, is unclear; nevertheless, we can assume that it is some altered structure in the infant. Thus *A* should continue, and we assume that if there was no further reward, *A* would eventually decrease its frequency, at least back to the level we saw at the beginning of the study. But *A* does not decrease in the absence of *B*. Quite to the contrary, *A* increases in the absence of *B*. Now this becomes more difficult to explain by simple associative learning because a habit learned may continue but not likely increase. In fact, it is necessary to now introduce a new construct, namely, the increase in *A* is due to the absence of *B*. This increase we call *frustration/anger* and claim that once the association is made between *A* and *B*, the elimination of *B* produces in the infant a new structure that calls forth a new response. But now the notion of a simple habit has broken down and we need far too many additional structures to support a simple associative model. Even here in this simple model, we run into trouble because even associative models of this kind involve cognition and, possibly some kind of intention (Rescorla, 1987).

Circular reactions, as we would expect at this age, are also like habits. There is no mentalism here. Piaget and Inhelder (1969) stated that, at Stage 2,

> An elementary "habit" is based on a general sensorimotor scheme within which there is not yet, from the subjects' point of view, any differentiation between means and ends. The end in question is attained only by a necessary succession of movements which lead to it, without one's being able to distinguish either an end pursued from the start or means chosen from among various possible schemes. (p. 9)

We recognize that in Stage 3 or even Stage 4, a child who has learned an association between a particular means and end will continue that means in the absence of the ends. So, for example, the 10-month-old child returns to search for the object once found in location *X* even when the object is no longer to be found in that location but is seen moving to location *Y*. By Stage 5, this is no longer the case; however, our 2-month-olds are not in Stage 4 or 5, so we remain perplexed as to why by 2 months such association continues. Even more puzzling is why in the absence of the end (*B* event), the response increases.

Perhaps the movement from circular reflexes to intentions begins earlier or occurs more rapidly than has been thought. Perhaps they can be observed provided we construct the appropriate experimental conditions. Such a view allows for the maintenance of the sensorimotor sequence, as discussed by Piaget, but requires that we change the timing of these emerging skills. Thus, the acts of these 2-month-olds is not only centered on their own bodies, but involves attempts to produce environmental actions, and so are secondary circular reactions. The effect of this interpretation is to reduce the model Piaget offers to a single one in which intentions appear from the beginning. This also has the effect of either restricting any developmental sequence to a brief period—the first 2 months of life—or to promoting a nativistic view.

An Intentional Stance

It seems obvious that my very description of what happens in this experiment assumes an interpretive and therefore a particular stance (see Hirsch, 1967; Overton, 2006). Given that I assume a particular stance—following Brentano (1973)—let me restate it explicitly: *All goal-directed systems are intentional*. How these goal-directed systems differ depends on the process underlying the goals. Although some goals contain both affective and knowledge states (or knowledge systems; see Newell, 1982), and some even the addition of consciousness (see Duval & Wicklund, 1972), others, the action patterns are determined by evolutionary and prenatal adaptive processes, which occur to specific affordance contexts in the physical-social world. Further, the very term *act* implies intention, and it is this intention that differentiates acts and action from behavior (Overton, 2010, Chapter 2, this *Handbook*, this volume).

Such a propositional system of intention, if developed, enables us to deal with such diverse questions as "Does a T-cell have intention when it moves after a foreign protein?" "Does a leaf have intention when it moves toward the sun?" "Does an 8-week-old intend to pull the string?" or "intend to try to get the lost objects back?" "Do adults intend to go to work each day?" In each case, the answer to the question is yes, and we need to see how it might be the case.

What is meant when I say that an infant, child, or adult has intention? To understand this problem we need to resort to a levels-of-meaning analysis. Human organisms may achieve a level different from animals and within the human organism levels may differ as a function of ontogeny. A levels analysis has been explored by Fischer (1980; Mascolo & Fischer, 2010, Chapter 4, this *Handbook*, this volume) and Mounoud (1976), and I borrow from their analysis. It may be the case that different levels require different degrees of ability. The lowest level of an ability requires no mental representations for its emergence or, in fact, may exist at or prior to birth. Within the organism, higher levels of skill may require more coaction with the physical-social world. Such a view of levels allows for both a nativistic and culture-influenced world view. It may be the case that, across organisms, the same level of an ability may be achieved through different means. As such, one should be wary of concluding that similar abilities across species have similar histories. Werner (1948) considered this problem in his analysis of the equivalence of actions and called this the "constancy fallacy."

This level-of-ability approach of intention touches on an issue that remains a problem in development, which has been touched on earlier; the notion of equivalence of actions across age. One can often observe that a very young infant can perform some action that, when performed at an older age, would be considered to represent some underlying complex structure. Take, for example, the problem of imitation. Imitation is particularly important because the establishment of a true imitative response heralds the development of an understanding of self (Baldwin, 1903/1894). The newborn infant will imitate certain body movements. For example, a tongue protrusion by an adult will produce a tongue protrusion in the infant (Meltzoff & Moore, 1977). Other forms of imitative action have been reported (Field, Woodson, Greenberg, & Cohen, 1982). Although there may be some question as to the reliability of this action (Anisfeld, 1991), such actions have been called *imitation*.

Imitation has a particular meaning, usually inferring some intention on the part of the imitator (Piaget, 1954). The finding that matching behavior exists in the newborn constitutes a challenge for developmental theory. I could claim intentional action like that in the adult in the newborn. However, this is a nativistic explanation implying no development. Alternatively, the same action can be said to have different meanings. We can say that the action at Time 1 is called *X*, whereas at Time 2 it is called *Y*. This solution has the effect of saying that action *Y*, the more mature action, does not exist until Time 2. Thus, for example, imitation in the newborn is called *matching behavior*, whereas in the 8-month-old, it is called *imitation* (Jacobson, 1979). It is much like a stage-theory notion because action *X* at Time 1 is not *Y*, and it is not *Y*-like.

Another way of handling this problem of the meaning of action is to consider that both *X* and *Y* are functionally similar but that they represent different levels of meaning. In this case, *X* and *Y* acts could be called the same, recognizing that *X* and *Y* are at different levels. In the imitation example, both acts are called *imitation*, but it is recognized that newborn imitation is at a level different from 24-month-old imitation. This position requires that we consider that a particular ability may have multiple levels. These levels are ordered and may be controlled by different processes. Moreover, the level of the ability may be found *both* as a phylogenetic as well as an ontogenetic function. Thus, from a phylogenetic perspective, a nonhuman animal, a rat, may imitate, but this imitation is at a level different from that achieved by a 2-year-old child. Likewise, from an ontogenetic perspective, newborn humans may imitate, but newborn imitation is not at the same level as that achieved by a 2-year-old. Whether the levels found phylogenetically match those found ontogenetically is unknown, although there is every reason to assume that they do.

Such a view of levels allows for the development of an ability while at the same time allowing for its existence across the entire developmental span. Moreover, this developmental process may be seen both within and across species. The problem of equivalency is especially relevant to the understanding of intention. Because the theory of intention across age requires the assumption of various levels of intention, these will be described in some detail, with particular focus on the last level to emerge. The last level is based on the acquisition of consciousness and therefore touches on the development of the self-system.

Levels of Intention

In every system, there is a hierarchy of knowledge. Even at the lowest level of knowledge, the system has a body of knowledge that includes knowledge of that system's goals. Each system acts using the knowledge at that particular level to attain its particular goals (Newell, 1982). The first type of intention is likely tied to evolutionarily derived but adaptive action patterns, which are tied to particular affordance contexts in the physical-social world (see Darwin, 1872; Searle, 1984). The second type is knowledge-bound connections to goals. These are acquired early as a consequence of the infant's coactions in its world.

This second type of knowledge has at least two levels; one, knowledge-based connections to goals. The second is knowledge of the knowledge. On what basis could such a claim rest? Perhaps on no more than the general claim that a metacognition is not in the same knowledge level as another cognition. Consider the case of memory. A memory of a memory is not of the same class as another memory, because the systems or levels that support it and the material from which it is made may not be the same. Consider the metaphor, often mentioned, that the property of wetness cannot be derived from the properties of oxygen and hydrogen. In the same fashion, consciousness emerged at some point in evolution and in ontogeny, in a way underivable from its constituent parts. Searle (1984) made a similar claim in regard to properties of the mind. In discussing artificial intelligence, he asserted that different levels of knowledge come from different types of *machines*. A human brain is not a computer and because "understanding is a property that comes from a certain kind of machine only, a machine like the human brain" (Gardner, 1985, p. 174), Searle applied such an analysis to intention as well. He saw intentions as caused by the specific properties of the human brain.

In the second knowledge-bound level of intention, when we have knowledge of our thoughts and actions, we appear to be viewing ourselves. This knowledge level involves our highest level of consciousness. Blushing, as Darwin (1965/1872) first noted, is one of the most human of all emotional expressions. He stated that "it is not the simple act of reflecting on our own appearance, but the thinking what others think of us, which excites a blush" (p. 325). It seems clear that this knowledge level is in some way unique to the other form of knowing and that it is reasonable to assume that a metaknowledge—knowledge of knowledge—has differential effects vis-à-vis the levels of intention. Intentions associated with this level of knowledge phenomenologically appear quite different from intentions at another level. For example, I intend to study a particular problem. This is a direct operation on a plan that is quite different from the intentions following this, which proceed from the plan of which I have no consciousness, although I might, and which act, as it seems, independent of my generation of other plans or intentions. It is a familiar experience to most of us to be thinking about a problem—a direct intention—when another intention arises, for example, a desire for a glass of water. Intentional action on this action pattern does not prevent intentions at other levels from proceeding. This possibility appears to occur. In fact, it is one way of conceiving of intrapsychic conflict which was given so much attention in Freud's tripartite notion of the psyche (Freud, 1961/1923).

In this overview, three processes have been identified that support the levels of intention idea. These are (1) evolutionary intentions, (2) learned intentions, and (3) conscious intentions. There is a need to consider unconscious intentions, something which is considered elsewhere (Lewis, 2014). These levels have an ontogenetic course and may have a phylogenetic one as well. Most important from my point of view, these levels, once developed, do not become transformed as new levels are reached. For each adult human, therefore, these levels coexist and at times may even conflict. Moreover, a particular level may be involved for one set of goals and another for another set. The regulation of our immune competence system is usually left to the first level whereas thinking of a happy event in order to go to sleep is an example of the third.

Applying these three different processes in the search for a levels analysis has proved useful, as have Dennett's (1987) work on intentional stance, Fodor's (1981a, 1981b) work on propositional attitudes, and Mitchell's (1986) analysis of deception. I have borrowed from each of these to outline a levels analysis, which appears later. In doing so, I have strayed from the theory of sensorimotor intelligence in several respects: (1) Intention as a property of all goal-directed systems is assumed, thus avoiding the problem of an intentional stance; (2) development is not transformational, at least in this regard. Such a view allows for the operation of all types throughout development. This avoids the inherent problem of regression, which is not readily handled by transformational theories; and (3) the levels view allows for the consideration of consciousness as the highest level of intention.

Outline for a Theory of Intentions

There are three levels: necessity, coactive necessity, and consciousness.

Necessity

This first level of intentionality, which corresponds to the reflex period in sensorimotor development, is called *necessity*. The action, although intentional, is both predicated and prescribed by survival or adaptation. This intentionality can apply to cells and infants and even in some aspects to mature humans. For example, breathing or heart actions are examples of this first level. That automatic or involuntary processes are intentional appears to violate our common-sense understanding; however, at this level, intentions are all derived through adaptive evolutionary functions related to survival and developed epigenetically. Commerce with the external environment is in part in the service of the internal adaptive function within the infant. These adaptive functions necessitate no response from the environment. Consider the early capacities of the infant. These response systems operate so that the infant intends to suck when an object is placed in its mouth, to blink its eyes when an object expands in its visual space, and to grasp an object when it is placed in its palm. They grow out of the child, and its biological heritage, and may be accommodated to by the environment but are not created by them. These behaviors are goal-directed, internal, self-sustaining, and adaptive.

The organism acts from goals built into its systems. For us, as for others, goals contain desires. Survival or adaptation is the intended goal. Desires at this level are likely positive or negative (approach versus avoidance) states, which are associated with action to satisfy goals (see, e.g., Darwin, 1872; Plutchik, 1980). At this level, necessity, intention, and action patterns are equivalent. Necessity is synonymous with adaptation that has goals; there is no mental representation. The system starts relatively undifferentiated. As the differentiation of this system expands, so too does its intentional system.

Do I wish to claim that this lowest level is intentional and what benefit for a theory of intention is derived by doing so? Some might be uncomfortable with including such action patterns within this realm, and might argue that it is not useful to claim any form of mentality for such action. Nevertheless, it may be helpful to do so. To begin with, in assuming intentionality for all goal-directed systems I give even to reflexes some intention, because they operate from the goal of survival and adaptation.

Coactive Necessity

The second type of intention involves the infant's coactions with the environment (i.e., individual ←→ context). It is similar to the first level in the sense that intention is directly tied to action patterns, thus the term *coactive necessity*. However, the adaptive functions now require environmental input and as such the intentions arise from the coactions among action patterns and the environment. It could be argued that all an organism's adaptive functions are interactive, that is, are related to the environment. Although this may be so, there appear to be differences that warrant the distinction. The smile of the infant exemplifies this. Until 3 months or so of life, the infant's smile appears related to internal adaptive functions. The infant smiles often when in REM sleep (Wolff, 1963). The infant may or may not smile to a human face. Early in this first level, the infant's smile does not appear to be related to exogenous factors but rather to endogenous adaptive activities. At a later point in this level the infant's smile is no longer simply part of the internal adaptive goal, but involves an affordance context that is independent of the child. By the next level, the infant smiles to environmental events, because it results in desired outcomes.

Consciousness

The most mental level of intention involves the mental act of consciousness Here the organism not only has the flexibility of abstract representation of actions and goals, but is now self-reflective (the self turned toward the self) of these goals and actions. This awareness or consciousness allows the child to consider that it has divergent intents. This is captured by the recursive statement "I remember that I wished to do something." At this point, intentions, which were flexible vis-à-vis goals and actions, are now viewed by the child. By this act of consciousness, intention itself becomes available to consider. As such, intention itself is changed. I can now say, "I am aware that I intended to do *X*, but that is really not what I wish to do." The manipulation of intentions themselves is one property of consciousness.

Conscious intent, like all levels, is supported by emotional action patterns. Nevertheless, cognitive capacity and the new level of consciousness, now becomes the material of intention. Here what is meant is that to be aware of desires, as opposed to having them but not being aware, becomes a new kind of desire which supports this new kind of intention. Now, and for the first time, intentions can be disassociated from the direct effects of emotional action patterns. In a sense, my self-reflection that "I wish for . . ."—a cognitive act—creates its own intention. The degree to which I am not self-reflective, not conscious, that I want something is the degree to which action patterns control my behavior rather than the other levels of knowledge. Such a view has been addressed in considering the topic of primary versus secondary thinking and is consistent with the belief that unconscious actions can be in conflict with conscious desires, thus allowing for interpsychic conflict (Freud, 1959/1915).

By articulating different levels of intention I have shown that only certain action patterns, evolutionarily derived adaptations to certain physical-social features of the environment, can occur without the complex intentions associated often with adult actions. This might be accomplished by using the words *intentionally* and *intention* in a more exact way, giving *intentionality to all goal-directed systems*, even evolutionarily derived ones like action patterns, and *intentions to conscious actions*. However treated, an important distinction can be made between early (or even later) action patterns, which do not require any reflective actions from those that do. These findings from our studies of a specific action pattern to a blocked goal prior to the emergence of consciousness is just one example of the complex sets of behaviors that have been reported on in the last decade which demonstrate that the human infant is capable of complex coactions with its world of objects and people, and which do not require conscious intention.

THE EMOTIONAL SYSTEM

To discuss the role of consciousness in emotional development, it is important to consider in greater detail how to best understand the term *emotion*. As stated, emotions can be defined as a set of evolutionarily derived and learned action patterns to specific contexts, and our consciousness in regard to these action patterns in specific contexts. This definition contains three aspects: affordance context, action patterns, and consciousness. Frijda (1986), from a different perspective has used similar terms such as stimulus, psychological manifestations, and experience. Let us examine these three aspects of emotion in detail.

Emotion Affordance Context or Elicitors

Emotional acts require the presence of an affordance context. An affordance context may be either external or internal. External affordances may be nonsocial, such as loud noises or a hot stove, or may be social, such as seeing the face of a familiar person (de Groot, Smeets, Kaldewaij, Duijndam, & Semin, 2012). Internal affordances may range from changes in blood sugar level or mental activities, such as making a self-attribution. The developmental issues associated with contexts or affordances are many. First, there are classes of affordances with little developmental history. A hot stove touched by my fingers lead to pain throughout life. The sight of food, once associated with relief of hunger, almost always serves as a positive affordance but only if the person is hungry and not sated after eating a big meal. Even for very direct affordances such as a hot stove, the life events of the organism may be such as to inhibit or restrict the usual course of the action pattern-affordance relation; for example, the Melzack and Wall's studies of dogs raised so as to be unable to respond appropriately when they touched a hot plate (Melzack & Wall, 1965; Wall, Melzack, & Bonica, 1994). What these studies showed was that the specific context or affordance, if it could be measured, remains consistent in its effect but other aspects necessary for the organism to realize its effect may interfere with the action associated with it. Exactly how or where in the emotional process this interference occurs is not known. Or, in another example, the effect of the context may be modified by the deactivation of the action pattern associated with it. For example, pain action patterns can be deactivated by competing contexts, such as loud music played into the patient's ears during dental surgery, or by drugs that inhibit receptor functioning or block information from reaching the spinal cord or brain. Finally, a specific context may be rendered ineffective through failure on the part of the organism to experience the action pattern. The failure to experience the action pattern might be the result of a reinterpretation of the action pattern through competitive learning, that is, in anorexia, food and eating are associated with negative outcomes, or some unknown motivation that prohibits the experiencing of a particular action pattern.

The model connecting contexts to action patterns has many examples, from those that appear almost hiccup-like to those that are learned. Consider what happens when we hold an infant up by its hands from a supine position and let it drop. There is an automatic action pattern of hands and arms flailing out and in, almost like trying to hold on to something. We say the falling sensation (an elicitor) produces a Moro reflex (an action pattern). This is biologically connected, having the function of helping the infant to hold onto something when falling. Later, the contexts of the action patterns are described in some detail. However, even these contexts, which may have some one-to-one correspondence with specific action patterns, can be conditioned to other contexts and so may be acquired through an associative learning process that was not present until learning took place. Moreover, later in development ideas can lead to complex action patterns such as shame or pride. These thoughts about the self and attributions about the self can serve as contexts once the child is capable of the cognitions necessary for these ideas. These mental contexts not only serve new action patterns such as shame or pride, but influence the action patterns originally elicited by the literal physical events in the environment.

This approach is based on the assumption that emotional behavior has an evolutionary history and specific epigenetic ontogenetic programs. In the case of facial expressions, in particular, but in all aspects of the action patterns as well, evolutionary epigenetic adaptive processes resulted in the connection of these specific contexts to specific action patterns. While taking a nativist perspective, this idea has been well represented by the work of Izard (1971). In Izard and Dougherty (1982), he states that "emotion expressions are innate and emerge ontogenetically as they become adaptive in the life of the infant and particularly in infant-caregiver communication" (p. 98). Moreover, studies show that certain emotions have similar facial expressions across widely different cultures which "provide a sound basis for inferring that the fundamental emotions are subserved by innate neural programs" (p. 98). However, for Izard there is also a strong link between the action patterns to an elicitor and to the experiences of the child: "It is reasonable to infer that the link between facial expression, neurochemical processes in emotion, and certain actions or action tendencies is the inner emotion experience and its motivational properties" (p. 101). Izard's view of an emotion is that of an isomorphic relation among affordance contexts, action patterns including expressions, and experience, which does not take the idea of consciousness into account. Although I agree that there may be a strong connection between contexts and action patterns, the "inner emotion experience" is not so connected initially but develops over the first year and a half of life.

The alternative view, which does not necessarily postulate a tightly knit connection, is one that can be called an *arousal attributional model*. In this model there are no tightly knit connections between affordance contexts and actions, but rather the idea of general arousal to an elicitor and the interpretation and attribution of this arousal utilizing information learned and interpretation about context, social expectations, and cognitive capabilities (Lazarus, 1982). Such a view has long history in the study of emotion, having such contemporary supporters as Ortony and the early work of Schachter (Ortony et al., 1988; Schachter & Singer, 1962). It may also be related to socialization of specific scripts that inform members of the group about what behaviors are appropriate for what situations. Such theoretical approaches require that sufficient cognitive capacity be present early in life for the infant to exhibit specific behaviors-in-context.

The model proposed utilizes the idea of action patterns that are connected to or become connected to affordance contexts and which mostly dominate the infant's behavior in the first year of life. Later in development the child's thoughts become the contexts of action patterns. The argument rests on the assumption that what have been called the *primary emotions* (anger, contempt, fear, disgust, happiness, sadness, and surprise) are action patterns that are not learned. What is learned is how the action patterns are expressed and which event they become related to, as well as their verbal labels.

As can be seen in the earlier examples, the structure that supports the affordance context-action pattern connection undergoes change. Within the class of early contexts there are some that appear strongly evolutionarily and prenatally connected to an action pattern—although socialization factors may strengthen or weaken some—as well as contexts that are connected to an action pattern through learned associations. Learned associations between contexts and actions also may be subject to developmental change because new abilities come on line or old ones are extinguished. For instance, the affordance context may change with cognitive development.

It is likely that there is a developmental sequence related to the context-action pattern association. Very young infants' context-action pattern connections are for the most part unlearned and part of the early adaptive action system that results in action in the world. However, as the infant gets older, the affordance contexts become more related to subject-object differentiation and learned associations. After 2 years, the affordances become, in part, thoughts about the self.

To summarize, then, the developmental process in terms of affordance contexts is a changing one, one which starts out in a more hiccup-like fashion where specific contexts in the child's environment lead to specific action patterns. Over time these action patterns are recruited to other contexts through learning. Finally ideas become the affordance contexts.

One final issue in regard to the context-action pattern has to do with the existence of what have been called *emotional receptors*. Briefly, emotional receptors provide a way to connect the context to a unique action pattern. Emotional receptors may be relatively specific loci or pathways in the CNS that mediate between the specific context and particular action pattern, or a more general arousal and the cognitions about it. Information about infant emotional receptors is rare so that any discussion of their development is speculative.

Specific receptors are likely select cells or neurostructures located in the CNS or in the ANS, are thought to be evolutionarily derived, which require highly specific stimuli. When these receptors are activated by a particular elicitor, instinctive behavioral patterns are released that presumably increase the organism's chance of survival (Hess, 1970). For instance, the quality of babyishness is considered a releaser of the action pattern of approach in adults, children, and even other babies (Brooks & Lewis, 1976; Hess, 1967). It has been speculated that the schema of the human face constitutes an innate (i.e., specific meaning "present at birth"; see Bateson, Chapter 6, this volume; Mameli & Bateson, 2011) releaser of the smiling response in babies, and Bowlby hypothesized that smiling behavior increases the chance of infant survival because it makes the infant more appealing to the mother (Bowlby, 1969; Spitz & Wolf, 1946; Wolff, 1963).

Findings based on EEG and brain imaging has not found specific brain centers for the different emotions, only hemisphere differences with the left associated with approach action patterns and the right withdrawal action patterns. Although the amygdala has been shown to play a critical role in emotional behavior, its activity coacts in complex ways in which areas of the brain, particularly structures of the regions of the limbic system and hippocampus. Theories of specific cells for perception comes from the early work of Hubel and Weisel (1962) who identified specific cells in the visual cortex of the cat that are activated only when a bar of light is presented at a certain angle. Different cells respond to different angles. Other cells respond only to the movements through the visual field and movement only in a single direction. Some cells are so highly specialized that they are activated only by a line in a particular orientation and of a specific length and width. Other cells in the visual cortex respond to patterns such as curves and animals. In monkeys, some cells are so finely attuned that they respond only to specific shapes and objects (Gross, Rocha-Miranda, & Bender, 1972).

Tomkins also suggested the idea of affect receptors, and speculated on the role they might play. "Organized sets of responses are triggered at sub-cortical centers with specific programs for each distinct affect are stored" (Tomkins, 1962, p. 243). Little attention has been paid to development issues pertaining to specific receptors. In general, these receptors are thought to be in place at birth and to be biologically determined in origin. Speaking about the program of these receptors and the consequence of their elicitation, Tomkins states that these programs are "innately endowed and have been genetically inherited" (p. 243), thus there may be little reason to postulate a developmental course in the maturation of specific receptors. If Tomkins is correct, they exist at birth and are influenced by neither development nor culture.

Action Patterns in Humans and Animals

Although some have considered emotional expressions apart from other emotional acts, here I include emotional expression within the larger set of acts and use Darwin's phrase, action patterns. Action patterns are specific changeable organized sets of actions including facial configuration, body movement, and changes in the autonomic and central nervous systems as well as hormone systems. Let us look at this set of acts separately keeping in mind that their coordination is rather loose.

Action Pattern Expressions

Emotional expressions are those potentially observable surface changes in face, voice, body, and activity level that make up part of an action pattern. Elaborate coding systems have been designed to measure the facial muscular changes in children and adults. The measuring systems were derived initially from Darwin's observations. Tomkins elaborated on these expressions and both Izard and Ekman devised facial coding systems that look at and examine muscle groups in the face which define for them specific emotions (Ekman & Friesen, 1978; Izard, 1979; Tomkins, 1962, 1963). According to Ekman and Friesen (1978), the possible combination of muscle activity in the face can be more than 10,000 possible combinations of muscle movements. The evolutionary history of facial neuromusculature suggests that facial expressions are a phylogenetic development with human beings having more neuromusculature than any other mammal, including the great apes. The coding system for both Ekman and Izard attend to those areas of the face that seem to reflect the most differentiated action patterns, those that appear around the eyes, the eye openness, the eyebrow movement, and mouth.

Other manifestations of an action pattern are bodily movement. People studying body posture consider it under the rubric of nonverbal communication, while those studying facial expressions consider it under the rubric of emotion and they publish their findings in different journals. This absence of any integration between face and body movement is a problem both in understanding emotional action patterns and in the study of their development. There is no question that posture and face inform the observer about the specific action pattern. For example, sitting upright and forward when someone is speaking is associated with interest and attention, whereas slouching and turning away may indicate boredom. Some bodily postures convey sexual interest. For example, when courting, adults often throw the pelvis out to display more of the lower parts of the body (Birdwhistell, 1974). Unfortunately, little work has been done in terms of body posture as a measure of emotional expression as it relates to other features of an action pattern, especially in children (Aviezer, Trope, & Todorov, 2012; Boone & Cunningham, 1998). Although there are few studies with children looking at decoding body movement, there are a few; for example, Boone and Cunningham (1998) found that 4-year-olds can correctly identify sadness through body activity. There is a report by Aviezer et al. (2012) on the discrimination of positive and negative emotions and that body cues are better than facial expression in this discrimination. It is likely that for humans as well as animals there are elaborate bodily displays or action patterns in need of greater clarification. From a developmental perspective, facial expressions are the usually measured action patterns in the young child, whereas expressions of posture and body movement as well as facial are measured in older children.

Vocalizations are also an aspect of emotional expression, and are certainly part of an action pattern. Scherer (1979) has developed techniques for analyzing the frequency patterns of infants' vocal behavior, finding, for example, that average pitch frequency can be used to determine anxiety or tension level. Vocal expressions are extremely powerful and may have the capacity to elicit similar emotional action patterns in others; that is, they are contagious. For example, movies are much funnier when seen with others who laugh out loud, than when seen in a silent theater. Or people express more sadness and cry when others are crying. Because of their potential contagious nature, vocalizations may be the target of early socialization efforts in terms of eliminating them from the infant's behavioral repertoire. Although not well understood, vocal displays of the action patterns are considered inappropriate in many cultures, certainly in upper middle class American culture. People are not supposed to laugh too loudly when happy, to cry too intensely when sad or frustrated, to growl when angry, or to groan in pain. It is clear that we socialize vocal behavior. Think of what we say when we comfort a child with "It's okay, don't cry," or when we socialize "Don't cry, babies cry." No wonder that in our studies of crying, we find a significant decrease in crying over the first 2 years.

Locomotion and body posture are other modes of expression. Running or moving away and moving toward an object or person are locomotive responses associated with withdrawal and approach action patterns. Indeed, infant movement away from an unfamiliar toy or person, independent of facial expression is often used to reference fear, even when no fear face is seen (Schaffer, Greenwood, & Parry, 1972; see also Adolph, Kretch, & LoBue, 2014, for a discussion of this). Following and holding a caregiver reflects an attachment to the adult (Ainsworth & Wittig, 1969).

Action Pattern Emotional Expression Coordination

Although there are some data on emotional expressions in each of these four different modalities (facial, postural, vocal, and locomotive), the relation among them has received almost no attention. It seems reasonable to assume that facial sobering, crying, and running away from a cohesive pattern of responses that reflect an action pattern associated with fear. On the other hand, a particular modality may be used to express an action pattern as a function of specific rules of socialization or a response hierarchy in which one modality has precedence over another. It may be the case, for example, that the least intense action patterns are expressed first in facial, then bodily, then vocal behaviors. Such a hierarchy might be determined either by a set of biological imperatives or by a set of socialization rules. In the absence of any data on this problem, the relation among these different expressive modalities can only remain speculative. However, it seems reasonable to propose that the more intense the action pattern, the greater the number of different modalities that are used to express it.

The use of one or more channels to express a particular action pattern may be determined by a complex set of processes. Of particular interest is the effect on an expression when another is inhibited. Inhibition in a particular channel can be experimentally produced, for example, by preventing a child from moving about. Such conditions of inhibition may modify or alter the use of the uninhibited channels. For example, we have found that infants between 8 and 15 months, when prevented from running away from an approaching stranger because they are restrained in a high chair, will express their emotional state more intensely through facial neuromuscular changes. Interestingly, if children of similar age are allowed to roam freely, their facial expressions are significantly less active. The emotional expression of locomoting away is sufficient to indicate distress and, thus, facial expressions are needed less so. Our research with Japanese and American babies also reveals just such a process (Lewis, Ramsay, & Kawakami, 1993). When we observed facial expression and cortisol stress reactivity to inoculation in Japanese and American babies, we found that the Japanese infants showed far less facial reactivity, but higher levels of stress hormone than did the American babies. Such a finding suggests that when facial expression is minimized for whatever reason, the other features of the action pattern may be more intense. Suomi (1991) found a similar negative association between increased stress hormones and decreased expression in his studies of monkeys. Thus the inhibition of the expression of an emotion may lead individuals to express their action patterns in other ways (Buck, Miller, & Caul, 1974).

Emotional expressions are also an important communication function; however, how people respond to expressions varies as a function of both their values and cultural rules. Keltner and colleagues have discussed some of the importance of the communicative functions in that they provide information to others of the individual's emotional state, their intentions, and the relational status. The facial expressions can even serve as signals that elicit prepared responses in others (Matsumoto, Keltner, Shiota, O'Sullivan, & Frank, 2008). This communicative function has two aspects. The information function serves to tell others what the child's internal feeling might be, which in turn allows the adult to act accordingly.

The development of knowledge about emotional expressions exists but it is mostly about the discrimination of different facial expressions in young children. By 3 years of age children are quite good at knowing what facial expression is likely in particular context (Russell &

Carroll, 1999; Widen & Russell, 2010, 2011). Once consciousness emerges the child can use emotional expressions to mislead the other as well. Feigning disappointment or anger, for example, can be used to manipulate others. Such deceptions serve a wide set of social needs. For example, the toddler can scream when his parents' attempt to go out as a means of controlling their behavior. In fact, once the parents leave, most children quickly become calm and playful.

The Development of Action Pattern Emotional Expression Organization

This discussion of the various different aspects of expression raises an important question. From a developmental perspective, how do the different expressive features of face, gestures, activity, and vocal behavior get organized? Although Camras (2011) has suggested that the facial neuromusculature gets organized through a dynamic systems process, there is an even broader question, namely how all the expressive features of, face, voice, and body movement get organized. Perhaps, as she suggests, a dynamic system approach can handle this, but that remains to be seen (see Witherington, Chapter 3, this *Handbook*, this volume). Keeping in mind that all development entails processes of probabilistic epigenesis (Gottlieb, 1997; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume)—that is, the role played by any part of a developmental system—DNA, cell, tissue, organ, organism, physical environment, and culture—is a function of all of the interpenetrating and coacting parts of the system—the organizational principles clearly need a relational perspective (Overton, 2006, 2013; Overton & Müller, 2012) in which both biological and learning points of view are represented, as with the specific action patterns as suggested by Darwin (1872).

The developmental course of the set of emotional expressions is relatively uncharted. Nevertheless, parents have no difficulty in responding to questions designed to examine their beliefs about when and where their children express emotions. Generally, parents tend to agree about when they think their children first show a particular emotion. It remains to be determined whether the parental responses are congruent or whether their answers reflect the belief system of their society. Cultures that place a strong emphasis on particular emotions may perceive these emotions earlier than other cultures. Thus, in one study, most American parents see anger expressions in their babies within the first 3 months. This is less the case in Japanese culture, where parents see less anger and see it emerging somewhat later (Otaki, Durreit, Richards, Nyquist, & Pennebaker, 1986).

The development of emotional expression can be considered both in terms of the ability to produce various expressions and in terms of the ability to recognize or discriminate among expressions. Although there is considerable literature on infant's ability to discriminate facial expressions as well as their differential preference for certain facial expressions, only limited work has been done on the nature of the discrimination aspect of those features. An important theoretical issue is therefore raised. For the most part, investigators have concluded on the basis of such discrimination and preference data that infants are capable of facial expression differentiation. In fact, the data may not reflect the ability to discriminate emotions but a preference for a highly specific aspect of the face that has a different salience (Quinn et al., 2011). For example, is the discrimination of a sad versus a happy face based on differences in the hedonic qualities of the face or in teeth exposure because the smiling face usually has more teeth showing?

There are those who see these expressions as having specific affordance contexts, although it is recognized that even prototypic elicitors do not always produce specific facial patterns. This fact is likely to cause us to reject the idea that faces, body movement, and vocal behavior may have a biological connection to specific contexts. Clearly, the data do not support the strong view that specific affordance contexts are *always* determined by evolutionary and prenatal adaptive processes to specific action patterns. This has led to the counter idea, that there are no specific action patterns. However, as already suggested, we may not have a good sense of the nature of affordance contexts. Gibson (1960) wrote a paper on the nature of the stimuli (which he later called "affordances" [Gibson, 1979]) arguing that psychologists spend too much time looking at responses rather than the nature of the stimulus. This is particularly relevant here because it may be that we have not looked carefully enough at affordance contexts.

An action pattern can be viewed as a particular constellation of changes in the ANS as well as the CNS and hormone systems that accompany expressions and bodily behavior. These action patterns can and often do occur without mental operations. For example, as we have seen, 2-month-old infants, who are frustrated by the blockage of a goal, can show an action pattern of approach that consists of an angry facial expression, increase in arm pull to reinstate the reward, increases in heart rate, and no increases in stress hormone. Even so, a small percentage of infants show a withdrawal action pattern, a sad face, little pulling, some increases in heart rate but a large increase in stress hormone. These different action patterns to the same elicitor are likely due to differences in temperament and in socialization.

Our studies, as well as the studies of others, have shown that specific context-action patterns, having unique sets of behaviors including face, body, and voice physical changes, exist, although the association is weak for some connections. There may be many reasons for these findings including measurement error, individual differences including temperament as well as socialization factors, all of which decrease the association between specific events and the child's action pattern.

Nevertheless, for now the view that there are organized action patterns, evolutionarily derived, that are adaptive and provide the foundation for the infant and young child's emotional acts in the physical-social world seems reasonable. Although evidence for these action patterns are seen later when the role of the development of consciousness in the transformation of action patterns into ideas is discussed, it might do well to briefly mention some of these that have already been found and which do not appear to be learned or to have associated with them any elaborated mental acts. McGurk and Lewis (1974) showed that 1-month-old infants have intersensory integration so that a mother's voice, displaced from her face, is disruptive to the infant. Disgust faces seen in the newborn are not learned, but are open to the babies' coactions with the food the mother eats through her milk (Mennella, 2012). Mineka has shown that fear of some animals, such as snakes or spiders, may be determined by evolutionarily derived processes in some way and, therefore, the child needs only minimum contact to turn these animals into feared creatures (Mineka, Keir, & Price, 1980). Included in this are examples of "innate releasing mechanisms" (IRMs), which have been studied by the ethologists (Hess, 1967, 1970). Warneken and Tomasello (2013) have shown that parental pressure and encouragement *do not* influence helping behavior in the 1-year-old, suggesting as have others that helping may be a evolutionarily derived action pattern (Braten, 2009). The list of what appear to be determined by evolutionarily derived action patterns could go on to include the newer work on infants' actions around the perception of object permanence, theory of mind, and intentions, but I save these for a later discussion around the role of consciousness.

Consciousness and Self-Reflection

Earlier, three fundamental aspects of emotions—affordance contexts, action patterns, and consciousness as self-reflection—were discussed. The last several sections have discussed affordance contexts and action patterns, which brings me now to a consideration of consciousness as it relates to action patterns in context, and how all three define what I mean by "an emotion."

William James (1890) defined emotions as the experiencing of the body: "the bodily changes [that] follow directly the perception of the exciting fact and our feeling of the same changes and as they occur" (p. 449). Following James, we need self-reflection as in feeling in order to have an emotion. The question then is: What is self-reflection? As I have tried to make clear, one of the most complicated concerns about emotional life centers around consciousness or self-reflection. Consciousness can occur at multiple levels, and includes, for example, the body experiencing the level of sugar in the system and adjusting the secretion of insulin. In any complex system like a body, one part has to experience or feel something in another part in order to regulate bodily functioning. This level seems to correspond to what Damasio (1999) has called *core consciousness*. This core consciousness is not a mental representation, it is not open to our reflective awareness. This core consciousness is likely present at birth and exists across the animal kingdom. The highest level of consciousness refers to mental act or mentalism including a symbolic representation of me. This mental representation is what I mean by consciousness. This level of consciousness finds common ground with attribution and evaluative theories because the cognitions involved with attributions and evaluations are associated with the self and require time for their development.

The theory proposes that in order to have an emotion this level of consciousness must be present because context and action patterns need be experienced in a self-reflecting manner. Proponents of James's theory have maintained that the conscious feeling of bodily change is as central to the concept of emotion as are the bodily changes themselves. This self-reflection of James has become, at least for some, an evaluative process that determines what emotion people will have. This evaluation may involve contextual cues, past experience, and is likely to have large individual differences (Clore & Ortony, 2000).

The self-reflection of context and action patterns develops over the first year of the child's life.

Emotional experience is, therefore, not an automatic bodily response connected in a one-to-one relation to an action pattern as Izard (1971) has held. Rather, self-reflection, more than any other component of emotional life, is the most cognitive aspect of an emotion. Cultural and individual differences are apt to be the most apparent here.

The development of self-reflection is one of the least studied aspects of emotion and emotional development. Because there is no reason to assume that emotional experience necessarily has a one-to-one relation with an action pattern-in-context, the development of self-reflection may occur long after the emergence of these action patterns, which can be seen at the beginning of life. What this means is that although newborns may show an action pattern called by adults sadness when interactions with their mothers suddenly stop, it does not necessarily follow that the newborn has the self-reflection of the sad action pattern.

The topic of self-reflection is quite complex, requiring that we distinguish between core consciousness and more advanced forms of consciousness. The former entail some fundamental cognitive abilities, including, at a minimum, the ability to perceive and discriminate, recall, and associate. The more advanced consciousness, on the other hand, requires a particular cognitive ability, which is a self-representation and reflection. Until an organism is capable of a mental representation of itself, which generally occurs between 15 and 24 months in the normally developing child, this advanced form is not possible.

CONSCIOUSNESS AND THE SELF-SYSTEM

Another way to explore this problem of levels of consciousness is through the examination of the self system. This is especially so because the terms *self* and *consciousness* are often used interchangeably. I begin this section by recognizing that the levels of consciousness have also been discussed by others (see Damasio, 1999; Neisser, 1995; Stern, 1985). We use the terms *self* and *nonself* in reference to plants and to cells, as well as to humans. If the term *self* used here is confusing, consider several examples from the human literature. We use the term *self-regulation* when we talk about newborn infants (Kopp, 1982) and intersubjectivity in 6-month-olds (Rochat, 2009; Stern, 1985). Things do not get much better when we consider adult humans; for example, the Western view of self as "I self" versus an Eastern view of self as "we self" (see Geertz, 1984). We even have identified multiple personality disorder, the idea of multiple selves rather than a single self (Ross, 1989).

Even in our everyday lives we are confronted with explaining selves. Much of my motor action, although initially planned, is carried out by core processes of my body that include, by definition, self-regulation and self-other differentiation. The same, of course, is true of thinking. One level of consciousness is necessary to formulate, at least sometimes, what it is that we wish to think about, but another level of consciousness does not appear to be involved in the processes that actually conduct the task of thinking. Consider this example: We give a person the problem of adding a 7 to the sum of 7s that precede it (e.g., $7 + 7 = 14 + 7 = 21 + 7 = 28$, etc.). It is clear that as she carries out this task, she cannot reflect on herself doing the arithmetic. One aspect of the self has set up the problem, another solves it. These diverse examples from plants, cells, human newborns, and adults all address the topic of what it is that I mean when I use the term *consciousness* or *self*.

To anticipate what is to follow, a few declarative statements are made; statements that, if we could figure out a way to test, might prove useful:

- All living systems self-regulate. By this I mean that within any living system, there needs to be communication between parts of that system. This can include a unit as small as a cell, a plant or animal, or even a more complex organism. For example, as I sit here writing, my systems are self-regulating my temperature, producing shivering as the room cools, or regulating my blood sugar level and informing me that it is time to have a snack. Self-regulation is a property of living matter. Self-regulation makes no assumptions about a mental state or self-awareness. (See McClelland, Geldhof, Cameron, & Wanless, Chapter 14, this *Handbook*, this volume, for an extended discussion of self-regulation.)
- Some minimal differentiation between self and other is a necessary condition for action. How this differentiation is produced is unknown (see Butterworth, 1992). What appears to be so is that all organisms, even such things as T cells, cannot act without at some level being able to distinguish between self and other. The ability to self-regulate or to distinguish self from other is part of the core processes of all living systems (von Bertalanffy, 1967). It is not an extended consciousness as some believe (Damasio, 1999).
- Even higher-order functions such as perception, thinking, and complex actions, such as driving a car, can be performed by adult humans without a mental state or self-reflection; that is, without their being able to reflect

on, look at, and observe the processes that allow these behaviors to be carried out. I cannot watch myself think. I can only look at the product of my thinking.

- A unique aspect of some self systems is self-reflection or consciousness. By consciousness I mean the capacity of a self to know it knows or to remember it remembers. It is this "meta" ability that is referred to when I say self-reflection. This reflective capacity of self-awareness may be uniquely human, although we may need to include the great apes who may be also capable of this.

The notion of a self and its development has been viewed in relation to what is called by some *emotion*. Already discussed is emotion as including emotional action patterns and consciousness of them. People can have certain bodily states and yet be unaware that they have them; that is, they have states but no consciousness of them. Emotional states refer to the core processes of our self-system. These core processes as action patterns have goals, can learn and profit from coactions in the world, can control functions, and can react to events including people. However, in order to experience our emotional states we require consciousness or what Damasio (2003) refers to as *feelings*.

As an illustration of the self distinction between action patterns and self-awareness of them, consider Pribram's (1984) description of a patient in whom the medial part of the temporal lobe, including the amygdala, had been removed bilaterally. Here we see a distinction between the subject's consciousness or mental state and her bodily state of hunger.

> These patients, just as their monkey counterparts, typically ate considerably more than normal and gained up to 100 pounds in weight. At least I could *ask* the subject how it felt to be so hungry. But much to my surprise, the expected answer was not forthcoming. One patient who gained more than 100 pounds in the several years since surgery was examined at lunchtime. "Was she hungry?" She answered, No. "Would you like a piece of rare, juicy steak?" No. "Would she like a piece of chocolate candy?" She answered, "um-hum," but when no candy was offered she did not pursue the matter. A few minutes later when the examination was completed, the doors to the common room were opened, and she saw the other patients already seated at a table eating lunch. She rushed to the table, pushed the others aside, and began to stuff food into her mouth with both hands. She was immediately recalled to the examining room, and questions about food were repeated. The same negative answers were obtained again, even after they were pointedly contrasted with her recent behavior at the table. Somehow the lesion had impaired the patient's feelings of hunger and satiety, and this impairment was accompanied by excessive eating! (Pribram, 1984, p. 25)

Given the existence of the various levels of consciousness, we are confronted with the following question: When I say "I know X," is it the case that I *must* know that I know X. If it is the case that I can know that I know X, when is it the case that I do know that I know X? These kinds of epistemological questions require different levels of consciousness. It seems to me that these epistemological questions are best addressed by the analysis of different levels of consciousness since from an epistemological point of view, knowledge can be bodily or reflective consciousness, but the knowledge of the knowledge is always reflective consciousness. Knowledge of the knowledge is the capacity of the self to reflect on itself. This ability to reflect on itself is what makes consciousness so important to understand.

THEORIES OF THE DEVELOPMENT OF DIFFERENT LEVELS OF CONSCIOUSNESS

There are two major views on the development of self-reflection or consciousness, one that I label the *social coaction* point of view, and the other biologically related to brain development.

Social Coaction and the Development of Consciousness

The development of the self as reflected consciousness is a topic that has received much thought and has a long history. I cannot do justice to this history, but I will attempt to touch on some significant theories, most of which suggest that reflected consciousness has a social origin. A hundred years ago, William James, in *The Principles of Psychology,* considered the problem of consciousness and mentioned its duality or, in my sense, its various levels:

> Whatever I may be thinking of, I am always, at the same time more or less aware of myself, of my personal existence. At the same time, it is I who am aware, so that the total self or me, being as it were duplex, partly known and partly knower, partly object and partly subject, must have two aspects discriminated in it, of which, for shortness, we may call one the "me" and the other the "I." (James, 1890, p. 43)

James went on to distinguish a hierarchy of consciousness, with a "bodily me" at the bottom and a "spiritual me" at the top, with various social selves in between. He envisioned a developmental trajectory, from the earliest physical experiences of the self as an entity to the later spiritual or nonmaterial experiences.

James's duality of self can be noted in the philosophical literature from Descartes to Wittgenstein. However, James's duality and Wittgenstein's were relational in nature, not split into a dichotomy as was Descartes (see Overton, 2006). Nevertheless, Descartes considered two classes of experience, with pain as an example of one, grief of the other. The first, pain, comes to us through our senses, or what I might refer to as James's "bodily consciousness." Grief, in contrast, does not arise from immediate sense impressions and requires a reflecting self.

James's thinking about the self and self-development branched in two directions, one cognitive and the other social. Within a cognitive framework, Baldwin (1903) described the development of the self in terms of its relationship to others, whereas Piaget (1960) viewed this development in terms of the emergence and development of symbolization and thinking, as the child moved from a level at which thinking emerged (approximately 18 months) to the egocentricism of thought and the increasing lessening of egocentricism (i.e., decentering) up to around 6 years of age. Piaget writes:

> That the child being ignorant of his own ego, take his own point of view as absolute, and fails to establish between himself and the external world of things, that reciprocity, which alone would ensure objectivity.... Whenever relationship dependent upon the ego are concerned—they are at the crux of the matter—the child fails to grasp the logic of relations for lack of having established reciprocity, first between himself and other people, and between himself and things. (Piaget, 1960, p. 272)

According to Piaget, having reached a symbolic level of functioning—which permits early reflection—at around 18 months, complete decentering is a slow process that may not be completed until around Age 6. It is with this decentering that the child becomes capable of taking the perspective of another. This permits viewing himself as others might view him, thereby indicating movement from a subjective to an objective self point of view.

At about the same time as James, Cooley struggled with similar problems concerning the self and its origins. Cooley, writing about the social nature of human beings and social organization, posited a reflector or "looking glass" self (Cooley, 1902). The self is reflected through other; thus, other people are the "looking glass" for oneself. In addition, Cooley stressed the relational idea that self and society form a common whole, with neither existing in the absence of the other. Cooley believed that infants are not conscious of the self, or the "I," nor are they aware of society or other people. Infants experience a simple stream of impressions, impressions that gradually become discriminated as the young child differentiates itself, or "I," from the society, or "we."

Following Cooley, Mead also drew a distinction between the conscious and processes of the self, using James's "I" and "me." The "I" constitutes the processes of the self and the "me" is the conscious self-reflecting on the "I." Mead assumed that the movement from the subjective "I" to the objective "me" takes place within a social nexus and is made possible only thorough social learning. Mead saw taking the perspective of another as the way the child was able to develop an objective self, and like Cooley, argued the relational position that knowledge of the self and others developed simultaneously, with both forms of knowledge dependent on social coaction. Heavily influenced by Darwin, he felt that the human infant is active rather than passive, selectively responding to stimuli rather than indiscriminately responding to all events. Hence, Mead believed that the infant actively constructs the self (here he is referring to the conscious self). He stated:

> Self has a character which is different from that of the physiological organism proper, the self is something which has a development; it is not initially there at birth, but arises in the process of social experience and activity. That is, it develops in the given individual as a result of his relations to that process as a while and to other individuals within that process. (Mead, 1934, p. 135)

The similarity between Mead's and Cooley's ideas is considerable: They share belief in the relational duality of self, subjective and objective, and the role of the child's social coaction in promoting *his development from the processes of the self to reflected consciousness*. Although sharing much of the ideas presented here, their reliance on social coactions rather than brain development can be used to differentiate their ideas from what can be seen as the role of biology in this process.

Although psychoanalytical views of the self are not presented in detail here, we need to keep in mind two of Freud's central ideas concerning the self's conscious and unconscious processes, and tripartite structure. The id and ego can be characterized as representing a bodily and a conscious self, although Freud's ideas about this tripartite division of personality have been questioned. In general, classical psychoanalytic theory has not paid much attention to the self, although self-psychology has redressed the balance. I restrict my discussion of self-psychology, only briefly mentioning the work of Erikson, Mahler, and Stern. Each takes a developmental perspective like my own. Erikson does not deal directly with self-development except from the point of view of the self's struggle at each stage (Erikson, 1950). Nevertheless, the challenge of the stages bears directly on issues of self-development. Mahler, Pine, and Bergman (1975) articulate a self-system that clearly develops in a sequence. There is some similarity between Mahler's point of view and Erikson's in that she describes the development of the self as a struggle between separateness and relatedness, and calls this the separation/individuation process. This process and struggle continues across the life course (Mahler et al., 1975). Of special interest is Mahler's description of the child in the last half of the second year. She posits an increased awareness of self (a reflected consciousness), and a concomitant heightened concern with the mother. In addition, she feels that both empathy and understanding of what it means to be separate and autonomous emerge between ages 18 and 24 months. The child's "love affair" with the world is modified as he learns about frustrations and limitations. In the third year, individuality is consolidated, separations from the mother become easier to bear, and the ability to take another's role becomes more pronounced. The child has developed a self that is separate from, but also related to, others. Stern (1985) speaks of four forms of self, which, although developing over time, are all available to both child and adult: the emergent self, the core self, the subjective self, and the verbal self.

In most of these theories, the process of self-development or reflected consciousness has to do with the child's actions in a social world. Baldwin, Mead, and Cooley all focused on the child's action in a social world. Although it is unclear whether Mead saw any biological processes at work in the process of the development of objective self-awareness, he certainly argues for the child's involvement with its social world as the process of its development. The child cannot develop a sense of the self, or self-awareness, alone. Mead uses the example of a boy running down a road. The boy has a rudimentary awareness of his body, but this awareness does not constitute a genuine self-reflection. For Mead, the child's developmental task is to detach his bodily awareness from within himself and assume an outside point of view. That is, individuals need to gain a vantage point external to themselves and then look back at themselves. This ability to look back at oneself is self-awareness, or what I have been calling *consciousness*. For Mead, the way others characterize one's self leads to this self-awareness. This view of the conflict between the self and other as the process of the development of a reflecting self or consciousness is found in its more modern form by Duval and Wicklund (1972). They suggested that at least three conditions need to be met if the child is to develop self-awareness: (1) There must be an entity who has a different point of view than the child; (2) the two different points of view must concern the same object; and (3) the child must be aware of these two different opinions simultaneously. To begin with, the infant acts, perceives, and even thinks but does not turn his attention on himself. The turning of attention on the self requires a conflict between the child's action and the actions of others. This conflict enables the child to objectify his actions, leading to thoughts, in particular self-awareness. However, how can an infant learn to do this if he does not have the idea of himself and the other and therefore a conflict (see Gergely & Watson, 1996, for a suggestion of how this might be done)? They concluded that, in fact, the parent–child relationship is likely to lead to this objectification. This occurs, in part, because coactions eliminate the time gap between the two perceptions, the child's own perception and the child's perception of the other as different from one's own.

It is the simultaneity of differing opinions and perceptions that is important. It is conflictual situations, ones in which there are punishments and negative prohibitions, that are likely to be the most effective in generating this perceptual difference. Interestingly, this analysis bears a similarity to the psychoanalytic view of the emergence of secondary thought processes. The inability of the id to achieve its purpose in the world creates ego mechanisms. Thus, wishing for something to eat causes lawful planning in the world only to the degree that the environment is in some conflict with the id's desires. However, there is not much empirical support for this social coaction as the process of the emergence of self-referential behavior. In fact, there is no empirical evidence for it at all. We have found that the attachment relationship between mother and child is unrelated to the emergence of self-referential behavior (Lewis, Brooks-Gunn, & Jaskir, 1985; see also Schneider-Rosen & Cicchetti, 1984; Tajima, 1982).

In summary, coactions with the child and its caregivers appear to be the source of the development of a reflecting consciousness. Poor caregiving, then, should logically result in disruptions of self-awareness. This view is held by almost all social theorists. Although such a view is appealing, and on its face reasonable, closer examination reveals this view's flaws. Most importantly, except for special classes of psychotic or autistic children, there is no evidence that poor caregiving results in failure to develop self-awareness. Although poor parenting has been shown to be associated with how children think of themselves (i.e., whether they see themselves as good or bad people), to reduce their capacity for empathy, there is no support for the idea that poor parenting leads to the lack of self-awareness. Mahler's studies and theory grew out of her work with autistic children. Her explanations of individuation might be reasonable for this special category of children, but even here I have some doubt. Autism in children is now thought to be strongly biologically influenced. In some sense, then, the theory of social origin of self-awareness remains in doubt. There is no doubt, however, that the qualities that we consider ourselves to possess, those aspects of our conscious self, are influenced by social factors.

The parent as mirror plays an important role in developing the aboutness of the self but not in developing a reflected self. Although it has been argued that through children's coactions with their parents, the meaning system attributed to the child by the parent is the process of change (Kaye, 1982), there are other mechanisms that may be involved. The adult's meaning system, as expressed in behavior toward the child, does produce that which that parent thought the child already possessed. In a sense, parents believe that their children possess a reflected self. This is a reasonable position from the standpoint of hermeneutics: Meaning is not found within the individual but results from collective agreement as to meaning. The achievement of consciousness, however, is likely to involve other processes, while the aboutness of self-reflection is likely to be socially derived.

Consciousness and the Development of Brain Function

Although social coaction between the child and its social world may affect consciousness, it is likely it does so through its effect on the development of brain functioning. In our work on consciousness, we have operationally defined consciousness by equating self-referential behavior with this process. Elsewhere (Lewis & Brooks-Gunn, 1979a; Lewis & Ramsay, 2004) we have suggested that self-recognition in mirrors, personal pronoun usage, and pretend play are useful measures of self-referential behavior, and we have used these to examine the relation between brain function development and reflected consciousness.

Given that there appears to be a developmental onset of these self-referential behaviors usually absent before 15 months, given that a mental age of 15 to 18 months is necessary for its display, and given that it is absent or delayed in children with autism (Carmody & Lewis, 2012), it is likely that developing biological processes play an important role in the development of consciousness. Finally, given that monkeys cannot, but the great apes and humans can, suggests a phylogenetic as well as an ontogenetic pattern. These findings provide strong support for the idea that brain development may be associated with the onset of a mental representation of the self or consciousness. But to be clear, brain development itself is not a split-off feature of an encapsulated brain; the brain develops according to processes of probabilistic epigenesis, through complex relational bidirectional coactions with other bodily processes and environmental contexts (Overton, 2006).

This idea of the significance of brain development for reflected consciousness is further supported by the findings that specific brain region activation is associated with adult self-referential behaviors. The left superior temporal gyrus and the left medial frontal gyrus are activated when subjects engage in a theory-of-mind task relative to reading sentences (Fletcher et al., 1995; Gallagher et al., 2000; Mitchell, Heatherton, & Macrae, 2002). Activation of the left superior temporal cortex (Brodmann area 22), the left inferior parietal cortex, and the left and right occipital cortexes (BA 18) occurs when subjects judge whether adjectives are relevant to themselves (Fossati et al., 2003; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004). In a study of brain activation to hearing one's own name, Carmody and Lewis (2006) found activation in the middle and superior temporal cortex and the left middle frontal cortex. In general, there is agreement that self-referential behaviors activate regions near the temporoparietal junction, although there are data suggesting activation of the medial frontal cortex as well (Fletcher et al., 1995; Kampe, Frith, & Frith, 2003).

To measure brain activation developmentally as a function of the capacity to show self-representation, one would need to study the relation between the emergence of this representational ability and changes in brain function. Obtaining functional magnetic resonance imaging (fMRI) or positron emission tomography (PET) scans in very young children has been shown to be difficult (Souweidane et al., 1999), and there are few, if any, published fMRI studies of children between 15 and 30 months of age, which is the critical age range for the development of self-referential behaviors (Paus, 2005; Saxe, Carey, & Kanwisher, 2004).

One way to study brain development is to use magnetic resonance imaging (MRI) to measure the relative amounts of gray and white matter in different cortical brain regions (Toga, Thompson, & Sowell, 2006). MR images show a gray–white matter contrast in a sequence that reflects the time course of brain development (Barkovich, 2000, 2005; Paus et al., 2001), and changes in MRI features are informative in determining the developmental changes in white and gray matter for normal and clinical cases (Barkovich, 2002). Different MRI techniques are available to assess brain development and involve either qualitative judgments or quantitative measures. Although the qualitative descriptions help characterize brain development, computational analysis of MR images allows the detection of individual changes in white matter that signal the biological underpinnings of development of motor, sensory, cognitive, and perhaps social changes. To that end, quantitative measures may prove more valuable than the qualitative judgments of change.

Quantitative measures include volumetric analyses of gray and white matter (Thompson et al., 2007), development of white matter relative to gray matter (Carmody, Dunn, Boddie-Willis, DeMarco, & Lewis, 2004), and the diffusion tensor imaging (DTI) techniques to assess white matter integrity (Anjari et al., 2007). DTI provides data on the anatomy and the density of white matter fibers and development (Dubois, Hertz-Pannier, Dehaene-Lambertz, Cointepas, & Le Bihan, 2006), as well as providing images of the cortical association tracts (Mori et al., 2002).

We were interested in using the standard clinical MRI scans to assess brain development in both clinical and nonclinical groups. Quantitative scores based on the difference between white matter and gray matter were obtained using quantitative assessments of T2-weighted MR images for specific brain regions, which generate age changes in white matter development (Barkovich, 2002; Dietrich et al., 1988; McArdle et al., 1987). Given this technique, it is possible to measure individual differences in development by region and relate these individual regional differences in development to individual differences in children's self-representation.

To study this problem, we studied 15 infants from 15 to 30 months of age and related their development of particular brain regions to their scores on a self-referential scale made up of mirror self-recognition, personal pronouns, and pretend play (Lewis & Carmody, 2008). Figure 11.4 shows the correlations between specific brain regions and scores on the self-representation scale.

The findings from this study indicate that the degree of brain development in a specific region, independent of age, is related to the emergence of children's self-representation. This held for the self-referential score, as well as the three components that make up the score. It is the degree of development in the left temporoparietal junction that is most related to self-representational behavior. This is consistent with other findings that implicate the

Correlation between Self-Referential Behavior and Brain Myelination

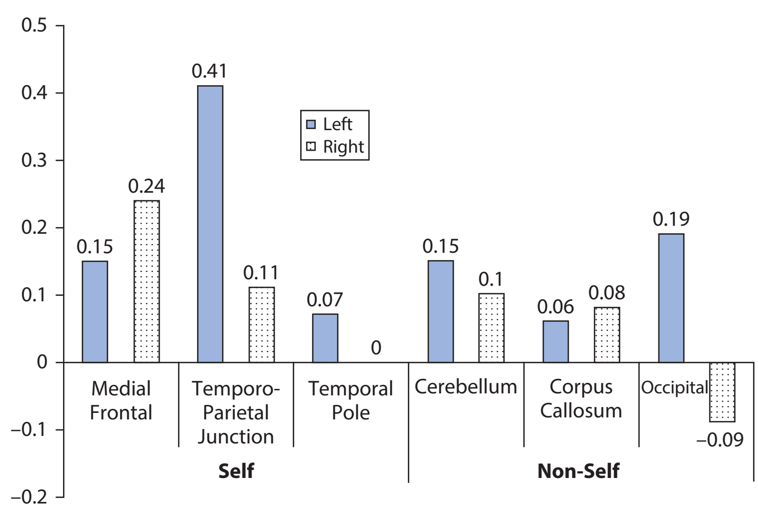

Figure 11.4 Relation between brain development and self-representational behavior. Solid bars represent left; dotted bars represent right hemispheres.

Source: Adapted from data in "Self-Representation and Brain Development," by M. Lewis and D. P. Carmody, 2008, *Developmental Psychology*, *44*(5), pp. 1329–1334.

temporoparietal junction in its role in self-representational behavior (Samson, Apperly, Chiavarino, & Humphreys, 2004; Saxe et al., 2004; Saxe & Kanwisher, 2003). This brain region, as well as regions located nearby, have been found to be activated during several types of self-representational behaviors, such as when subjects engage in a theory-of-mind task relative to reading sentences (Fletcher et al., 1995; Gallagher et al., 2000; Mitchell et al., 2002), when subjects judge whether adjectives are relevant to themselves (Fossati et al., 2003; Macrae et al., 2004), and when subjects hear their own name (Carmody & Lewis, 2006).[1]

To deal with the problem of how to understand the development of the mental state of the idea of me, or consciousness, we need remember the earlier discussion of intention in order to address the issue of the meaning of an action. As we have seen, there are core processes of the self that can be seen in the newborn infant's imitation of a tongue protrusion (Meltzoff & Moore, 1977). This is a core process of the self, it is not the same as having a reflected self, seen in the intention to "buy the same toy Tommy has." Both the core processes of the self, as part of bodily experience, and consciousness or the mental state involving the idea of me, appear to be the consequences of different biological processes and perhaps different brain structures. LeDoux's work (1990) suggests that specific brain regions may be implicated in different kinds of self-processes. LeDoux's findings indicate that the production of a fear state can be mediated by subcortical regions, the thalamic-amygdala sensory pathways. Similar findings have been reported in humans, which suggests that action patterns as core processes can exist without a reflected self. For example, Bechara et al. (1995) and Weiskrantz (1986), among others, have discussed a phenomena called *blindsightedness*. Patients have been found who lack the visual cortex, at least in one hemisphere. When they were asked if they could see an object placed in their blind spot, they report that they could not see it—that is, their reflected consciousness of the visual event was absent. However, when they were asked to reach for it, they showed that they could reach for it. Thus, they could see the object, yet did not have a reflected consciousness of it. These findings, as well as Gazzaniga's work (1988) on split-brain patients, suggest that separate brain regions are likely associated with core consciousness or the processes of the self and reflected consciousness. A similar analysis involving memory has been suggested by Tulving (1985). Karmiloff-Smith (1986), from a developmental-cognitive perspective, has also taken up this type of distinction, arguing as I do that early in the developmental process, knowledge is part of the core system and therefore implicit, whereas later knowledge is explicit or reflected consciousness (see also Dienes & Perner, 1999).

As we have seen, two theories about the development of consciousness exist; the social coactive and the brain development views. Both appear to be at work and an integration of them needs to be undertaken. The integration of the social coaction as it affects brain development processes needs to be studied as there is increasing evidence of the powerful bidirectional effect on each.

MEASUREMENT OF REFLECTED CONSCIOUSNESS

Measurement follows from the constructs we make; therefore, if we are interested in the development of consciousness as I have defined it, we need to measure self-referential behavior rather than action patterns. Because early imitation, intersensory integration, and coordination between infant and mother all are likely to reflect the core processes of self, they are not adequate measures of a higher level of consciousness.

The study of the idea of me requires, for the most part, symbolic language capacity. If the emergence of this mental state occurs before 2 years of age, using language as a measure of this mental state is difficult. In an adult or older child, we can ask, "Who are you?" "Tell me something about yourself," or "Tell me something that you know that others don't know." Alternatively, following Laing (1970), we can see whether the child understands statements such as "I know you know that I know where you put your teddy bear." As is readily understood, all of these questions

[1]However, studies have found evidence for both left- and right-hemisphere involvement in self-representation; the left hemisphere showing greater activation on tasks involving self-representation, whereas the right hemisphere showing activation in tasks involving self in comparison with others. For example, Ruby and Decety (2001), using PET, reported left parietal activation when subjects mentally simulated an action with a first-person perspective and right parietal activation when subjects simulated an action with a third-person perspective (i.e., imagining the action of the other). In addition, Turk et al. (2002) found in a study of face recognition in a split-brain patient that the left hemisphere in comparison with the right hemisphere showed more activation to self than to a familiar face, whereas the right hemisphere showed more activation to familiar faces of others than to the self.

imply some idea the child has about himself, or consciousness, because the recursive knowledge about what others know about what you know explicitly implies a self referent.

Without language, however, the child cannot through language explain this idea to us. One alternative is to require, without using language, that the child do certain tasks and see whether she can do them. If the child understands the task given, it is possible to demonstrate that the child has the idea, even though he does not have language. Thus, for example, in the work on deception (Allen & Lewis, in press; Lewis, Stanger, & Sullivan, 1989) and in the research on theories of mind, Wellman (1990) and Moses and Chandler (1992), for example, have been able to show that the child can deceive and also place herself in the role of another. In each of these types of studies, there is an implicit theory of mind that includes consciousness (see Carpendale & Lewis, 2010; Chandler & Birch, 2010).

Unfortunately, even these studies require that children understand complex language although they do not have to produce it. Thus, for example, in the deception studies, children have to understand the experimenters' instructions and, therefore, cannot be much younger than 3 years. By this age, it seems clear that children have consciousness. The question, then, is whether this level of consciousness emerges earlier, and if so, how might it be measured. We could still focus on language and argue that this consciousness can be measured by whether children have acquired their names; we are what we are called. The risk of accepting this as proof is that the child may have been taught to use its name by associating it with a visual array, a photograph of itself, without consciousness being present (see Putnam, 1981, for a discussion of this type of problem).

A language measure, a bit less suspect, is that of personal pronoun usage. Because parents rarely use the label "me" or "mine" when referring to the child or to themselves (they say, "I am [or Mommy is] going to the store"), the use of these terms by the child is likely to be a reasonable measure of consciousness. This appears even more the case when we observe children's use of the terms and how they behave when using them. One can observe a child saying "mine" as she pulls the object away from another child and toward herself. Because moving the object toward oneself does not move the object as far away from the other as possible, the placement of the object next to the body, together with the use of the term "me" or "mine," appears to reference consciousness. Children begin to use personal pronouns including "me" and "mine" by the latter part of the second year of life, which can provide a linguistic demonstration of the emerging mental state (Harter, 1983; Hobson, 1990).

Another procedure that can be used to measure consciousness is self-recognition. We have studied self-recognition in infants and young children in detail (Lewis, 1992a, 2003; Lewis & Brooks-Gunn, 1979b; Lewis & Ramsay, 2004). The procedure is simple. Unknown to the child, her nose is marked with rouge and then the child is placed in front of a mirror, where it is possible to observe whether the child, looking in the mirror, touches her marked nose or whether she touches the image in the mirror. The data from a variety of studies indicate that infants even as young as 2 months, when placed in front of mirrors, show interest and respond to the mirror image. Children will smile, coo, and try to attract the attention of the child in the mirror, although they do not behave as if they recognize that it is they in the mirror; this is an evolutionarily derived adapted action pattern produced in the context of *babyness*. Indeed, even dogs, cats, and older children and adults are attracted by babyishness. At older ages, when locomotion appears, on occasion, infants have been observed going behind the mirror to see whether they can find the child in the mirror. In addition, they often strike the mirror as if they are trying to touch the other. Somewhere around 15 to 18 months of age, they appear to begin to know that the images are themselves because they touch their noses or comment about their noses when looking in the mirror. The mental state of the idea of me or consciousness is captured by the children's use of self-directed referential behaviors. The touching of their noses when they look in the mirror seems to reveal that they know that it is "me" there.

The ability to use the mirror to reference herself has been mistaken for the child's understanding of the property of mirrors. There is ample evidence that although children are able to produce self-referential behavior through the use of the mirror-mark technique, they do not know many of the properties of reflected surfaces; for example, they cannot use the mirror to find an object only seen in its surface (Butterworth, 1990). What is important about the self-referential behaviors in the mirror is that they need not be a marker of general knowledge about reflected surfaces, but rather a marker for the child's knowledge about herself. They are the equivalent of the phrase "that's me." This recognition, if put into words, says, "That is me over there; this is me here."

Measuring other aspects of reflected consciousness is possible, pretend play in particular. From a variety of theoretical perspectives (Huttenlocher & Higgins, 1978; Leslie, 1987; McCune-Nicolich, 1981; Piaget, 1962/1951), it is apparent that pretense is an early manifestation of the ability to understand mental states including one's own and others'. Pretense involves double knowledge or dual representation of the literal and pretend situation. The dissociable relation between the two allows the child to distinguish between appearance and reality. Research by Piaget (1962/1951) and subsequent investigators (Fein, 1975; Lowe, 1975; McCune, 1995; Nicolich, 1977) indicates that pretense emerges in children by the middle to latter part of the second year of life. The capacity for pretense not only marks consciousness but also the beginning of a theory of mind that is based on mentalism, not that which is based on evolutionarily derived adapted action patterns such as gaze behavior, joint attention, social referencing, and preverbal communication abilities (Bretherton, 1991; Carpenter, Nagel, & Tomasello, 1999; Leslie, 1987).

There are studies that have examined the relation between verbal measures of self-recognition (including the use of the personal pronoun "me" and one's name) and the mark-directed behavior (Bertenthal & Fischer, 1978; Lewis & Ramsay, 2004; Pipp, Fischer, & Jennings, 1987). These studies have generally found that verbal measures appear after the mark-directed behavior (Harter, 1983). It also is apparent that self-referential and pretense behaviors emerge at approximately the same point in development (see Lewis & Ramsay, 2004). A mental state of the idea of me, or consciousness, is taken for granted in Leslie's (1987) model on the relation between pretend play and theory of mind. That pretend play emerges as soon as the onset of self-recognition would support the belief that both reflect the emergence of consciousness, as well as a source for a theory of mind.

In a series of studies on self-referential behavior, Lewis and his colleagues have established that self-recognition starts to emerge by 15 months and that, for the most part, all typically developing children demonstrate it by 24 months, thus showing an onset as well as offset (Lewis & Brooks-Gunn, 1979a). Moreover, children need a mental age of 15 to 18 months in order to show mirror recognition (Cicchetti & Sroufe, 1978). Children who show self-recognition show embarrassment, whereas those who do not show recognition do not show embarrassment (Lewis, Sullivan, Stanger, & Weiss, 1989). Self-recognition is strongly related to other self-referential behaviors, such as personal pronoun usage as well as pretense (Lewis & Ramsay, 2004).

Self-recognition, personal pronoun use, and pretend play all indicate self-referential action which we use to infer reflected consciousness. It is apparent that, with development, self-representation increasingly becomes a more complex and multifaceted phenomenon that progressively includes other cognitive and evaluative aspects of self-knowledge (Lewis & Brooks-Gunn, 1979b, 1979c). These results suggest that in terms of emergent time, self-recognition is earliest in the formation of a complex self-representation. Of the three self-referential abilities assessed, self-recognition was the one most likely to emerge first in development, suggesting that physical self-referential action may provide the core aspect of self-representation that continues to develop beyond the second year of life.

Consistent with the present findings is work that indicates children's emerging understanding of a theory of mind by the middle of the second year of life. For example, Meltzoff (1995) reports that 18-month-old toddlers have the ability to understand the intentions of others. After observing adult models demonstrate the intention to act in a certain way by starting, but not completing, a given activity, the toddlers, when given the opportunity, performed the complete acts the adult intended. Similarly, Asendorpf and colleagues (Asendorpf & Baudonniere, 1993; Asendorpf, Warkentin, & Baudonniere, 1996) found increases in imitative play linked to the presence of self-recognition in 20-month-old infants. Indeed, many studies link self-recognition to other abilities that mark more broadly the emergence of self-representation. For example, self-recognition is related to children's self-conscious emotions, empathy (Bischof-Kohler, 1994), as well as altruism (Zahn-Waxler, Radke-Yarrow, Wagner, & Chapman, 1992). Self-recognition is related to autobiographical memories (Harley & Reese, 1999) and is associated with imitation (Asendorpf, 2002). The degree of correspondence between self-recognition, pretend play, language self-referents, and the emergence of ownership suggests the emergence of consciousness in the middle of the second year of life (Friedman, 2011). The absence or delay of self-recognition, pretend play with others, and personal pronoun usage during this time frame has been associated with mental age delays and with ASD and is a further indication of the effects of the lack of self-referential action at this point in development (Carmody & Lewis, 2012; Dawson & McKissick, 1984; Ferrari & Matthews, 1983; Hobson, Chidambi, Lee, & Meyer, 2006; Lewis & Carmody, 2008; Mundy, 1995).

THE ROLE OF CONSCIOUSNESS IN DEVELOPMENT

The division of the child's capacities into the broad categories of social, cognitive, and emotional does a disservice to the theoretical perspective that argues for an integrative person approach (McClelland, Ponitz, Messersmith, & Tominey, 2010; Overton, 2010, Chapter 2, this *Handbook,* this volume; Santostefano, 2010; Turiel, 2010, Chapter 13, this *Handbook*, this volume). All these capacities after all take place within the individual child, and as such have to be interrelated and interconnected. The metaphor sometimes used to characterize this association is a series of concentric circles each with some overlap with the others. My preference for a metaphor is more like a tree with a central trunk and with increasing differentiating branches. This metaphor fits Werner's (1948) view of development as a gradual differentiation among the various domains. The organization of development follows from the assumption that social, emotional, and cognitive knowledge are features of the same unified relational development system (Lerner, 2006; Overton, 2013, Chapter 2, this *Handbook*, this volume; Overton & Lerner, 2012) that is fundamental to the individual's consciousness. Individuals develop social, emotional, and cognitive knowledge in relational reciprocal bidirectional (←→) coactions with their worlds. The change from a unified system of knowledge based on the emergence of reflected consciousness to one that is differentiated, integrated, and specialized occurs as a function of developmental processes. In the tree metaphor, the trunk represents the unified, integrated system generated by consciousness, whereas the branches represent the separate areas of knowledge, some of which are interrelated, whereas others are independent. This model allows for both the integration of knowledge from a developmental perspective and the functional independence of the end product. Thus, as a central premise, the development of consciousness provides the scaffolding for the development, integration, and separation of the various other actions of the child.

Figure 11.5 presents in schematic form the proposed transformations related to consciousness. As can be seen, each of the early classes of action, called here *adapted action patterns*, is transformed by the emergence of consciousness. Thus, perceptual-sensory action patterns become a theory of mind, evolutionarily derived adapted social coactions become social relationships, and the early or basic emotional action patterns become the self-conscious emotions. Both foci are considered later.

Before doing so, it is important to restate my idea of action patterns as evolutionarily derived adaptive complex actions occurring in specific environmental affordance contexts as part of the core processes of the self system. These actions are features of the core self, although quite flexible, open to differences as a function of the infant's social coactions, as well as to differences in temperament and personality. One can use the term *procedural rules* to indicate this idea of core self-bodily processes.

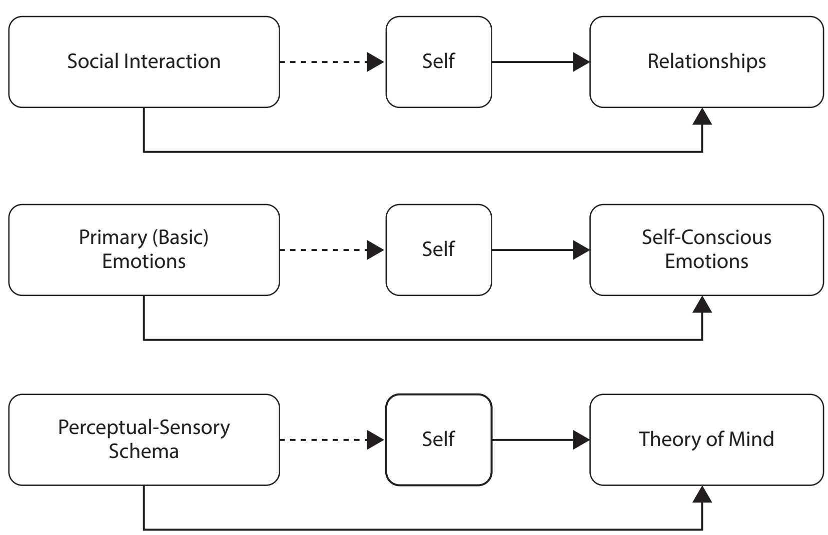

Figure 11.5 Role of the self in development.

It is to be noted, however, that with the rise of consciousness these procedural or core activities become conscious, and conscious actions can become procedural.

Consciousness and Levels of Knowing

The work on social cognition predates and provides the logical basis for the newer work called *theory of mind* (see Chandler & Birch, 2010, for a review of this earlier work). When using the term *social cognition*, we imply that there is a role of the self in knowing. To the degree that the self as knower is part of the process of knowing, that is the degree to which the cognition is social (Lewis, 1993, 1997). So, for example, I may know about a hurricane by being in one, or I may know of it by reading it in the newspaper. In both cases, I have knowledge, but in one, that knowledge is gained through the self's experience of the phenomenon, whereas in the other, it is through the self's knowledge of words. In French, *connaitre* and *savior* capture this distinction.

Another example has to do with knowledge that involves the self. This is best captured by the sentence, "I know that you know that I know your name." Such recursive sentences and their meaning cannot be independent of consciousness because the self knows something about what another self knows about itself. The meaningfulness of such a sentence is dependent on the knowledge of myself and knowledge of another self's knowledge of myself.

The epistemological issue of the relation between the knower and the known has been widely recognized for more than a half century (Lewis, 1983; Merleau-Ponty, 1964; Overton, 2006, Chapter 2, this *Handbook*, this volume; Piaget, 1960; Polyani, 1958). Consciousness involves the relational reciprocal bidirectional coaction of the knower with objects, events, or people. Social cognition depends on just such a connection. Following the work of Mead (1934) and Cooley (1902), explicit knowledge of the self and knowledge of others are dependent on one another: "I cannot know another unless I have knowledge of myself." Furthermore, a child's knowledge of self and others is developed through coactions with these others, social coaction and consciousness being the basic unit out of which social cognition derives. Many who subscribe to an "interactionist" position agree that knowledge of others and the world in general is derived through coaction: "To understand what a person is, therefore, involves understanding what sorts of relationships can exist between mere things or between persons and things" (Hamlyn, 1974, p. 7).

Because what an infant knows of the other through coactions—usually nonsocial "other," characterized by physical properties such as weight, length, and so on—has been the major focus of researchers, the fact that knowledge of other, gained through coactions, must provide information about oneself has been ignored. If I find one object hard and the other soft by holding them, then not only do I know something about objects, in this case, hardness, but I know something about myself, how hard the object feels to me. As Merleau-Ponty (1964) states, "If I am a consciousness turned toward things, I can meet in things the actions of another and find in them a meaning, because they are themes of possible activity for my own body" (p. 113).

A "theory of mind," like social cognition, involves explicit knowledge of one's own and others' mental states (Gallup, 1991; Leslie, 1987; Povinelli & Eddy, 1996; Premack & Woodruff, 1978). From the broad social cognition perspective, children's perspective-taking or role-taking abilities, their abilities to "put themselves in the place of the other," or their "theory of mind" has been examined in various situations including those that assess children's capacity for the expression of empathy. It has long been recognized that taking the point of view of another presupposes explicit knowledge of one's own self (Leslie, 1987; McCune, 1995). However, it is important to keep in mind that what is being discussed has to do with the content of consciousness. It is not about the process of that consciousness.

Given our studies on the development of consciousness, let me suggest a brief outline in the development of a theory of mind, which ultimately involves self-reflection. There are at least three or four aspects to its development: (1) I know; (2) I know I know; (3) I know you know; and (4) I know you know I know.

- Level 1 is called *knowing* (or I know). This level prevails from birth until the beginning of the second year of life and is likely to be driven by basic processes common to other mammals. It is based on adaptive evolved complex action patterns and involves little or no language; it is not supported by the mental state of the idea of me or consciousness. For example, there is now evidence using eye gaze to indicate that young infants can anticipate an intention of another by selectively looking at one consequence over another (Baillargeon, Li, Gertner, & Wu, 2011). Many organisms share in this level of knowledge. For example, when an object in the visual field rapidly expands, infants, as well as adults and animals, show surprise and discomfort. This response is simply built into the core features of perceptual-motor knowledge or action patterns. Likewise, a rat running toward a wall perceptually knows it's a wall and does not run into it. In the past 30 years there has been an expanded test of infant competencies, which reflect such a knowledge level. Infants' competencies however, are not the same as understanding and the distinction between competence and understanding is necessary in order not to confuse this level of knowledge from the others.

- Level 2 is *I know I know*. This level involves a reflected consciousness as measured by self-referential action. It is based on the mental state of me, and allows for the capacity to reflect on one's self and to reflect on what one knows. This mental state is a metarepresentation. It is similar to a memory of a memory. Whereas a child at the first level may have a memory, it is at the second level that metamemory is possible. Here the child remembers that she remembers. As we have shown, this capacity emerges somewhere in the middle of the second year of life (Lewis, 2014).
- Level 3 is *I know you know*. This form of knowing takes into account the mental state that not only do I know something, but I believe others know it as well; it is the ability and basis of shared meaning. This does not imply shared attention which belongs to Level 1, although with the emergence of Level 2 this action pattern can become a thought. This representation, that you know what I know, does not need to be accurate. Adults know more than children know; thus, the child may not really know what the adult knows. The child is likely to make errors, something called egocentric errors. That is, she assumes that what she knows is what the other knows. At this level, children know, they know they know, and they also know you know. What they cannot yet do is place themselves in opposition to what they know. This level, in combination with the earlier ones, accounts in part for the early ability to deceive. A 2½-year-old child who deceives knows that he knows and he knows that you know; thus, deception is possible. It is also the reason why children are likely to make the traditional false belief error.

Before going on to the fourth level, it is worth mentioning that the third level may not be distinct from the one before it in which children know they know. It is possible that the mental state of the idea of me and what I know may emerge at the same time as the mental state of what I know about what others know. In other words, it is likely that what I know about me is part of what I know about the other. If, indeed, this is the case, then a separate level might not be called for.

- Level 4 is the adult-like level. It addresses the coactive and recursive nature of cognition. It is characterized as *I know you know I know* or recursive knowledge. At this level, not only are there two actors, as at Level 3, but each actor has a perspective. These perspectives can be different. It is when there are two perspectives that one has the ability to recognize false belief. Only when one has reached the level of knowing that "they know I know" can one's knowledge about what they know be corrected, because you can check their knowledge of what they know about you against what you know. That is, once a child knows that she can be the subject and also the object of the knowledge of another, she is capable of recognizing the difference in perspectives between individuals. It is at this final level of perspective taking that mature meta-knowledge can emerge.

As these levels of knowing are reached and mastered, there is at the same time an increase in general cognitive competence, in particular, language usage. Language ability is laid down on the general cognitive scaffolding that allows the language to reflect increasingly the available cognitive ability. Our problem in studying children's early development is that language ability may not precede this general cognitive capacity but may follow it. Thus, children's observed social action and cognition may reflect a level higher than their verbal capacities.

Social Relationships and Consciousness

When I think about relationships, by definition, they involve me; and when I think about relationships, one of the things that I may think about is what the other thinks of me. Recursive knowledge can become quite complex, as, for example, when I think of what others think that I think of them. In his discussion of interpersonal relationships, Asch (1952) makes a similar point: "The paramount fact about human interactions is that they are happenings that are psychologically represented in each of the participants. In our relationship to an object, perceiving, thinking, and feeling take place on one side, whereas in relations between persons, these processes take place on both sides and are dependent upon one another" (p. 212).

Knowledge about self and other, whether they occur sequentially or at the same time, eventually become a part of the duality of knowledge. For example, Bannister and Agnew (1977) note, "The ways in which we elaborate our construing of self must be essentially those ways in which we elaborate our construing of others. For we have not a concept of self, but a bipolar construct of self-not self, or self-other" (p. 101). The definition of social knowledge involves the relation between the knower and the known, rather than characteristics of people as objects. By utilizing the self in knowing, we can differentiate when we are treating people as objects from when we are treating them as people. If the self is not involved, then the people are being treated as objects; when the self is involved, people are being treated as people.

Developing Relationships

The developmental issue in social relationships is quite complex, especially given the wide acceptance of attachment theory and the argument that infants form relationships with their mothers, at least by 1 year of age. Some have argued that this occurs even earlier, perhaps by 3 months. If, however, we believe that social relationships require reflected consciousness, then children cannot form relationships that early, although adults can. We would do well to consider Hinde's (1976, 1979) discussion of the nature of relationships. He has argued for eight dimensions that can be used to characterize them. The first six describe what can be considered to be coactions whereas the last two characterize relationships. These six are (1) goal structures, (2) diversity of interactions, (3) degree of reciprocity, (4) meshing of interactions, (5) frequency, and (6) patterning and multidimensional qualities of interactions. These six features describe interaction that is likely supported by the core processes of the system of self, at least on the part of the infant. Interactions however are not relationships. This is often misunderstood and again has to do with the difference between competency and understanding, this time in the social realm. Infants can engage in coactions as can their mothers and it is the infants' evolutionarily derived action pattern processes that allow for this. Although mothers can form relationships with their infants because they possess consciousness, infants cannot. Thus, the nature of the infant–mother relationship is complex and asymmetrical because the mother but not the child possesses Hinde's last two features. Relationships require the consciousness of both parties. In this regard, Hinde's two additional features are relevant. These two features include: (7) cognitive factors, or those mental processes that allow members of an interaction to think of the other member as well as of themselves; and (8) something that Hinde (1979) calls penetration, which I would interpret as something having to do with ego boundaries, which also has to do with the consciousness of the two participants.

If reciprocal bidirectional coactions alone (Features 1 to 6) are insufficient to describe a higher level human relationship, then an asymmetrical pattern exists between the infant and his mother. This pattern is likely to be supported by the core processes of the self in the case of the infant and by reflected consciousness in the case of the mother. Because of this, it needs to be distinguished from adult relationships because in adult relationships two sets of reflected consciousnesses are needed (Lewis, 1987). Such a view was suggested by Sullivan (1953) who argued that a relationship is by necessity the negotiation of at least two selves. Higher-level abilities are vital for a relationship because without two selves (one has only an I-it, not an I-thou), there can be no relationship (Buber, 1958). Emde (1988) also makes reference to the "we" feature of relationships, and in support of the timetable of reflected consciousness or self-awareness points to the second half of the second year of life for its appearance.

My model of mature human relationships requires that we consider different levels in the development of a relationship over time, rather than seeing it exist in the adult form from the first. Uniquely mature human relationships may arise from coactions only after the development of consciousness and the ability to represent self and other on the part of the child. From this point of view, the achievement of adult human relationships for the child has a developmental progression. This progression involves, first, coactions built into core processes which may be similar to those shown by all social creatures, and second, cognitive structures or mental states, in particular, consciousness, and with it such skills as empathy and the ability to place the self in the role of other (Lewis, 1987). The relationships of 1-year-olds do not contain these cognitive structures and, therefore, may not be like that of adults. By 2 years, most children have reflected consciousness and the beginning of such skills as empathy (Borke, 1971; Zahn-Waxler & Radke-Yarrow, 1981). Their actions toward others now approximates more closely those of the adult level. Mahler's concept of individuation is relevant here, for as she has pointed out, only when the child is able to individuate can it be said that the mature level of relationship exists (Mahler et al., 1975).

Such an analysis raises the question of the nature of the child's relationships before the emergence of consciousness. For me, relationships not built on mental states are complex social species-patterned processes, action patterns, which through adaptive processes may be evolutionarily derived features of the social organisms. It is not unlike the action of one bird's flying off a fence which sets off the other birds' flight. Some social coactions are related to complex core processes that influence others' core processes (Spunt & Lieberman, 2013; Waldrop, 1992). In humans, the best example of this being that the yawning of one person sets off yawning in another.

Working Models

The nature of higher-level relationships is dependent on many factors. These include core processes, the nature of socialization practices, the mental states of consciousness, and the cognitions about the coactions of self and other; that is, the meaning given to them by the selves involved (Bowlby, 1980). Main and colleagues (Main, Kaplan, & Cassidy, 1985) and Bretherton (1987) consider a more cognitive view of attachment, as suggested by Bowlby (1980), that of a "working model." By a working model, these authors suggest a schema concerning the mother as a secure base. By focusing attention on the child's cognitive construction rather than on just the interactive patterns of the dyad, the theory of attachment and relationships moves toward a greater realization that an attachment relationship involves the self and the mental states involved in self and other. Leaving aside the question of at what ages this occurs we find, Bowlby (1973) stating, "The model of the attachment figure and the *model of the self* are likely to develop so as to be complementary and mutually nonconforming. Thus, an unwanted child is likely not only to feel unwanted by his parents, but to believe that he is essentially unwanted" (p. 208; emphasis added). Although Bowlby confuses the model of the self and the content of the self, the idea that a child's self is necessary for the development of relationships is clear. Although Bowlby also falls into a too mentalistic language when he says that the child believes that he is unwanted, even so, such a representation must involve a child capable of reflected consciousness.

As soon as we come to consider relationships in terms of mental states or representations, we need to return to the child's capacity for consciousness. This occurs after the first year of life, somewhere toward the middle of the second year. If this is so, then our observation of the attachment relationship at 1 year reflects: (a) action patterns of coactions based on socialization patterns that the child will subsequently use to form a working model of the relationship, and (b) the adult caregiver's relationship, which includes the adult's consciousness, as well as the working model of the parents' attachment relationship with their parents.

Emotions and Consciousness

Considerable time researching and writing about the relation between emotion and consciousness has been spent in my book, *The Rise of Consciousness and the Development of Emotional Life* (2014). Here briefly summarized is my proposed model of emotional development where core processes, here referred to as early action patterns or what have been referred to as the *primary emotions* such as joy, sadness, fear, and anger, are altered by the development of consciousness, first altering these early action patterns but also giving rise to the self-conscious emotions such as embarrassment, pride, guilt, and shame.

Transformation of the Early Emotional Action Patterns

Before going on to discuss the self-conscious emotions, a consideration of the transformation of the early action patterns (called joy, fear, sadness, disgust, interest, and anger) by the emergence of a consciousness is necessary.

The argument clearly implies that in the beginning year of life, the expression of the action pattern of happy is not the same thing as experiencing happiness, if we use the definition of experience as a mental act. The rise of consciousness also enables the child to engage in deception or to manipulate these action patterns as they choose. Thus, for example, the infant's action pattern marking wariness toward a stranger seen in the second half of the first year can be used by the child in the third year to deceive her parents into believing that she is frightened so that they do not leave her with the babysitter she does not like. This manipulation of the action patterns for the child's purpose can be compared to an old distinction that has been made between signs and symbols. Recall that signs bear a one-to-one correspondence with what they are to represent, whereas symbols do not. To explain this implication, the above example of fear serves my purpose. Prior to consciousness, the action pattern of fear represents some biological connection to a set of external physical properties, a sign. With the onset of consciousness, the sign becomes a symbol; *something to be used in various ways* by the child. It is important to recognize that in development, processes are not transformed, but rather the new is added to the old. In this way, consciousness of my fearfulness is added to the old action pattern itself. This process underlies the transformation of all the early action patterns. Let us use the example of disgust, to highlight this transformational issue.

The action pattern called *disgust* has as its affordance, objects/foods that do not taste or smell good and has an evolutionary adaptive function designed to rid these noxious stimuli from the infant's mouth. Adults also have this action pattern to things that do not taste or smell good although cultural rules may alter its appearance. However, through the learning of standards, rules, and goals, we also develop moral disgust; for example, the disgust we have at the sight of one man's brutality against another. I would suggest that moral disgust occurs only when (a) a reflected consciousness emerges, and (b) when the child develops standards, rules, and goals (Rozin, Haidt, & McCauley, 2008). One effect of consciousness, then, is that it allows for the early action patterns-context association of disgust to become something that is mental, that is, ideas about moral behavior. If, as suggested, the early action patterns can become ideas, it may also be true that biological action patterns with goals can be used for all kinds of ideas. Again let me return to the disgust action pattern. If a person does not like another, it may be possible to use the biological action pattern to fuel the dislike. Thus, one can say to another who one dislikes, "You disgust me." Disgust, the idea, is then used to show contempt, to humiliate or shame the other, that is, to spit out or withdraw from them.

Whereas others have attempted to connect the early emotions with latter ones, the scheme that was used with the example of disgust can apply to all the early action patterns. In a word or two, how the action patterns become ideas. These connections are suggestive but we need to recognize that only further careful research will be able to confirm their association.

- *Disgust* as withdrawal action pattern to rid the mouth of noxious tastes and smells becomes on the one hand withdrawal as in moral disgust, and as in approach, humiliation and shame to others and the self.
- *Anger* as an approach action pattern to overcome a blocked goal becomes approach as in persistence of action in the world, or rage and aggression, and on the other hand, withdrawal as in guilt.
- *Happiness* as an approach action pattern toward familiar, becomes as an approach joy and pride, and as in withdrawal, hubris.
- *Interest* as an approach action pattern becomes curiosity and creativity, and as a withdrawal action pattern self-directed attention and somatization.
- *Fear* as both an approach and a withdrawal action pattern to the unfamiliar becomes a withdrawal pattern of anxiety or an approach as in stimulus seeking and risk taking.
- *Sadness* as a withdrawal action pattern in response to loss becomes a withdrawal pattern of shame or an approach pattern of empathy.

Creating New Action Patterns

Returning to the role of consciousness in the development of the self-conscious emotions, the role of consciousness affects two different sets of self-conscious emotions; self-conscious *exposed emotions* and self-conscious *evaluative emotions* (Lewis, 1992b). All of these self-conscious emotions require consciousness, although, as in the case of the evaluative self-conscious emotions, even more ideas are required.

Although the action patterns that appear early—such as joy, sadness, fear, and anger—have received considerable attention, the set of later-appearing action patterns has received relatively little attention. There are likely to be many reasons for this; one reason is that these self-conscious emotions cannot be described solely by examining a particular set of facial movements, necessitating the observation of bodily action, as well as facial cues. A second reason for the neglect of study of these later emotions is the realization that there are no clear specific affordance contexts for these particular emotions. Although happiness can be related to seeing a significant other, and fear or wariness can be related to the approach of a stranger, few specific situations will be related to shame, pride, guilt, or embarrassment. These self-conscious emotions are likely to require classes of events that only can be identified by the individuals in relation to themselves.

The expression of self-conscious emotions involves elaborate cognitive processes that have, at their heart, mental states about the self. Although some theories, such as psychoanalysis (Erikson, 1950; Freud, 1963/1901; see also Tomkins, 1963), have argued for some universal affordance for self-conscious emotions, such as failure at toilet training or exposure of the backside, the idea of an automatic noncognitive process of these emotions does not make much sense. These complex emotions must rest upon cognitive processes (Lewis, 1992a; see also Darwin, 1872). There may be a one-to-one correspondence between thinking certain thoughts and the occurrence of a particular emotion; however, in the case of this class of emotions, the process of its expression is a cognitive event. Cognitive factors may play a role in the expression of any emotion; however, the nature of cognitive events are much less articulated and differentiated in the earlier ones (Plutchik, 1980).

The need for cognitive processses having to do with the self was known to Darwin (1872). He suggested that these emotions were a consequence of our thoughts about other's thoughts of us, there being, therefore, no clear or universal elicitors. Darwin saw these latter emotions as involving the self, although he was not able to distinguish among the various types (see also Tomkins, 1963, and Izard, 1977, for similar problems). His observation in regard to blushing indicates his concern with the issue of appearance and the issue of consciousness. He repeatedly makes the point that these emotions depend on sensitivity to the opinion of others, whether good or bad.

Self-Conscious Exposed Emotions

Having attempted to clarify those specific aspects of self that are involved in self-conscious emotions, first let me consider self-conscious exposed emotions. The self-conscious exposed emotions have been differentiated from the self-conscious evaluative emotions because the latter require fairly elaborate socialized cognitions around standards, rules, and goals, and attributions relevant to the self (Lewis, 1992b; Lewis & Michalson, 1983). The exposed emotions consist, at least, of embarrassment, empathy, and jealousy. Although some work has been done observing empathy (Bischof-Kohler, 1991), most of the work has been conducted on embarrassment (Lewis, 1995), where I have tried to distinguish between two different types of embarrassment—one related to exposure and one related to evaluation, which has much in common with shame.

Exposure embarrassment emerges once self-recognition can be shown, around 15 to 24 months of age, whereas evaluative embarrassment does not emerge until $2\frac{1}{2}$ years. An example of exposure embarrassment is the embarrassment that occurs when one is complimented (Lewis, Sullivan, et al., 1989). Praise rather than a negative evaluation is the source of this type of embarrassment. Another example of this type of embarrassment can be seen in our reactions to public display. When people observe someone looking at them, they are apt to become self-conscious, look away, and touch or adjust their bodies. In few cases do the observed people look sad. If anything, they appear pleased by the attention. We measure exposure embarrassment by the combination of gaze aversion (turning away briefly), no frown, and nervous touching.

When I wish to demonstrate that embarrassment is expressed just through exposure, I announce to a class of students that I am going to point randomly to a student. I repeatedly mention that my pointing is random and that it does not reflect a judgment about the person. I close my eyes and point. My pointing invariably elicits embarrassment in the student pointed to. When we experimentally point to a child and call his name, it invariably leads to exposure embarrassment. In a series of studies, we have demonstrated the effectiveness of complimenting, pointing to the child, and asking him to perform, for example, dance to music, in front of us as three different elicitors of exposure embarrassment (Lewis, Sullivan, et al., 1989; Lewis, Stanger, Sullivan, & Barone, 1991).

The relation between self-recognition measuring consciousness and exposure embarrassment has been explored and we find that exposure embarrassment is significantly more likely to be seen once the child shows self-recognition. However, wariness or fearfulness are unaffected by the child's emerging consciousness (Lewis, Sullivan, et al., 1989). Thus, whereas joy, sadness, fearfulness, disgust, anger, and interest as action patterns all emerge before self-recognition and consciousness, the exposed self-conscious emotions, at least embarrassment, require its emergence. Looking at another nonevaluative self-conscious emotion, empathy, a similar result has been reported (Bischof-Kohler, 1991). This should not be surprising given that adult empathic responses require that one be able to place oneself in the role of the other, an ability that obviously requires explicit consciousness.

Self-Conscious Evaluative Emotions

Self-conscious evaluative emotions not only require consciousness but also an elaborate set of other cognitive capacities. Because of this, these emotions do not emerge until $2\frac{1}{2}$ to 3 years of age (Lewis, 1992b). They all require consciousness, as well as knowledge about standards, rules, or goals. These standards are inventions of the culture that are transmitted to the child and involve the child's learning of and willingness to consider them as their own. This process of incorporating the standards has been discussed by Stipek, Recchia, and McClintic (1992). What is apparent from this work is that learning starts quite early in life. Standards, rules, and goals imply self-evaluation, and therefore consciousness, for it would make little sense if we had standards but no evaluation of our action vis-à-vis them.

Having self-evaluative capacity allows for two distinct outcomes: We can evaluate our acts and hold ourselves responsible for the action that is being evaluated, or we can hold ourselves not responsible. In the attribution literature, this distinction has been called either internal or external attributions (Weiner, 1986). If we conclude that we are not responsible, then evaluation of our acts ceases. However, if we evaluate ourselves as responsible, then we can evaluate our acts as successful or unsuccessful vis-à-vis the standard. Finally, global self-attributions refer to the whole self, whereas specific self-attributions refer to specific features or actions of the self (Dweck & Leggett, 1988; Weiner, 1986). These are sometimes referred to as performance versus task orientation (Dweck, 1996). In every one of these processes, the mental state of the idea of me needs to be considered.

The terms global and specific are used to specify the tendency of individuals to make specific evaluations about themselves (Beck, 1967, 1979; Seligman, 1975). Global evaluations about themselves refers to an individual's focus on the total self and on her performance. Thus, for any particular action violation, an individual can focus on the totality of the self and then use such self-evaluative phrases as, "Because I did this, I am bad [or good]." Janoff-Bulman's (1979) distinction is particularly relevant here. In global attributions, the focus is on the self and performance. The self becomes embroiled in the self. The focus is not on the self's acts as in task focus, but on the self. There is little wonder that in using such global attribution one can think of nothing else, and one becomes confused and speechless (H. B. Lewis, 1971). We focus on ourselves and not on our actions. Because of this, we are unable to act and are driven from the field of action into hiding or disappearing.

Specific attributions, in contrast, refers to the individual's propensity to focus on specific actions of the self and on the task. It is not the total self that has done something wrong or good, it is specific acts in context that are judged. Individuals use such evaluative phrases as, "my action was wrong, I mustn't do it again." Notice that the individual's focus is on the task in a specific context, not on the totality of the self. These cognitions, which focus on the self, create the self-conscious evaluative emotions. Our research indicates that these emotions do not emerge until after the onset of consciousness, in the middle of the second year of life, and not until the child is capable of the complex cognitions associated with standards. By $2^1/_2$ to 3 years, these cognitive capacities are present and so is the emergence of these self-conscious evaluative emotions (Lewis, 1992b).

The role of consciousness, defined as self-reflection, is central to both classes of emotion. This self-reflected consciousness is the highest level of consciousness and should not be confused with lower levels. By using the terms action patterns, procedural rules, or the processes of the self system to denote these early levels, it appears that emotional life in its more adult form takes time to emerge, although aspects such as facial expressions can be seen relatively early.

From the point of view of emotional life, especially for the self-conscious emotions—starting with embarrassment, empathy, and envy, and including shame, pride, and guilt—consciousness as in the self knowledge of the unique set of standards, rules, and goals, the self-evaluation of one's action vis-à-vis these standards, the distribution of cause of the success or failure (responsibility), and the self attributions, either global/performance focus or specific/task focus, involves self-reflection.

Although recognizing that the separate domains of functioning, such as mentalism, social, and emotional life, are arbitrary divisions, these divisions have a heuristic value in allowing for the demonstration of the role of consciousness in each of them. Nevertheless, it is recognized that they all occur within a child and therefore must be related. Indeed, any demarcation between mentalism—knowledge that others have desires, thoughts, or motives—and social relationships as well as emotional life cannot be separated from the knowledge of ourselves or consciousness. What we know of ourselves and others is not separate, and is what makes us social coinventors within our common social niche.

CONCLUSIONS

Consciousness is not readily defined, neither by myself nor by others. This is the phenomenological experience or the idea of me, a self-reflection. The development of consciousness so defined may not be readily open to naturalistic explanations whether these are social coaction or development of brain processes, or both. The acceptance of a first person perspective requires an approximation of what behaviors may reflect it. This is especially difficult, for although it would be quite easy to examine it in language, the infant does not possess it. For example, a statement such as "I know you know that I know your name" has built into its meaning a reflecting self. I have argued that the reflected self is likely to emerge over the first year and a half of life. Its development is likely to involve social coactions as well as developmental biological processes in areas of the left temporal lobe and frontal cortex.

I have used measures of self-reflection appropriate for this age and found they include mirror self-recognition, personal pronoun usage, and pretend play (Lewis & Carmody, 2008). These measures are used in part because they reflect self-reflection and also avoid early action patterns sometimes referred to as procedural rules or core consciousness. It is important that we do not confuse the various early action patterns with later, more complex thoughts about ourselves. This has led to a consideration of a levels of consciousness approach and allows us to use the terms action patterns, procedural rules, or the processes of the self system to denote the earliest levels of consciousness from the highest level of the self system, that of self-reflection or consciousness.

The levels of consciousness analysis suggests that the earliest of the behaviors observed in the self system are not self-reflection as we understand it from the first person adult perspective. Rather, they can be seen in specific actions such as learning to pull a string which results in a desired outcome. It is only later that the reflected self emerges, and it is this level of consciousness that unites as well as organizes the various cognitive, social, and emotional domains of competence within the individual child.

To connect consciousness with emotional life, it is apparent that what is needed is to deconstruct the term emotion into affordances, action patterns, and reflected consciousness in order to develop a more powerful theory of emotional development (Lewis & Michalson, 1983). Indeed, others have made a similar suggestion, especially given that the development of these three aspects may have a different developmental course, as well as being related to different processes.

Using this analysis, it is likely that emotional life can be viewed in the adult human as made up of evolutionarily derived connections between affordances and the core processes that have been called action patterns. Although evolutionarily derived, the activation of the action patterns requires the infant's (and even fetus's) coactions with its environment. These have different temporal features as well as differences in the degree of social coactions necessary in their emergence. In addition, the demonstration of individual differences in emotional life are likely a function of other properties of the epigenetic developed biological system of the child (called, by some, *temperament*) as they coact with affordances and core processes embedded in the meaning system of the child.

Attention needs to be paid to the self-system. Although terms like consciousness, feeling, and experience are likely to cause confusion, they can best be understood as referring to different kinds of information within the self-system. An information analysis approach of the self-system allows for the differentiation of information within the system where both procedural rules or the processes of the self (core consciousness) and a reflected self or consciousness both supply data to the self system. By 2 years of age both information systems are in place.

And perhaps most importantly, the consideration of the various levels of the self-system allow for the coordination and integration of a single self in which the various domains, including emotional, social, and cognitive, form a unified whole. Thus while information at any level of the self-system allow for coordination and integration of features of the self-system, special attention need be given to the emergence of consciousness within this system, for it is here where mentalism arises, and with it the uniquely human features underlying cultural and moral behavior.

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CHAPTER 12

Development of Personal and Cultural Identities

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INTRODUCTION

This chapter is about dualisms: dualisms in general, and, more particularly, about those dichotomies of thought that set selves apart from society, and conceptually isolate individuals from their cultures. As it turns out, and for reasons that we will work to make plain, more focal questions about the suspect cleavage between selves and societies, or persons and collectives, are best approached only after first considering the foibles of dichotomies more generally. Even this, however, is too large an undertaking for one chapter (for a more general discussion of dualism's impact on human development and developmental science generally, see Overton, 2013, Chapter 2, this *Handbook*, this volume). Instead, the intent here is to proceed by giving over the early pages of this chapter to a short side trip into the much-celebrated case of Cartesian mind-body substance dualism. Even this is still too ambitious. Hundreds of thousands of pages, over thousands of years, have been dedicated to matters of mind-body dualisms. Whole libraries could easily be filled with commentaries on Descartes alone. It is enough for our purposes, however, if this introductory detour through earlier claims about the alleged vices and virtues of dualistic thought prepares us to make better sense of the alleged opposition between selves and societies.

In setting out our agenda, and otherwise declaring our intentions at the outset, it also seems appropriate to begin by confessing to what are more personal, even intrapsychic reasons for struggling to avoid reproducing the dynamics that have arguably fueled the traditional self-society dichotomy. Our motives stem from various unresolved professional identity problems of our own—problems that have given rise to our somewhat maverick program of research; an ambidextrous undertaking favoring psychology, on the one hand, while simultaneously reaching for sociological or cultural relevance with the other (Chandler, 2000, 2013; Chandler & Dunlop, 2012; Chandler &

Lalonde, 1998, 2004; Chandler, Lalonde, Sokol, & Hallett, 2003; Chandler & Sokol, 2003; Lalonde & Chandler, 2004). One unwelcomed side effect of these genera-bending efforts has been a dose of professional awkwardness, and a propensity to bump into unanticipated disciplinary roadblocks as we have worked to steer an explanatory course that meanders back and forth between matters of individual identity, on the one hand, and cultural identity, on the other.

It is told that, before the fall of the Berlin Wall, conductors on the subway linking that then-divided city were obliged to stop (as borders on the surface were crossed) and change uniforms before the train could proceed. Something not unlike this is still required of social scientists hoping to transit freely between selves and societies. Be as interdisciplinary as you will, the usual warnings go, but do not imagine that you are free to commit either the psychologists fallacy (Chandler & Proulx, 2010), by attempting to drag individualistic constructs across the border into collectivist territory, or the ecological fallacy (see Achen & Shively, 1995; Piantadosi, Byar, & Green, 1988), by imagining that it is possible to infer the nature of individuals through the study of social aggregates. That is, decades after the Iron Curtain came down, transiting social science barriers still ordinarily requires a complete change of ideological uniforms. All conceptual baggage, including pockets full of concept terms and whole methodologies, continue to belong to one or the other of these discipline-driven domains, and (should cross-disciplinary travel be planned) still need to be discarded in favor of entirely different scholarly outfits. All of this stripping down in public has grated on our own modest sensibilities, and prompted us to seek out some means of dressing up our ideas in ways that are less chameleon-like—ways that are hoped to be judged suitable on both sides of those conceptual borders set in place by traditional self versus society dichotomies.

It is not, however, automatically self-evident how we are meant to accomplish our goal of somehow supervening the barriers intended to keep selves and societies in separate watertight compartments. What has seemed clear enough is that nothing quite so ambitious is likely to be accomplished in one ground-leveling, across-the-board conceptual sweep. Rather, here a page has been taken from the books of philosophers of science such as Lakatos (1978) and Laudan (1977, 1996), who have reasoned that, although those subscribing to this or that paradigmatic framework are obliged to defend their own core concepts against all possible incursions, such paradigmatic notions are nonetheless surrounded by what have been described as belts of more satellite-like concepts—concepts that, after the fashion of overlapping Venn diagrams, can be made to successfully compute within more than one paradigmatic horizon. The notion that these and other post-Kuhnian (1962) philosophers of science have promoted, and that have been modeled in our own research, is, then, that the best hope for successfully promoting commerce between warring paradigms is to begin by capitalizing on whatever overlapping conceptual machinery they might share, and to employ this common coinage as bargaining chips in ultimately negotiating some *rapprochement*. Although saying even this much gets well ahead of the account we hope to provide here, it does, hopefully, hint at the direction this story is heading.

We take it that something like Lakatos and Laudan's stance approximates what is meant by Overton (2013, Chapter 2, this *Handbook*, this volume) who, like others, insists that detailing the demarcation criteria that separate one *standpoint, point-of-view*, or *line of sight* from the next is an important step, but only the "*first step* toward establishing a broad stable base for empirical inquiry" (Overton, 2010, p. 16; emphasis ours). The open question then becomes, what are these second and subsequent steps that need to be taken? This chapter is intended to offer a partial response to such questions by repeating some of our own efforts to get our conceptual feet beneath us. We mean to do this in three rather lengthy steps.

The first of these steps (Part I) takes up the still-live question of whether Descartes is or is not really dead. In the second step (Part II), we present certain of the contemporary claims being made about the possible merits of either resuscitating Cartesian dualism, or working to drive still further nails into its coffin. Finally, in our relatively longer third section (Part III), we suggest one possible way of escaping from such either-or alternatives by reporting out on a single case—a still ongoing program of research in which we have sought out and attempted to capitalize on concepts that lie along the belted interface of ideas otherwise wholly owned by either this or that half of the self versus society dichotomy.

This solution strategy is illustrated by drawing out ways in which both individuals and whole cultural communities share a common obligation to somehow defeat time by enduring in the face of inevitable change. In filling in the details of how notions of both selfhood and culture live in such an overlapping conceptual space, we work to persuade the reader that, unlike inherently individualized concepts such as *depression*, or uniquely sociological notions such as *urbanization*, there exists a class of familiar concepts that work equally well, and have substantial utility in both the individual and societal/cultural domains. That is, in ways not unlike those advocated by Lakatos (1978) and Laudan (1977, 1996), we argue for the existence of a belt of satellite-like concepts that can be made to successfully reside within more than one paradigmatic horizon (see Overton, Chapter 2, this *Handbook*, this volume, for an elaboration of Lakatos and Laudan's approaches to scientific research programs). Here our candidate construct is *continuity* (both personal and cultural continuity), and our target problem is youth suicide. Before any of this discussion, however, we have unfinished work to do trying to articulate what dualistic thinking has ordinarily been said to be about, and why saying such things has proved to be so contentious.

PART I: CHECKING TO SEE IF DESCARTES IS REALLY DEAD

In hopeful ways that still remain uncertain, the future of dualistic thought seems to have come to another of its habitual inflection points. Improbable as it may seem to many weaned on the works of various contributors to this volume and others (e.g., Muller & Newman, 2008; Overton, 1997, 2008, Chapter 2, this *Handbook*, this volume), there has recently come into being a whole new phalanx of pugnacious, heavily armed cognitive scientists—contenders not only prepared to champion René Descartes (1993/1641), but to go down fighting in support of the combative propositions that all are natural-born dualists, and that dualistic thought (like essentialist thought, moral thought) has been confidently shown to be an evolutionarily engineered, universal attribute of the whole of humankind (e.g., Bering & Bjorklund, 2004; Bloom, 2004; Gopnik, Meltzoff, & Kuhl, 2009; Gottfried & Jow, 2003; Kuhlmeier, Bloom, & Wynn, 2004; Slingerland & Chudek, 2011; Wellman, 1990; Wellman & Johnson, 2007).

In the opposite corner are all the rest who hope to have rejected all such arguably false dichotomies (e.g., Boesch, 1991; Eckensberger, 1996; Hodge, 2008; Ingold, 2000; Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume; Lerner, 2006; Mascolo & Fischer, Chapter 4, this *Handbook*, this volume; Mistry & Dutta, Chapter 10, this *Handbook*, this volume; Overton, 2013, Chapter 2, this *Handbook*, this volume; Valsiner, 2012; Witherington, Chapter 3, this *Handbook*, this volume). As Nietzsche (1988/1880) summed up such views,

> the general imprecise way of observing everywhere in nature opposites . . . where there are not opposites but differences in degree is a bad habit that is responsible for an unspeakable amount of pain, arrogance, harshness, estrangement [and] frigidity . . . because we think we see opposites instead of transitions. (Cited in Gjerde & Onishi, 2000)

For such reasons, the large majority of contemporary social scientists are, according to Overton (2008), "all one or another variety of contextualists in orientation" (p. 316). All of this building consensus would be less problematic than it is, however, if it were not for those pesky diehard neo-Cartesians.

None of this is secret. Even Bloom (2004, 2006a, 2006b), one of the most vocal advocates for rehabilitating Cartesian substance dualism (Hodge, 2008), is quick to admit that the current "scientific consensus [is] that Descartes was mistaken" (Bloom, 2004, p. xii)—not just a little bit mistaken, but deeply and unconscionably mistaken, all in ways thought to have regularly served as a brake on the wheel of intellectual progress, and as an impediment to our eventual scientific salvation (Damasio, 1994; Nagel, 2012). Surprise among surprises, then, who among us was not somehow blindsided by the discovery that there are those once again plotting Descartes' comeback.

Before supposing to help arbitrate these competing views it seems important to try and first take a fuller measure of how it came to pass that Descartes has, for centuries, been understood, not only as dualism's standard-bearer, but often its whipping boy. More particularly, it seems not enough to simply announce, as have legions before us, that Descartes drove a potentially fatal wedge between minds and bodies, but to also explore how he might have come to this divisive thought, and to speculate about what drove him to do so.

Exploring Contemporary Dualisms

Although many would argue that the rest are all derivative, it is important to acknowledge that Cartesian mind-body substance dualism is not the only available dichotomy. Notably, and especially for the purposes of this chapter, there are numerous others, including, for example, the supposed exclusivity of subject and object; the impassible divide between the universal and the particular, or interpretation and observation; and, most pointedly, the impenetrable division between selves and societies. Generations of those aspiring to clear thought have all been cautioned to reject as false all such forced dichotomies, and urged instead to achieve some better insight that offers a synthesis (perhaps even a dialectical synthesis) of each and every one of these reportedly destructive ways of splitting asunder what God and informed judgments have joined together. Clearly, more also needs to be said about the usual defenders of such oppositional views (see Overton, 2010, Chapter 2, this *Handbook*, this volume).

As we hope to make clear, we personally share in what has been portrayed as a common antidualistic heritage, and will be at some pains to set ourselves against first one and then another of those competing, "nothing-but" or "divide-and-conquer" undertakings (Overton, 2010, p. 12) that keep popping up. At the same time, we have provisos.

The most important proviso is that, in ways that have, perhaps, escaped notice in certain quarters, the several centuries old rebellion against Cartesian dualism has grown a bit long in the tooth, and needs to be understood as an increasingly dated rump revolt—not at all the sort of conceptual device likely to turn the crank of a next generation of developmental science (Lerner, 2012; Lerner & Benson, 2013). Perhaps Descartes really was just dozing, and not really dead after all. One could, of course, attempt to hold him up to some mirror, hoping for clear signs of life. Then, again, such reflections have a way of being more about us looking back. The alternative is to what we now turn.

Mind-Body Dualism Redux

Mind-body dualism—the thesis that minds and bodies are somehow made of different (perhaps ontologically different) stuff is a very old and shopworn idea, available in various "shades of gray." For example, not only the most orthodox of adults, but children of a surprisingly tender age regularly come to the view that their private thoughts are not automatically on public display, and almost everyone appears to appreciate that "if wishes were horses beggars would ride." Others of a more rigorous bent have notoriously arrived at still more formal dualistic doctrines including what is now famously called *Cartesian substance dualism*—a thesis that insists, along with much else, that bodies and souls are best understood as made of radically different ontological stuff, and so naturally pass, untouched, like Cartesian ships in the night.

Descartes' foundational ideas on this matter did not, of course, emerge *de nova*. The long rehearsed "Thesis of the Substantiality of the Soul" (i.e., the High Church's centuries old doctrinaire claim that "our vital activities proceed [not from our corrupt bodies, but] from an animating principle capable of subsisting in itself . . . a principle that is not itself composite, extended, corporeal or essentially and intrinsically dependent on the body" (Soul, n.d.) was, for example, already a part of every medieval schoolboys' usual catechism. Loosely related beliefs having to do with the afterlife, funerary rites, the continued existence of disembodied spirits, souls, ghosts, and so on, are naturally much older still, and are everywhere to be found within archaeological and anthropological records of societies that existed in still earlier times and in the most remote of places (e.g., Corcoran, 2001; Kim, 2001). Still more ready to hand, much of today's ordinary citizenry is typically quick to voice such dualistic sentiments (e.g., Chudek, McNamara, Birch, Bloom, & Henrich, 2013; Slingerland & Chudek, 2011), all in ways that are only partially distinguishable from the thoughts of children, religious holdouts, and the generally unschooled. In short, the live prospect that something like mind-body dualism is ontogenetically and historically early, and everywhere underfoot, is not in serious doubt.

Nor is it only our minds and bodies that, like the animals, are meant to go "two and two, each with its counterpart number" (Genesis, Chapter 7, Verse 9). Rather, it is the whole of things and our thoughts about them that commonly take on meaning only in relation to their negative corelative contraries; day and night; land and water, minds and bodies are only prototypes, widely imagined to manifest themselves everywhere at once. In ways that could be easily seen as saying much the same thing, various contemporary contributors to the relevant scientific and philosophical literatures (e.g., Bruner, 1986; Dawkins, 2006; Dennett, 2006; Lakoff, 1987) have been similarly quick to agree with William James (1878), who insisted that "to say that all human thinking is essentially of two kinds . . . is to say only what every reader's experience will corroborate" (p. 237). In short, there is no shortage of evidence and opinion available within the academy to support the common claim that people of many times and places and stripes have been conceptually inclined to sort matters into more or less oppositional categories, including the categories of minds or souls versus bodies and brains. Call all of this *dualism light*; palpable to many, but importantly different from the much stronger stuff that has so intoxicated Descartes and a recent generation of self-declared cognitive scientists and evolutionary behaviorists (e.g., Beier & Spelke, 2012; Bloom, 2004; Gopnik & Meltzoff, 1997; Gottfried & Jow, 2003; Kuhlmeier et al., 2004; Slingerland & Chudek, 2011; Wellman & Johnson, 2007)—a group for which the evident perspicacity of infants and young children, along with a sizeable dose of Darwinian orthodoxy (see Bateson, Chapter 6, this *Handbook*, this volume; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume, for critical reviews of orthodox Darwinian perspectives), is regularly taken to be sufficient evidence that Descartes was right all along.

Boosters and Scoffers

The pressing question for the moment is not, however, whether ordinary people's thoughts ordinarily work to sort things into mutually exclusive categories (including the categories of minds versus bodies), but, rather, whether Descartes (along with all of his born-again admirers) actually had it exactly right in supposing that all are natural-born substance dualists (Hodge, 2008), with all of the accompanying metatheoretical baggage that such claims automatically entail. Although some see this prospect as being just right, you will likely not be surprised to hear (or hear again) that contemporary responses to such ideas are scattered all over the map.

At one end of this array are all those born-again Cartesians (referred to here as *Boosters*) who—having gleaned what is taken to be supporting evidence from our collective past, along with state-of-the-art data focused on the behaviors of human infants—have succeeded in persuading themselves that intuitive substance dualism is not only evident in the lives of primitives, and present at the outset of life, but is thankfully here to stay (e.g., Astuti & Harris, 2010; Bloom, 2004; Cohen & Barrett, 2008; Kim, 2001; Slingerland & Chudek, 2011; Wellman, 1990).

In the opposite and better populated corner (referred to here as *Scoffers*) are all those other state-of-the-art developmentalists who—although prepared to acknowledge that certain forms of dualistic thinking have formed a persistent millstone around the neck of many current scientific practices (Damasio, 1994), and may well be part of both our ontogenetic and evolutionary history (Atran & Norenzayan, 2004) and our worst grown-up moments (Ahn, Proctor, & Flanagan, 2009)—nevertheless remain unprepared to count such dualistic ways of being as our best effort, our inevitable legacy, or the standard against which our humanity is properly measured.

Much more is scheduled to be said about both halves of this Booster versus Scoffer dichotomy, but only after having first explored another important distinction; one between what has been termed *transformational* and *variational* change (Overton, Chapter 2, this *Handbook*, this volume; Ram & Grimm, Chapter 20, this *Handbook*, this volume). Before coming to even this, however, it will prove useful to first more fully explore what Descartes actually intended by his watertight distinction between minds and bodies, and to consider what might have prompted him to divide up the world in this either/or fashion.

The Descartes We Thought We Knew

As already hinted at earlier, there is nothing particularly proprietary about dualistic frameworks, including Descartes' own version of mind-body substance dualisms. Predecessor views are centuries, even millennia old, constituting, for example, important parts of late Aristotelian thought and the work of many earlier philosophers such as Augustine. Others—various contemporary nativists and evolutionary theorists similarly eager to demonstrate young children's previously overlooked competencies (e.g., Beier & Spelke, 2012; Bering & Bjorklund, 2004; Bloom, 2004; Slingerland & Chudek, 2011; Woodward, 2003)—are equally committed to demonstrating that hardwired dichotomies of thought are documented features of the ordinary workings of all human minds. Among such neonativists accounts, even the faintest whiff of some sort of belief in disembodied spirits, or the existence of an afterlife hinted at by scrapings on some cave wall, is often seen to be sufficient evidence to convict those who harbor such imaginings as being committed mind-body dualists.

If even half of such imaginings should prove true (i.e., if, as is often alleged, some version of dualistic thought were to prove to have been present from the very outset—Bloom, 2004), then one would still be left to wonder why it is that Descartes is so regularly picked out, and either celebrated or demonized, as the father of mind-body dualism. There is, for example, no reputed father of the notion that we regularly breathe in and out. Clearly, some case need to be made for why Descartes is so widely credited with having put dualism seriously on the map, and for coming to some better understanding of what might have prompted him to do so.

Answers to the first of these questions—the one about why Descartes is so generally credited with having fathered mind-body dualism—may very well boil down to simple location, location, location (to the fact of his having been the right person, at the right time, in the right place). That is, Descartes primarily lived and worked in the first half of continental Europe's 17th century, a place and tipping-point in history where new ideas, including his own, posed and promoted the basis for the Enlightenment's eventual emancipation from God and the Church, and so helped usher in the shift from the medieval to the modern period (Husserl, 1929/1960). During his own lifetime numerous philosophers, including Galileo, were condemned and worse by the Roman Catholic Church for harboring such thoughts; a fate from which Descartes only narrowly and only partially escaped. Promoting dualistic ideas, especially those that encouraged Rationalist thoughts that ran contrary to existing Church dogma, was not an occupation that many survived. Similarly, had Descartes come along much later, many of his claims would have simply blended seamlessly into a growing chorus.

Doubt, Dualism, and Cartesian Anxiety

The second question asked above—the one about Descartes' possible motivations—is less straightforward. Even psychologists are expected to show a certain restraint when speculating about answers to such why questions. Nevertheless, the conclusion promoted here (e.g., Boyes & Chandler, 1992; Chandler, 1975, 1977, 1987, 1988; Chandler, Hallett, & Sokol, 2002) is that Descartes did not simply stumble arbitrarily onto his plan to drive a wedge between minds and bodies. Instead, he felt obligated (we would suggest mistakenly obligated) to promote such dualistic views, all in an effort to accomplish his own rescue from drowning in a bottomless pool of skeptical doubts. Throwing caution to the wind, it is further suggested that, like so many others, including not only more contemporary orthodox dualists, but also emerging adults more generally, Descartes' chosen method of radical doubt effectively condemned him to fruitlessly shuttlecock back and forth along what Gadamer (1975) termed the dogmatism/skepticism axis—a misleading binary opposition that subsequently set the stage for centuries of debate between *empiricism* and dogmatic versions of *rationalism*.

Most familiar snapshots intended to capture the bold outlines of Descartes' life and works paint a rather somber and bloodless portrait of yet another disembodied French scholar lost in 17th-century metaphysical thought. On closer inspection, however, this frozen image seems far removed from a more feverish truth. Locking minds and bodies away in watertight compartments is not the sort of isolationist tactic undertaken without good reasons. Descartes was clearly motivated. Like so many others before and after, what he assumed to be his intellectual obligation to insist that minds and bodies occupy separate realms of existence is, perhaps, better understood to have its roots in soil turned more by personal anxieties, in this case *Cartesian anxieties* (Bernstein, 1983), than by more abstract matters of toplofty metaphysics.

By his own account, Descartes struggled mightily to somehow find some way of arbitrating between a familiar, but "unrequited yearning for some absolute foundation for certain knowledge" (Chandler, 1987, p. 141), all set in opposition to his own irrepressible insight that his and everyone else's best attempts to access the raw truth risk triggering yet another nonreducible plurality of competing opinions. That is, he became convinced that to doubt that there are determinate and unambiguous criteria for knowledge necessarily leads to what he called "the dread of madness and chaos where nothing is fixed, where we can neither touch bottom or support ourselves on the surface" (cited in Bernstein, 1983, p. 18).

To rescue himself, along with others, from such madness Descartes committed to the task of identifying some Archimedian point, some taken-for-true framework on which ultimate knowledge could be grounded (Chandler, 1975, 1987). In addition to promoting some form of mind-body dualism, the outcome of this struggle was that Descartes convinced himself that he had also managed to dance his way to the end of doubt. That is, through the ruthless application of what he termed *methodological skepticism*, he eventually arrived at the redemptive conclusion that he had successfully rejected any and all ideas that were potentially subject to doubt. Because he could not escape his unwavering certainty that it was he himself who was doing the doubting—a fact that committed him, he thought, to the inescapable truth of his own existence—"*Cognito ergo Sum*" (I think, therefore I am).

Descartes' personal struggles to accommodate the unavoidable necessity of interpretation, and the consequent ambiguity of all knowledge (Sass & Woolfolk, 1985), warrant our collective sympathies. That is, we, along with an impressive list of likeminded thinkers, all know exactly what it feels like to have drunk from the poisoned well of generic doubt (Chandler, 1975, 1987), and, like Descartes, to find ourselves awash in a sea of potential relativism, where it no longer seems possible to either touch bottom or support ourselves on the surface of our ungrounded beliefs. Clearly, he was not alone in all of this.

A century later, Hume (1938), for example, said of himself that he, too, became so wrought by what he perceived to be irreconcilable differences in human understanding that he was "ready to reject all belief and reason, and look upon no opinion ever as more probable or likely than another" (p. 267). A great many others have subsequently struggled to name and corral such generic doubts. Feyerabend (1976), for example, spoke of the looming prospect of *epistemological anarchism*; MacIntyre (1981) of *metaphysical homelessness*, Rescher (1980) of *a loss of epistemic community*, and Douglas (1971) of the *specter of solipsism*. Trying to escape the same threat that we may all end up occupying eternally separated solipsistic worlds, Berger and Luckmann (1967), for example, describe the *vertigo of relativism*, Sartre (1965) a *plurality of solitudes* and Laing and Cooper (1964) *a relativistic hall of mirrors*. All of these theorists, and more, feared the same thing: that the resulting plurality of available opinion is nonreducible (Habermas, 1971); that the possibility of shareable and demonstrable knowledge risks becoming irreparably destroyed (Douglas, 1972); and that the best warrant for any belief may be no better than blind liking (W. G. Perry, 1970). In short, what Descartes saw clearly is that, given the seemingly unavoidable necessity of interpretation, the very possibility of shared belief threatens to break down irremediably, and that we are all at risk of becoming permanently enclosed within the impenetrable walls of our own personal prejudices.

Given all such sympathies and kudos for struggling to avoid otherwise finding ourselves permanently lost in thought, it will be argued here that Descartes was not only mistaken, or otherwise unhelpful, but, more importantly, that his widely shared commitment to so-called methodological skepticism (and its corrosive reliance on mind-body dualism) unintentionally, even paradoxically, proved to lay the groundwork for its own eclipse, first by British, and later not so British, Empiricism—victims all around of a shared but unsustainable conviction that "without absolute certainty everything is lost" (Gadamer, 1975).

Does Ontology Recapitulate Philosophy?

A flirting relationship with skepticism is not, of course, confined to 17th-century French philosophers (Broughton, 1978; Chandler, 1975, 1977, 1987, 1988), their progeny, or even to those who inhabit the world of more contemporary grown-ups (Chandler et al., 2002). As is widely recognized, young people, from a surprisingly tender age, come to doubt the convictions of others; especially the assumptions of those evidently less well informed than themselves (Chandler, 1988; Chandler, Boyes, & Ball, 1990). This insight is, for example, the whole raison d'être of the enterprise that has been termed *theories of mind* (Chandler, 1988).

Among the things that the theories of mind literature makes clear is that while others, for example, may mistakenly imagine that the coast is clear, from a surprising early age infants and young children already appear to understand that people do not have eyes in the back of their head, and come to appreciate instead that it is entirely possible to sneak up on someone as they naively go about believing that what they cannot see will not hurt them. That is, even infants quickly come to question and doubt the veracity of the beliefs of others less well informed than themselves (Carpendale & Chandler, 1996; Chandler & Carpendale, 1998).

The evident limitation that sets the fledgling doubts of young persons apart from those of more radical skeptics such as Descartes is that they mistakenly imagine that ignorance is the worst of intellectual crimes (Chandler, 1987). That is, what the young fail to appreciate is that, even when they and others have access to all of the same information, the constructive character of all knowledge claims still leads all of us to interpret the world differently (Carpendale & Chandler, 1996). In view of this developmental limitation, all of the doubts available to the young may be called *retail doubts* (Chandler, 1987). That is, although youth do evidently appreciate that others may well hold to wrongheaded beliefs different from their own, responsibility for such dubious beliefs tends to be mistakenly understood as due exclusively to differing degrees of access to the same otherwise self-evident and unvarnished truths (Chandler, 1988).

Interpretive Theories of Mind

The doubts of young preteens is not, however, the same thing as coming to the unsettling insight that interpretation is nonelective, that truth may lie entirely in the eye of the beholder, and that all are prisoners locked away within our own idiosyncratic perspectives and private epistemic worlds (Chandler, 1987; Chandler et al., 2002). The insight that all knowledge entails interpretation is what we and our colleagues have come to term *generic doubt*. Such generic doubts, seemingly lost on the very young and, perhaps, on those living through certain dogmatic historical moments, represents an appreciation that knowledge is irrevocably person relative.

There is, in fact, an early and sizeable developmental literature (e.g., Blasi 1976; Broughton, 1978, 1983; Chandler

& Boyes, 1982; Damon, 1977; Enright & Lapsley, 1980; Flavell, 1986; Selman, 1980), bolstered by some of our own research efforts (e.g., Boyes & Chandler, 1992), which demonstrates that something like generic doubt allows adolescents and young adults to appreciate, perhaps for the first time, that our own heartfelt interpretations of experience are not necessarily shared by others. Such threshold achievements, it has been argued (Chandler, 1975, 1987), are what newly set the stage for the emergence of *wholesale generic doubts*.

Think of *The Tragedy of Othello* (Shakespeare, 1963; Othello: Act III, Sc. iii). Think of the wicked contrivances of his supposed ally and primary antagonist Iago. Think of Desdemona (Othello's wife) and her missing handkerchief, and how its potentially suspicious whereabouts hints at prospects that, for Othello, at least, open the gates to the green-eyed monster of doubt. Think about how this is different, if at all, from Descartes' own ability or inability to any longer touch bottom or support himself on the surface. Doubts of this caliber, wholesale generic doubts, have no place among those simple, ignorance-based uncertainties of childhood. They are, instead, the newly achieved province of adolescents and young adults, along with many of history's assemblage of skeptical thinkers and dualistic philosophers.

Here, then, it would seem, is the common, but wrongheaded dilemma mistakenly imagined to be facing all of those newly alert to the generic possibility of wholesale epistemic doubts. Either there are certain dogmatic matters that lie beyond the prospect of doubt, or there are not. Such imagining—the prospect that these limited choices actually constitute our only available alternatives—are the real progenitors of dichotomous thought. According to the unrepentant skeptic, there are no settled matters, no solid flotsam that one might cling to in our sea of epistemic troubles, and we are all adrift, wet and huddling together in the dark.

Alternatively, it is possible to imagine—to dogmatically suppose—that there is (perhaps still to be discovered) some Archimedean point, some taken-for-true framework on which ultimate knowledge can still be grounded. Descartes convinced himself that he had found such a touchstone, grounded in his inability to doubt that he doubted. This dogmatic turn, we mean to argue, was his Achilles' heel, as it continues to be the fatal chink in the armor of more contemporary, born-again Cartesian *Scoffers*.

As Gadamer (1975) pointed out, however, both skepticism and dogmatism, although seeming opposites, are equally guilty of creating the same pernicious binary opposition, the same misleading assumption that between absolute certainty, on the one hand, and chaos or nihilistic relativism on the other, no viable alternatives exist. As such, skepticism constitutes not only the dialectical antithesis of dogmatism, but remains parasitic upon it. Conversely, dogmatism is skepticism's secret sharer (Sass & Woolfolk, 1985), and hovers in the middle distance as the longed-for escape from the uncertainties, rootlessness, and alienations that all skeptical views inherently entail (Chandler, 1987). As Bernstein (1983) has argued, the resulting tension between skepticism and dogmatism consequently works to create a common axis of oppositional meanings that has largely dominated Western philosophy since Descartes.

This is not the place to attempt any sort of final resolution between such forced dichotomies, between blind dogmatic commitment, on the one hand, and utter doubt on the other. Rather, it is important to point out that, through the 20th century and beyond, various theorists (e.g., Bernstein, 1983; Gadamer, 1975; Habermas, 1971) have worked to show that reliance on any such objectivism-relativism axis is both misleading and distorting. Alternatively, such theorists point out, it is reasonable to militate for the possibility of accepting the ambiguity inherent in all human experience without automatically renouncing all hope for a kind of discursive truth capable of being argumentatively redeemed by a common community of interpreters. That is, various hermeneutic and critical theorists such as Gadamer (1975) and Habermas (1971), various French structuralist and poststructuralist thinkers and phenomenologists (e.g., Heidegger, 1953/1996), and a raft of other more contemporary deconstructionist and analytic philosophers have all more or less shared the common view that the other minds problem, the egocentric predicament of person-relative knowledge, can be dissolved by attention to our common commitment to shared forms of human life, and guaranteed by our common sociohistorical traditions, and our commitments to achieve a legitimate consensus with others (Chandler, 1987).

Be all of this as it may, for present purposes it is enough to take note of the fact that we are not necessarily trapped in the 17th century, and that Descartes' rationalist solution to the problem of the ambiguity inherent in all human experience is not, in and of itself, sufficient license to justify a commitment to the scoffer's view that rationality trumps empiricism, or that driving a wedge between bodies and minds is the only way out of our shared relativistic dilemma.

If, as just alleged, contemporary thought no longer obliges us to somehow accept as undisputable gospel

Descartes' now centuries old claims about the nature of doubt, and with them his derivative ideas about the nature of the relations between minds and bodies, then we find ourselves newly freed to attempt to sort out what is and what is not worth keeping.

Perhaps highest on the list of ideas not worth preserving are Descartes' now deeply suspect thoughts about our knowledge of the material world. Descartes was certainly clear enough about his convictions that certain details of mental life lay beyond doubt. With regard to matters concerning the material world, however, he was less persuasive. It is one thing to raise doubts about our convictions concerning the reliability of sensory experience, and quite another to attempt to win the argument that any confident knowledge regarding the material world can only be legitimated by the prospect that no truly benevolent or loving God would allow us to be irretrievably deceived—a very hard sell in a world where there seem to be 10 deceptions for any purported truth. Clearly, some part of such dubious arguments succeeded in opening the door to British Empiricism and a host of subsequent materialist theories. That is, an appeal to God's benevolence has proved to be somehow less compelling than Descartes had hoped—a new set of doubts that threaten to condemn us to still another round of shuttlecocking between rationalism and empiricism, between dogmatism and doubt.

More importantly for present purposes are the subsequent doubts cast on Descartes' unbending distinction between minds and bodies. Because it was obvious, both to Descartes and others, that minds and bodies do influence one another, he was forced to adopt what is now universally understood to be the dubious conclusion that such interactions between otherwise conceptually watertight compartments needed, somehow, to be mediated by some point of mutual influence. His intemperate suggestion that such interactions might occur at the epiglottal sight of the pineal gland has gone on to constitute something of a textbook case of what have been termed *category mistakes*: If big minds and big bodies cannot be made to interact, how could it possibly help to miniaturize this problem somewhere within the dark folds of the brain stem?

The point to be made here ought not, however, to become somehow lost in yet another close-hauled debate about the potential efficacy of pineal glands. To do so would be to preserve the illusion that minds and bodies somehow belong, as Descartes imagined, to different realms of being. Rather, if we are to somehow escape this false dichotomy, it will prove necessary to come to a different set of insights. Some of these are to be found in the developmental literature concerned with what adolescents and young adults actually make of the prospect of mind-body dualism.

In What Sense Does Ontogeny Recapitulate Philosophy?

Descartes knew something important about the ways that minds and bodies are commonly understood to be different. With few exceptions, most every civilization has imagined something about personal persistence beyond physical demise. More pointedly, whether as ordinary adults, or as professionals struggling with centuries-old philosophical problems, we are all obliged to work out some way of arbitrating between the opposing poles of the dogmatism-skepticism axis. Descartes, it would seem, found a dogmatic path around this impasse. It came, however, at the costs of committing him to a belief in a benevolent God, and wedding himself to a form of mind-body substance dualism. Alternatively, and without exiting the same dogmatism-skepticism axis, he could have gone awash in a sea of relativism where he could no longer touch bottom, or support himself on the surface, where true belief was no better than blind liking. In retrospect, it now seems clear enough that these were not Descartes' only alternatives. He could, for example, have undertaken to exit the dogmatism-skepticism axis, concluding that rationality demands no more in the way of certainty than is humanly possible (Chandler, 1987). There are obviously serious differences of opinion here, and this is not the place to attempt to arbitrate between them. What does seem clear enough is that there is little or nothing in Descartes' struggles with radical skeptical doubt that will point us in a better way. He was, it seems, stuck between the rock of skepticism and doubt and the hard place of dogmatism.

One small opening out of this dilemma, a way not easily open to 17th-century thinkers such as Descartes, for whom only God could make something out of nothing, was to consider the unheard of possibility of a secular distinction between transformational and variational change.

Transformational Versus Variational Change

Without wishing to fully rehearse a distinction that has been argued to be one of the (perhaps the) fundamental building blocks of developmental and life-span developmental psychology (Overton, Chapter 2, this *Handbook*, this volume), it is perhaps enough here to say that although some things do vary as a function of the simple addition or subtraction of parts (Bynum, 2001), on other occasions things can and have been held to have passed through more dramatic, *discontinuous* or *emergent* changes that often leave the later-arriving bits hard to reconcile with what came before. Butterflies scarcely resemble caterpillars, for example, and if lead really could be successfully transformed into gold, then there would likely be little lead still lying about. Such *transformational* changes, assuming that they occur (good atomists think not), tend to be changes in the form, organization or structure of some system, and tend to unfold in some ordered or sequenced or even directional fashion, all in ways that tend to be permanent or irreversible (Overton, Chapter, 2, this *Handbook*, this volume).

Werewolves, et al.—A Metaphoric Transformation of Being the "Same" Thing

Another way of making this same distinction between transformational and *variational* change is to be had by trading on the work of Bynum (2001), a historian of the devotional and secular literatures of the 12th and 13th centuries, who elaborates a related distinction between *hybridized* and *metamorphic* change.

A student of (among other things) werewolf legends, Bynum characterizes hybridization (read variational change) as a form of species transgressions (e.g., man to wolf, maiden to mermaid, beardless to bearded lady) achieved by supposing that what is newly added (e.g., wolf fur, fish tail, beard) merely overcloths an earlier and still persistent core of essential human sameness that remains fundamentally unchanged, save for certain sidebar *accoutrement* such as long teeth that happen to subsequently arrive on the scene. By such lights, werewolves (or, for that matter, mermaids or bearded ladies or ox-men) are no more or less than the original thing plus new hairy, fishy, or horny bits.

Alternatively, it is also possible to imagine, Bynum argues, an exception-less change process that leaves no stone unturned—a metamorphic process by means of which one thing utterly transforms into something else entirely. Again, the Eucharist (bread into the body of Christ), lead into gold, butterflies that were once caterpillars, or even adults that were once infants, can and have all been seen as things transformed in just such ground-leveling ways.

In much the same ways that the *mechanistic* world views (Overton, Chapter 2, this *Handbook*, this volume; Pepper, 1942) that dominated Anglo-American psychology's conceptions of change throughout much of the first half of the 20th century and beyond championed dualisms of every sort, and worked to discount the very possibility of transformational or metamorphic change. The Roman Catholic Church, during the first millennium AD, similarly dictated that all secular change was mere hybridizations. As spelled out by Hugh of St. Victor (d. 1141), "whereas God can make something from nothing . . . human beings can only divide a thing into parts or assemble parts into a whole" (cited in Bynum, 2001, p. 22). Seen through such dualistic lenses, all truly miraculous or metamorphic (read transformational) changes were necessarily the handiwork of either God or the Devil. Then, at least, claims about godless transformational changes, wrought by merely secular means, were regarded as blasphemous and punishable by death.

It is Bynum's thesis that, toward the end of Western Europe's 12th century, and under the partial sway of the newly circulating work of Aristotle, still earlier preoccupations with only hybridized change began to give way to a different form of understanding that included the possibility of true metamorphosis. Expressions of this paradigm shift, she argues, include a renewed interest in the study of alchemy (e.g., base metals into gold); the proliferation of tales of vampires, fairies, and werewolves; and a piquing of interest in all manner of category and species transgressions (e.g., mermaids, ox-men, centaurs).

The intended relevance of all of this talk by Bynum of werewolves and 12th-century theology is to be found in the fact that, in a world imagined to be crosscut by insurmountable dichotomies—in a world where each pole within a given bipolar relation (bodies as opposed to minds; individuals in contrast to societies, etc.) is defined by its opposite, and, as Dewey (1917) put it, constitutes "its own non-negotiable whole" (p. 49), there can be no meaningful stitching up of such conceptually distinct pieces in any last-minute attempt to yield something wholly new.

Bynum's historical account also serves to bring out useful parallels to our own more contemporary and constantly shifting conceptions of change. In the wake of what has been termed the *cognitive revolution* (Bruner, 1990; Vauclair & Perret, 2003), for example, academic psychology experienced something of a renaissance of new interest in the possibility of transformational change—it can be argued that Piaget's whole theoretical enterprise is about such qualitative, transformational, systemic change (Flavell & Wohlwill, 1969; Moses & Chandler, 1992).

Although such interests continue to prosper, they now risk being eclipsed by yet another turn of the wheel that aims to privilege anything that broadcasts its supposed infantile origins or transcultural nature. As Chudek et al.

(2013) argue, adults and children from a surprisingly young age profess beliefs in souls and the afterlife (Atran & Norenzyan, 2004; Boyer, 2001), bodiless minds (spirits), mindless bodies (zombies), as well as minds entering new bodies (Cohen, 2007; Cohen & Barrett, 2008). Similarly, it is argued that cross-cultural research suggests that adults' intuitions about disembodied minds are strikingly similar across cultures (Cohen, Burdett, Knight, & Barrett, 2011). The shortest possible version of this argument is that, no matter how you dress it up, dualistic thought is both culturally ubiquitous and ontologically prime, and so needs to be seen as the naturalized, bred in the bone way in which sense of the world is ordinarily made. On such accounts, older and more ontogenetically mature thinkers may sometimes dabble in a witches' brew of imagined transformational change, but nothing that they may say or do, it is argued, alters the fundamental fact that humans are "intuitive dualists" (Bloom, 2004; Chudek et al., 2013). As such, we are all expected to genuflect in the direction of whatever is held up to be an evolutionary "truth" and transculturally "omnipresent," and to view anything that is not dualistic to its core as some sort of hybridized add-on somehow less endemically true about the human condition. Our dye has been cast, we are told—if ancients and infants and members of so-called primitive cultures appear to be in agreement then all alternative prospects are closed.

What gives such neo-Cartesian sentiments special pertinence in the context of the present discussion of mind-body dualism is the fact that much of what is currently taken to mark the leading edge of contemporary cognitive-developmental science would seem to be judged by the measure of its commitment to some increasingly dated version of classical Darwinian theory (Hodge, 2008)—a backward-looking view of hybridization on an evolutionary scale, a view largely abandoned (e.g., Damasio, 1994; Edelman, 1992; Gissis & Jablonka, 2011; Jablonka & Lamb, 2005; Keller, 2010; West-Eberhard, 2003) outside of certain closeted psychological circles that admits only to the possibility of variational change.

As it is, the highest praise in certain contemporary cognitive-science circles is reserved for those who arguably succeed in putting the earliest possible finger on what was once generally thought to be some grown-up competence. The thought here (e.g., Beier & Spelke, 2012; Bering & Bjorklund, 2004; Bloom, 2004; Slingerland & Chudek, 2011) is that, if it is possible to identify some behavior before the environment or culture or some mysterious dialectical process has yet intervened, then there will be no need to imagine anything as transformational or metamorphic change. If all that it means to be genuinely human can be shown to be already somehow fixed in the genome or in the ancient history of human evolution, then we are free to go about the business of normal science, without becoming overly bogged down worrying over things that are better understood as hybridized iterations of the virginal stuff of which we were originally made.

If, by contrast, one's explanatory horizons are somehow expanded to include the very possibility of transformational change (i.e., views that sponsor, for example, the possibility that adults are actually free to be qualitatively different from juveniles), then a different set of questions newly present themselves: What particular sort of epigenetically generated, transformational, and even emergent, structural or organizational version of ourselves are now free to entertain (Boyes & Chandler, 1992; Chandler, 1988; Chandler et al., 2002; Lerner & Benson, 2013), and where along such a scalloped developmental or historical course do yardsticks meant to measure what is natural to the human condition best find their place? Human children, for example, have short attention spans, are amateurs at human relations, commonly employ some restrictive form of logic, and tend to be functionally blind to most of the forms of social intercourse going on around them (Moses & Chandler, 1992). Similarly, a long train of cultures, including our own, have, at various moments in history, regularly sanctioned certain ways of being that their neighbors often judged to be uncivilized (Geertz, 1973; Gjerde & Onishi, 2000; Hodge, 2008). If not everyone agrees, what proportion of the available cultures need pile on to the same set of sanctions before one is entitled to proffer claims about universality?

Resurrecting the Boosters Versus Scoffers Distinction

For many contemporary neo-Cartesians—Boosters—the serious prospect that some particular way of being (however immature) tends to be commonplace often seems enough to raise its status to that of still another transcultural universal. By contrast, for those who have left conceptual room for the possibility of metamorphic or transformational change, answers to questions about what the course of evolution has left in store need not automatically be seen to be the same thing as answers to the question "What is inbuilt, or the first in some sequence of developmental achievements?" Why, your typical Scoffer might ask, is it more in keeping with what Bloom (2004) has called the *new science of child development*, to conclude that all are natural-born dualists simply because most children are, than it is to suppose that something like the newfound skepticism of adolescents similarly qualifies as yet another universal evolutionary milestone? Doing things early can be a good thing, but it is not the same thing as a measure of what seems, for the moment, to be our ontogenetic destiny.

Unsurprisingly, then, the lines drawn here between Boosters and Scoffers would appear, not only to have to do with the limited problem of dualism per se, but turn, instead, on a whole spectrum of related metatheoretical demarcation criteria, including (as a particular instance) the key question of whether change can be transformational, in addition to being merely variational. Seen from this altitude, simply drawing attention to the fact that juveniles, along with various ancient and so-called primitive groups, tend to have heads full of spirits and ghosts need not be taken as the same thing as actually showing, as Bloom (2004) and others cited above have proposed, that some homespun version of "dualistic thinking comes naturally to us" (Bloom, 2004, pp. xi–xii), and so defines the limits of our possible understanding of mind-body relations. Why not suppose instead that whatever early and sometimes persistent impulse there may be to envision minds and bodies as walled-off within hermetically sealed conceptual containers is actually better understood, not as both the alpha and the omega of human ontogenesis, but, rather, as merely symptomatic of a developmental phases along the way toward reproductive and other sorts of maturity? These and questions like them have shaped the better-elaborated working models of those Boosters and Scoffers whose theoretical positions are briefly sketched below.

PART IIA: SCOFFERS—THE NEW OPPOSITION TO CARTESIAN SUBSTANCE DUALISM

Although, as briefly outlined pages earlier, Cartesian substance dualism appears to be finding a new home among certain groups of contemporary cognitive scientists, critiquing Descartes, along with representatives of other archaic forms of substance dualists, has been such a popular and well documented enterprise over the past century (Hodge, 2008) that it is all but impossible to belatedly join in without simply repeating in brief what others have already said more fully. Consequently, only a short set of *CliffsNotes* is offered here. Our guide will be Overton (e.g., 1997, 2008, 2010, 2013, Chapter 2, this *Handbook*, this volume) who, over decades, has served as a standard bearer in a sustained and systematic crusade against what he describes as *split metatheories*.

Of course, Overton is not the first or only major contributor to this critique. Well over a century ago, Nietzsche (1988/1880, p. 67)—as quoted earlier—wrote that his generation, like our own, is everywhere plagued by the same "general imprecise way of observing everywhere in nature opposites . . . where there are not opposites." Four decades later Dewey (1917, 1925) echoed much the same sentiment, stating that "dualism appears to me only two monisms stuck loosely together, so that all the difficulties in monism are in it multiplied by two" (p. 491). Geertz (1973) cautions us that, not unlike our troubles with split minds and bodies, or selves and societies, "The thing to ask about a burlesqued wink or a mock sheep raid is not what their ontological status is. It is the same as that of rocks on the one hand and dreams on the other—they are things in this world" (p. 10).

Not wishing to be further drawn into some competition over who can produce the longest slate of pithy antidualism quotes, it is perhaps enough for present purposes to simply state that a long list of contemporary scholars' scholars (e.g., Boesch, 1991; Eckensberger, 1996; Ingold, 2000; Latour, 1993; Witherington, 2011) still rank dualism right up there with the worst of mortal sins, and often provide advice about how it is best avoided.

Here, according to Overton (1997, 2010, 2013, Chapter 2, this *Handbook*, this volume), is what he and others are so critical about. Despite occasional tips of the hat to some off-the-shelf, additive brand of contextualism, much of contemporary psychology, he argues, remains committed, not only to a 19th-century epistemological empiricism, and an early 20th-century neopositivism, but, more problematic still, continues to be lost in a 17th-century ontological dualism—a form of Cartesian substance dualism that splits subject and object, mind and body, nature and nurture, structure and function, ideas and matter, as well as the individual and society, into bipolar pairs, with each fragment presented as "independent, individual, isolated, foundational parts of an aggregate reality" (Overton, 1997, p. 327).

The standard approach to managing such antinomies, Overton argues, has been to elevate one concept of the pair to a privileged position, while treating the other as a sort of epiphenomena or shadow of the machine. It is because of such divide-and-conquer strategies, he insists, that the field has ended up with so many erstwhile exclusionary accounts that simply turn a blind eye to either societies and cultures, on the one hand, or genes and neurons on the other, and so continually blunder into otherwise evident obstacles that those with one eye patched never seem able to foresee. Least sympathetic of all, Overton finds, are all of those *interactionists* who treat the aggregate as if composed of additive bits and pieces.

What is required, if there is to be an eventual repair for all of this, Overton reasons, is the adoption of some new and more *synthetic approach*, some *relational standpoint* that works to coordinate and resolve the tensions between all of those bipolar concepts previously locked into separate sealed off boxes. Although the necessity of some such reframing of metatheoretical postures is compelling enough (see Overton, Chapter 2, this *Handbook*, this volume), the practical problem faced by those of us wishing to take such advice to heart is that, as the natural inheritors of centuries' worth of dualistic thought, whole vocabularies of *split* concept terms have been built up, as has an entire toolkit bursting with dualistically inspired methods and accompanying standards of research excellence, none of which are easily set aside. Struggling to be a reformed dualist, it seems, is a bit like swearing off on swearing. We may bite back our words, but, sotto voiced, they keep echoing in our heads. The enduring success of various children's games, such as "Simon says" and "Mother may I," should be enough to convince us that more is required to get ahead than simply remembering to say or not say certain words.

Such fears of being locked in place by our own histories and languages may or may not be enough to create a certain sympathy for all those social scientists who continue to tacitly or reflexively employ what Overton calls *split approaches* in their work. Whether that well of sympathy is deep enough to drown out any animosity you may feel toward those who practice that new form of belligerent, in-your-face dualism endorsed by those we have previously described as Boosters will be put to the test by your reactions to the sections that immediately follow.

PART IIB: BOOSTERS—THE NEW CARTESIAN DICHOTOMISTS

As already noted by Hodge (2008), the *Boosters* position is given its most vocal expression in Bloom's 2004 broad-ranging, pop-psychology book entitled *Descartes' Baby*—a looping anecdote-filled, yet often entertaining account that harbors eclectic ambitions to cover just about everything from the mindreading abilities of still swaddled infants, to commentaries on "Good and Evil," disgust, the fine arts, Gods, souls, and science. "The premise of this book [Bloom announces] is that we are dualists who have two ways of looking at the world: in terms of bodies and in terms of souls" (p. 191). In doing so, he argues, all humans "implicitly endorse a strong substance dualism of the sort defended by philosophers like Plato [sic] and Descartes" (Bloom, 2006b, p. 8). "A direct consequence of this [he claims] is the idea that bodies and souls are separate. And from this follows certain notions that we hold dear, including the concepts of self, identity, and life after death" (Bloom, 2004, p. 191).

In an initial effort to "lay out the foundations of infants mental development" Bloom begins *Descartes' Baby* by saying "that before they can speak or walk or control their bowels babies see the world as containing both physical things, which are governed by principles such as solidity and gravity, and immaterial minds, which are driven by emotions and goals" (Bloom, 2004, p. xiii). "Babies [he claims] are natural-born dualists. They are dualists [he says] in the same way that they are essentialists, realists, and moralists. They are dualists in the sense that they naturally see the world as containing two distinct domains, what Wellman (1990) calls physical objects and real events and mental states and entities—what I have described as bodies and souls" (Bloom, 2004, p. 199).

Although happily acknowledging such views as his own, Bloom rightly avoids claiming any special originality for the bulk of such extravagant ideas, and presents himself instead as merely channeling the long dead Descartes. "It is clear [he says] that the mind and body have different properties. The Body is extended in space; the mind is not. The body is divisible; the mind is not. There are two distinct 'substances': a body, which Descartes was perfectly content to think of as a 'well-made clock,' and a soul, which is immaterial and intangible" (Bloom, 2004, p. 194).

Bloom is, of course, not the only available Booster. He cites approvingly, for example, the work of Wellman (1990), who he describes as undertaking to similarly sum up "the modern developmental evidence" (Bloom, 2004, p. 199). "My own position [Wellman (1990) is quoted as saying] is that young children are dualists, knowledgeable of mental states and entities as ontologically different from physical objects and real events" (p. 199). Bloom's book, and other of his writings (e.g., Bloom 2006a, 2006b) are similarly full of still other references to the writings of colleagues (not all of whom would be content to have themselves counted among the Booster class), whose work is similarly judged (at least by Bloom) to be supportive, and so are also awarded the presumably honorific title of being similarly modern.

Nor, it is important to stress, is all of the evidence on display in Bloom's book about infants. Quite grown-up people, especially Indigenous people, are similarly caught red-handed believing in all manner of ghouls and ghosts and things that go bump in the night. The same is true of other more thoroughly grown-up and modern types, those whose often implicit commitments to Cartesian substance dualism are said to be revealed through their funerary practices, their less than rational attitudes toward forgeries and knockoffs, and their inconsistent reactions to various other things that some, but not others, find disgusting.

Like many other *foundationalist* thinkers, whose ideas are encumbered by an unbridgeable distinction between minds and bodies, Bloom opts, whenever possible, for bodies; preferably bodies so fresh as to have no tread marks left on them by experience. Presumably like Descartes, he regards "intuitive dualism" as innate (i.e., biologically determined) (Bloom, 2004, p. 195), and consequently "a human universal" (p. 46). He does not stop here. "Given that the foundations of mindreading are inborn," he claims (p. 31), "we do not have to learn that other people know things and want things and have beliefs, emotions, desires, and feelings. This comes for free" (p. 24). Awkwardly, the notion of *for free* is left largely unelaborated. Similarly, "the roots of morality are [said, by Bloom, to also be] innate" (p. 100), as is the *essentialist* bias, which is similarly said "to actually [be] a human universal" (p. 46). Who knew? Some, ourselves included (e.g., Chandler et al., 2003), have years' worth of data indicating that some cultural groups evidence an essentialist bias or some brand of intuitive dualism, whereas others do not.

Although much was done in the case of the Scoffers crowd, where Overton was made the standard bearer, Bloom (2004, 2006a, 2006b) has been earmarked here as the spokesperson for a whole modern group of Boosters (e.g., Bering & Bjorklund, 2004; Gopnik & Meltzoff, 1997; Wellman, 1990) who are not only drawn to Descartes' notions of substance dualism, but similarly credit him with being a kind of Nostradamus whose 4-century-old ideas have somehow mysteriously divined our true essence and successfully prognosticated our futures.

Boosters presumably chose to endorse the idea that Cartesian dualism is alive and well not simply out of some shared wish to have an ancestor, but because they are convinced by their own empirical evidence that he was right. This leaves open the question of how good that evidence actually is.

As was done in the preceding two sections, a far from disinterested standard bearer will be chosen from the wide array of available critics (e.g., Boyer, 2001; Damasio, 1994, 1999; Nagel, 2012), in this case Hodge. In his 2008 article "Descartes' Mistake: How afterlife beliefs challenge the assumption that humans are intuitive Cartesian substance dualists," Hodge takes the time to sift through Bloom's evidence, and so proves himself to be a Booster's worst nightmare.

PART IIC: CRITIQUE OF THE NEO-CARTESIAN BOOSTERS

In his 2008 article Hodge presents arguments and evidence that are meant to deeply undermine the revivalist claims of Boosters such as Bloom (2004; 2006a; 2006b), Bering and Bjorkland (2004), Slingerland and Chudek (2011), Wellman (1990), and others who argue that intuitive substance dualism is the universal, natural, default position common to all of humankind. More particularly, Hodge argues that such dualistic views neither map cleanly onto many artifacts of human history (including most cultural iconography, funerary rites, or representations concerning the deceased and the afterlife), nor do they map onto a large body of available developmental and cross-cultural research (e.g., Barrett & Keil, 1996; Harris & Gimenez, 2005; Richert & Harris, 2006) that calls into question the prospects that young people, or anyone else, for that matter, necessarily share in any or all of the key dualistic assumptions that the mind and body are different substances; that the mind and soul are intentionally identical; or that the mind is the sole source of identity.

DUALISM LIGHT

Finally, Hodge (2008) makes a useful distinction between what he calls dualistic thinkers in the *broad* sense, who suppose that all tend to conceptually sort information into more or less mutually exclusive categories (e.g., Bruner, 1986; James, 1878; Lakoff, 1987), and others, such as Bloom (2004), who seems ready to make a necessity out of what may be historical and geographical accidents.

Of course Hodge is not the final arbitrator of what is clear or correct concerning the pros and cons of either Bloom's writings, or of neo-Cartesian thought more generally. What does seem clear enough though is that, both well before and after Descartes, and using the cognitive skills available to them, people of every stripe have struggled with how best to restore some harmony to the pieces of experience they keep tearing off. In the cultural context of the Greco-Roman, Judeo-Christian, post-Enlightenment worlds in which most of our contemporary, Euro-American social sciences have evolved, frameworks of understanding have been created that seem predisposed to locking much of our experience into watertight oppositional compartments. Perhaps, as Bloom's (2004) "new science of child development" alleges, this is all because all are natural-born dualists. Alternatively, such either-or forms of thought may only be characteristic of a certain early ontogenetic or historical moment that, given the prospect of transformational change, will give way to other ideas that are more synthetic. In any event, it would seem that among one's possible moves are either to embrace dualism and stop complaining, or, all of our culturally inspired dualistic baggage notwithstanding, to undertake to mount some enterprise aimed at bringing us all to some other less bifurcated place. Part III, to follow, is all about our attempts to pursue this second option.

PART III: DECONSTRUCTING THE PERSON–CULTURE DICHOTOMY—A PSYCHOLOGICAL AND CULTURAL CASE STUDY OF YOUTH SUICIDE

The third and final section of this chapter begins by drawing attention to the fact that, although typical 21st-century social scientists have supposedly been fully inoculated against the contagions of dualistic thought (especially those that threaten to isolate individuals from their sociocultural surround), most such immunization efforts seemingly offer only partial protection. Instead, many of these acquired antidualistic sentiments appear to run only skin deep. That is, notwithstanding a common lip service paid to *interactionism* and all things contextual, if one scratches the surface of most contemporary psychologists and sociologists, what comes quickly to light are persistent blood-thick ties to a common "Judeo-Graeco-Roman-Christian-Renaissance-Enlightenment-Romanticist philosophical tradition" (Rorty, 1987, p. 57)—a mode of thought within which every concept is still reflexively defined in relation to its negative corelative contrary. In short, like *Funes, the Memorius*, Borges' (1942) unforgettable protagonist destroyed by his inability to forget, most of us continue, often behind our own backs, to harbor the same pernicious, Cartesian-like tendency to dichotomize everything in sight—minds are still quietly held to be distinct from bodies, causes are required to keep their distance from effects, and individuals and their cultures are seen as in need of being carefully kept apart. This could either mean that Bloom and company have it exactly right, and that we are, in fact, natural born dualists, or, alternatively, it is possible that our most time-honored paradigms of thought are as stubbornly resistant to change as Kuhn (1962) and others have alleged, and are abandoned only well after their rope has already fully run out. Something urgently needs to be done about all of that. Part of a common theme running through this volume is that we may be poised on the edge of an anticipated transformational moment—a moment in which dualism seems on the verge of slipping from its familiar perch. What follows is a condensed version of our own effort to nudge this process along.

Most contemporary social scientists have been officially alerted to the alleged inevitability of some such impending paradigm shift, and should anyone risk forgetting, an elite group of metatheoretical prognosticators keeps reminding us (and have reminded us for most of a century) that the end of our old ways of thought is drawing near (e.g., Boesch, 1991; Damasio, 1994; Ingold, 2000; Latour, 1993; Lerner & Benson, 2013; Overton, Chapter 2, this *Handbook*, this volume). Despite such cautionary advice, most of us appear to simply go on, as we have before. Perhaps there should be no surprise in all of this. Who would have actually thought that it would be enough to show and show again that the real challenge for our discipline is to find some alternative countersynthesis, some better embodied, more relational solution that aims to dissolve traditional dichotomies of thought. As Smith (1974) put it, psychology may well have emerged from a tradition of Enlightenment thought, but it continues to remains fully embedded within it.

It is argued here that successfully finding some new path out of such old predicaments often turns on the availability of demonstration projects that work to show the utility of certain small concrete steps leading around previous obstacles. What is needed are demonstrations by example that show new ways of holding both halves of some old antinomy within the same awkward embrace. Our aim, in what follows, is to argue that empirical evidence about the intimately related notions of *personal continuity* and *cultural continuity* may well serve to model just such beginning steps. More pointedly still, these constructs will be used to justify a program of research that has aimed to make sense of the otherwise incomprehensible problem of youth suicide, both as it occurs in troubled individuals and in whole cultural communities.

Taking our own advice, we mean to similarly approach these complex issues in a series of small steps that begin by first aiming to get clear about what is intended by the notions of personal and cultural continuity, before focusing on the more specific issue of youth suicide. Finally, before concluding, a brief recap is provided of certain key results from a two-decade-long series of studies aimed at demonstrating that the construct of *continuity* survives the usual deal-breaking divide between psychological and sociological accounts of suicide, and potentially offers a different starting point for those hoping to find a way of reconciling the troublesome dichotomy between self and society.

One key manifestation of the familiar self versus society dichotomy that has been the intended and eventual focus of this entire chapter has been the divisive claim that single individuals and whole cultures are not only cut from very different bolts of cloth, but need to be studied using concepts and methods that have real currency only within the confines of their own disciplinary domain (Chandler & Proulx, 2008; Sani, 2008; see also Mistry & Dutta, Chapter 10, this *Handbook*, this volume). On such a familiar reading, suicide (our working case in point) must be imagined, for example, to be, either the outcome of deeply interiorized psychodynamic forces operating within the closed circuit of "self-contained individualism" (Cushman, 1990, p. 599), or, alternatively, understood to be the by-product of larger, more tectonic forces loose in the supraindividualistic world of shifting sociocultural affairs (Durkheim, 1897/2002; Sani, 2008).

Our best hopes of successfully escaping these well engrained dualistic traditions lay in: (a) a choice of constructs that have some prospect of being similarly cashed out in both individual and cultural economies of thought; and (b) the selection of a common research problem that has captured the attention of research communities on both sides of the self-society divide. As suggested earlier, our candidate construct is continuity (both personal and cultural continuity), and our target problem is youth suicide. In what immediately follows, better justification is provided for both of these perhaps less than self-evident choices.

Personal and Cultural Continuities

A chapter such as this, which puts the notion of *continuity* (the continuity of both selves and whole cultures) front and center, would do well to begin by first undertaking to make as clear as possible the sort of thing that continuity is taken to be. Doing so, however, turns out to be less straightforward than one might hope, and this is because the act of judging certain things to be more or less continuous than others is not best understood as simply picking out some list of identity-preserving features or attributes that objects do or do not have, in some measure. Rather, judging something to be persistent or continuous with itself is more like an *interpretive achievement*—a functional equivalency claim, or relational assertion about the purported intersubstitutability of two otherwise recognizably different identities. In short, the concept of continuity, as unpacked here, is less like a thing than a *practice*—more a solution strategy than yet another object or attribute of the environing world (Chandler & Proulx, 2008). Becoming clearer about all of this turns on first having something helpful to say about sameness and change.

Sameness

The interpretive problem that all claims about continuity are meant to solve arises out of the inherently paradoxical relation that obtains between time and existence. On the one hand, things (including ourselves and our cultures), if they are to be seen to exist at all, must be understood to do so "in time"—they must somehow be taken to *persist* in ways that allow them to be identified, first at one point in time, and then reidentified later. If this were not so, if any of the putative things in which we are interested proved to be wholly ephemeral and simply winked in and out of existence, then all talk about them would prove incoherent. The prospect of persistence or the continuity of things (including persons and cultures) is, then, so foundational a part of our sense of existence in general, and of selfhood and cultural identity in particular, that any account of ourselves and others that did not make adequate provision for our somehow understanding them as necessarily long-lasting would strike us as fundamentally nonsensical (Luckmann, 1979).

More particularly, if, at the best of times, we and our cultural confreres could not be somehow regarded as numerically identical (i.e., as deserving of being counted only once), then all backward-referring notions of duty and responsibility, and all forward-anticipating expectations about future prospects and just deserts would cease to have any interpretable meaning (Luckmann, 1979). For all of these and still other reasons, then, the minimal prospect of first identifying and then reidentifying ourselves and others as somehow understandably self-same has been regularly thought to count as a constitutive condition for what things, and persons, and even whole cultures are ordinarily taken to be. Imagine, to take just one example, the impossibility of St. Peter's job of guarding the Pearly Gates, if, every time we turned over a new leaf, we became a new soul in the world. Take another. Whole cultures are distinct from mere milling crowds only because their members maintain a common tie to a collective past, and hold a stake in each other's shared futures.

Change

Having argued against the notion of there being any prospect that identity can get by without some sense of sameness, here is the other issue. Time only manifests itself as things changing—a fact that threatens to render any existential criteria for sameness impossible to attain (Fraisse, 1963). Clearly, our bodies change, our beliefs and desires (along with our projects and our commitments and our interpersonal relationships) all change, often seemingly beyond all recognition. Cultures, too, are never static—one of the many painful reasons that you really can't go home again. In short, persons, along with our cultures, are like sharks, gill-less and awash in the temporal stream. If we stop moving we die. If this were not so, if human existence was not temporally vectored, and if change did not lie at the heart of subjectivity (Gallagher, 1998), then, as Unger (1975) points out, we could not understand the experience of innovation in our lives or novelty in the flow of our collective history (Chandler, 2001).

Self- and Cultural Continuity: Why Personal and Cultural Persistence Matter

In one of his last books (*Experiments in Contradiction*), Piaget (1980), along with Bullinger, described a series of studies involving children's comparative judgments regarding the relative size of a graduated series of chain-linked tokens, all carefully milled in such a way that, while each disk in the sequence was only marginally (and so subliminally) larger than its predecessor, items paired from opposite ends of the series were of an evidently different size. When faced with the task of making required side-by-side comparisons, young school-age children were quick and confident in their judgments of "no difference." When, however (and this was the whole point of this duplicitous exercise), they were confronted with more remote comparisons, many children found themselves confounded by what has been termed the *paradox of sameness and change* (Chandler & Lalonde, 1998). How, they puzzled, could it be that one instantiation of demonstrable equivalence after another could possibly result in such obvious discontinuities? How could sameness, sameness, and sameness add up to a required judgment of different?

Although it was not Piaget's manifest intention to begin a commentary on personal or cultural identity, it remains true that he did intend to engage one of life's deep mysteries—how are we to understand the crossing of boundaries (transitions from being one way to being another) without the loss of those continuities upon which the persistence of all identities—including personal and cultural identity—depend? More is obviously at stake here than the interchangeability of tokens.

The most widely discussed and otherwise accessible instance of such paradoxical relations between sameness and change is to be found in the case of *personal persistence*. Prodigal sons are everywhere underfoot, and, whether after years in the desert or just a simple trip to the corner store, we would all like to count ourselves, and be counted by others, as numerically identical—as somehow recognizably self-same or continuous despite whatever intervening changes time may have had in store. In fact, the concepts of both personal and cultural identity can be seen to rely on just such a warrantable sense of persistence—of finding some way of overcoming the false dichotomy between sameness and change.

The 20th-century philosopher Nozick (1981) has offered a useful terminology for addressing the usual dichotomy between sameness and change. Not unlike Piaget's graduated disks, you are, at this immediate moment, no doubt, interestingly different from the you of only moments or days or a lifetime earlier. If, however, we were to cast about in search of the best approximation of contemporary you, then the most likely candidate (what Nozick called the *closest continuer*) might well be, under ordinary circumstance, the you of only moments before. You, and marginally earlier instantiations of you, are, in this sense, analogous to two more or less adjacent Piaget-like tokens, awash in the stream of your own gradually transfiguring identity. Life, however, is long. Even childhood pictures of ourselves often confront us as strangers, and we all struggle to recognize ourselves across this or that conversion experience.

What about the less ordinary? What about you across a lifetime of such conversions; remote tokens, perhaps, freed from a common chain? What if you were, in fact, the prodigal son with only remnants of your former coat of many colors left over to identity you as legitimately being good old you—the rightful inheritor of your own just deserts? Would your indelible strawberry birthmark suffice to make the case? What if, in the interim of your absence, you had had a psychotic break, or a ground-leavening religious conversion, or had (like Descartes) fallen into a pit of despair? What about former caterpillars, now with their resplendent butterfly wings, or what about you now all grown up? All such extravagant (metamorphic?) transformations notwithstanding, we would again be up against it, confronted by the paradox, the same false dichotomy between sameness and change. Your task would still be to find some way of making sense of how it could be that, following an endless chain of small potatoes changes, you find yourself confronted by radical, potentially identity-destroying differences.

You are not alone in puzzling over such matters. In addition to somehow imagining that you are still changeable old you, imagine that you are St. Peter, whose task is to triage various old souls in and some out of the Pearly Gates. Are true conversions possible? Can some sins actually be washed away, and is it really possible to emerge pure as the newborn lamb? Are there more souls in the world than people born into it? No wonder the problem of numerical identity has been a theological thorn in the side—an accounting nightmare—for clerics over the millennia.

At least as it is taught in standard European American intellectual history (e.g., Cassirer, 1923; Habermas, 1991), any followable conception of selfhood or culture necessarily presupposes some way of summing across the various inevitable changes that time has in store. It is for such reasons that any account of identity (whether personal or cultural identity) that lacked provisions for linking each of us up with the persons and the cultural groups with which they identified, consequently, would prove fundamentally nonsensical.

Continuity as a Constitutive Condition of Self and Culture

Wary readers who find something dangerously enigmatic about talk of self- and cultural continuity are, arguably, within their rights. Perhaps, along with Deleuze (1994) and Derrida (1978) and Gergen (1991), and a whole army of increasingly dated postmodern theorists, personal and cultural persistence is little more than a Western myth. Perhaps, according to such post-everything accounts, we, along with Kierkegaard (2000/1843) and other assorted holdouts for coherence, are simply standing ankle-deep in the same Enlightenment trickle-down, and should all be looking to lose the Locke and lighten up (Proulx & Chandler, 2009). Maybe, but we think not.

Our warrant for arguing for the centrality of self and cultural continuity turns on the claim (to be elaborated below) that continuity is, in fact, a *constitutive* condition of anything that it could possible mean to speak of personhood or culture at all. As Harré (1979), Rorty (1976), and a host of other more or less contemporary philosophers (e.g., Maclntyre, 1977; Wiggins, 1971) have argued, some sense of personal and cultural persistence seems a minimal requirement for imagining any sense of responsibility and commitment, or the creation of any sort of moral order. As such, any claim to selfhood and community that did not include some discursive means meant to argumentatively redeem the implicit claim for self- and cultural continuity would, as Luckmann (1979) argues, be nonsensical. Further, and as more than two decades of our own research has shown (e.g., Ball & Chandler, 1989; Chandler & Ball, 1990; Chandler, Boyes, Ball, & Hala, 1986; Chandler et al., 2003; Chandler & Lalonde, 1998; Chandler & Lalonde, 2009), should all such efforts to interpretively override whatever false dichotomy wrongly divides sameness and change ultimately fail, then life becomes cheap, responsibility for self and others fly out the same window, and, for the first time, even suicide becomes a live possibility.

Here, then, is the problem that all need to solve. Because both selfhood and culture are acknowledged to be everywhere temporally vectored (Gallagher, 1998), no one seriously doubts that change is real. Our bodies change, our beliefs and desires, along with our projects and our commitments and our relationships, all change, often seemingly beyond all recognition. All ironies aside, change deserves, then, to be counted as a permanent fixture of our existence, and so seen to lie at the heart of both subjectivity and intersubjectivity. If it did not, then, as Unger (1975) reminds us, "we could make sense of neither the experience of innovation in the lives of individuals, nor novelty in the flow of human history" (p. 56).

Talk of change is, of course, only half of a matched pair; here is the other. No one (or at least no one apart from the occasional scorched-earth postmodernist) seriously believes that everything is simply change and flux (Chandler, 2001). This follows because change, though no doubt inevitable, is rarely exceptionless. If this were not so—if nothing about us remained sufficiently the same as to ensure our reliable reidentification—then life as it is ordinarily understood would simply have no meaning.

The interpretive problem that we are all obliged to somehow solve arises, then, out of the inherently dichotomous (and so paradoxical) relation that obtains between sameness and change. On the one hand, things (including ourselves and our communities), if they are to be seen to exist at all, must do so in time. That is, they must somehow *persist* in ways that allow them to be identified, first at one point in time, and then another. If this were not so, if nothing survived and things simply winked in and out of existence, then all talk of things, let alone all old obligations and new future prospects, would all prove to be fundamentally ephemeral and incoherent. Persistence in the face of change is, for such reasons, so foundational a part of our legal and political and theological conceptions of moral responsibility (Rorty, 1987), and so integral to our hopes for a bankable future, that any account of ourselves and others that did not make adequate provision for our somehow understanding one another as persistent would prove empty of meaning. For all of these and still other reasons, then, the minimal possibility of first identifying and then reidentifying things (ourselves and our communities included) as somehow self-same in time is standard thought (e.g., Habermas, 1991) to count as a constitutive condition for what things, and persons and cultures, are ordinarily taken to be. It simply will not do, for example, if someone, in the shape of some older and more shopworn version of his former self, turns up insisting that he is, in fact, the returning prodigal son. You want and expect proofs and bona fides, and, in order for him to make a believer out of you, he is required to do something, either by pointing to his indelible strawberry birthmark, or otherwise convincing you of some continuous plot or causal chain that makes him, if not the author, then at least the center of narrative gravity of his own storied life (Dennett, 1992). Continuity, taken in this more practice-oriented sense, is, then, the interpretive stuff that serves to give personal and cultural identity a fighting chance. All of this is so because, as Strawson (1999) puts it, there is,

> a deep presumption that if one is arguing for the existence of the mental self [or a working culture], one is arguing for something that exists for a substantial period of time . . . a diachronic singleness [that] allows one to regard the series of thoughts and experiences that make up one's life as the thoughts [and experiences] of a single self (p. 10) or enduring community.

Although it is, perhaps, possible to playfully imagine that either sameness or change is mere illusion, it is not possible to seriously manage one's personal or social life on such either/or assumptions. Instead, driven by the absurdity of the consequence to which such a split position (Overton, 2013) would inevitably lead, our common obligation is broadly taken to be one of working out how selves and cultures "can embody both change and permanence simultaneously" (Fraisse, 1963, p. 10).

Assuming, then, that neither personal or cultural sameness, nor change, can be made to work alone, what is clearly needed is to arrive at is some viable way of understanding selves and cultures as both simultaneously fixed and ongoing. Continuity, then, as the term is used here, is not a synonym for simple sameness, but, rather, a cover story for whatever interpretive achievements make it possible to hold both sameness and change in the same awkward embrace.

This notion—the ideas that self- and cultural continuity constitute a requirement for any sort of workable identity—is among the oldest of our old ideas. In the first chapter of Book Two of his *Physics*, Aristotle, for example, states that "animals differ from what is not naturally constituted in that each of these [living] things has within it a principle of change and of staying unchanged" (cited in Wiggins, 1980, pp. 88–89). More than a millennium and a half later, Locke, (1694/1956) similarly wrote in *An Essay Concerning Human Understanding* that, in order to meet even the minimal condition for identity, it is necessary to consider one's self and one's community "as the same . . . thing in different times and places." Nearer to our own times, William James (1910) likewise made continuity a cornerstone of his conception of identity, as have a long list of more contemporary philosophers such as Cassirer (1923), who spoke of *temporal unity*; Chisholm (1971), who talked of *intact persistence*; and Strawson (1999), who emphasized what he calls our *diachronic singleness*.

Each of these accounts, and those of many more contemporary philosophers (see, for example, Harré, 1979; Hirsch, 1976; MacIntyre, 1977; Parfit, 1971; Rorty, 1976; Taylor, 1991; Wiggins, 1980), along with a similar complement of key psychological theorists (e.g., Erikson, 1968; J. Perry, 1976; Piaget, 1968), all subscribe to the same common conviction that being seen to somehow remain continuous across the various moments of our temporal existence needs to be counted as a prerequisite for being recognized as any sort of person (or culture) at all (Chandler, Lalonde, & Sokol, 2000; Lewis & Ferrari, 2001). All of this adds up to a long brief in favor of what Flanagan (1996, p. 65) has referred to as our obligatory *one self to a customer rule*.

Such claims, that the earlier and later manifestations of an individual life or a persistent peoples must somehow count as belonging timelessly to one and the same continuant (van Inwagen, 1990), needs to be seen as true, not merely because so many of our intellectual heroes have insisted that this is so, but for at least *two* more persuasive reasons, one of which is quintessentially historical and *backwards referring*, the other *forward anticipating* and so all about our own as yet unrealized futures.

Life, according to William James (cited in Flanagan, 1996) is like a skiff moving through time with a bow as well as a stern. First, and with reference to things off the stern, each of us needs to be understood as temporally persistent because, if we could not count (or reidentify) ourselves and others as the same continuous and "numerically identical" individuals across time, then social life as we ordinarily understand it would come to a standstill. This follows for the reason that, in its backward referring aspect, continuity is no less than a moral, political, legal, and economic imperative (Whittaker, 1992). Without a way of owning our own past, our concepts of moral responsibility would be emptied of meaning (Rorty, 1973), all grounds for honoring our legal obligations would be lost (Whittaker, 1992), and all contracts and debts and promises would be canceled, every prospects for a just and moral world would evaporate, and Judgment Day would hold no terror. How could there be a heaven or hell, where those with a history of good and evil are meant to languish, if it were not possible to understand ways in which each of us legitimately owns his or her own past (Flanagan, 1996)?

Much the same proves to be true of our own as yet unrealized *futures*. As Bakhtin (1986) argued, persons are built up, not only out of "remnants of the past, but also from rudiments and tendencies of the future" (p. 26)—rudiments that give "a sense to one's life as having a direction toward what one not yet is" (Taylor, 1989, p. 48). Seen, then, from the bow, we behave as we do in the anticipation that, in Unger's (1975) words, we will later become the natural inheritors of our own "just desserts." In support of the same point, Flanagan (1996) argues that, "As beings in time, we are navigators. We care how our lives go" (p. 67).

For all of the backward referring and forward anticipating reasons just cited, then, the Janus-faced notion of self- and cultural continuity are ordinarily (many would say all but "universally") understood to be an immanent providence at work in the whole of human affairs (Shotter, 1984).

There you have it, the interpretive predicament that renders the notions of both personal and cultural continuity illusive. Things (selves and cultures included) are required to fully embody both sameness and change simultaneously (Fraisse, 1963).

> When this larger paradox, concerned as it is with things more generally, is mapped on to subsidiary *human* existence, what you get is a lot of flustered German philosophers, your occasional curious psychologist, and everyone else who has ever lost sleep over the puzzling question of just how much sameness is necessary, and how much change is permissible, before personal persistence and persistent peoples all fly out of the same window. (Chandler & Proulx, 2008, p. 215)

Somehow understanding sameness *within* change is, then, the problem, and continuity (or its absence) we propose, is the proper name given to the success or failure of efforts to solve it.

Continuity as a Relational Concept

Because they are required to somehow discount otherwise apparent evidence of change, all discursive claims about personal and cultural continuity necessarily carry with them the obligation to stand ready to provide some believable warrant meant to "argumentatively redeem" (Habermas, 1979) the claim that two recognizably different instantiations of what is alleged to be the same person or group of persons warrants being treated as functionally equivalent, and so counted only once. Should some older version of some former self turn up claiming to be the returning prodigal son, you want and expect proofs and bona fides. At the individual level, one might resort to something like pointing to the existence of an indelible birthmark, or by mustering arguments meant to convince you of the presence of some plot or causal narrative. At the level of whole cultural communities such demonstrations might take the form of pointing to collective tethers running back to a shared traditional past, along with mutual commitment to a common collective future. The concept of continuity, taken in both the individual and collective senses of interest here, is, then, neither a commentary on simple sameness, nor change somehow stood on its head. Rather, by these lights, continuity is a *relational* concept, a bridging conclusion backed by some procedural assurances of sameness within change.

The whole detailed story of how we and our research colleagues have gone about the often agonizing procedural business of actually documenting the levels of self-continuity evident in the lives of particular individuals, or of cultural continuity in whole collective communities, has spilled over onto more than 1,000 published pages (e.g., Chandler, 2000, 2013; Chandler & Dunlop, 2012; Chandler et al., 2003; Chandler & Lalonde, 1998, 2004, 2009; Chandler & Proulx, 2006, 2008; Chandler & Sokol, 2003; Lalonde & Chandler, 2004), and a complete accounting of these measurement efforts would require more in the way of detail than even this extended chapter would bear. Instead, it is hopefully enough to say that, with the assistance of a long list of research colleagues, research grants, and research partners, serious empirical efforts have been and continue to be made: (a) to document the self- and cultural continuity warranting practices of more than 400 individual youth and 200 Indigenous and non-Indigenous cultural communities; and (b) to relate these measure to various markers of health and well-being, including youth suicide. In sections to follow, we mean to more fully sketch some of the key findings to emerge from these research efforts. Before coming to these details, however, some better account needs to be provided to explain why what must have so far seemed an awkwardly toplofty discussion of selves and cultures in time has found itself caught up in the dark world of youth suicide.

Youth Suicide

Because, as St. Thomas Aquinas (1945/1273) reported, suicide somehow runs "contrary to a natural self-love, whose aim is to preserve us," many find it difficult, if not impossible, to imagine a good or sensible reason to take one's own life, and so feel obliged to suppose that all such acts of self-harm must somehow have been conceived in the very darkest and most personal corners of a troubled individual heart or mind. Potential societal or cultural matters faded into the background, and clinical depression, or some other similarly individualized (if still unspecified) chemical imbalance, consequently have become the usual foundational explanations of choice. By the early 20th century suicide had, then, become the darling of self-contained individualism, and paved the way for a present where flagging psychological defenses and failing dopamine systems seemed explanation enough.

While all of this was happening in a disciplinary quarter remote from the world of psychodynamic matter, the second shoe was dropping. It was 1897 and Émile Durkheim had just published his trendsetting monograph on the sociological determinants of suicide, setting in motion what has become a perennial interdisciplinary debate. Rather than searching for suicide's psychodynamic roots, Durkheim, along with a whole raft of other likeminded sociologists (e.g., Daube, 1972; Gagnon, 2010), reimagined suicides as *social facts*, best explained with reference to the sociocultural environments in which they occurred. To do otherwise—to rely instead on this or that private, individualistic accounting system—was, according to Durkheim, to commit what subsequent generations of anthropologists and sociologists have come to term *the psychologist's fallacy* (Chandler & Proulx, 2006; Cushman, 1990)—the alleged mistake of wrongly imagining that the negative outcomes of large-scale societal forces were best explained by appeals to personal intrapsychic processes.

Beginning with Durkheim, what generations of subsequent researchers have shown is that the rates at which such self-destructive behaviors occur rise and fall as a function of various social-cultural circumstances that regularly operate behind the backs of our individual worries and concerns (e.g., Allan & Allan, 2005; Bottomore & Nisbet, 1978). How could it be, they argue, that the suicide rates in some communities are tens or even hundreds of times higher than is found to be true in other times and other places? Did all of the sad and hopeless individuals somehow know to migrate to what proved to be high-risk locales?

Not to be outdone, psychologists and other champions of individualism have countered such acts of sociological imperialism (Chandler & Proulx, 2006) by branding all such macrogenetic encroachments into their traditional individualize domain as examples of what has been called the *ecological fallacy*—the supposed know-nothing tendencies to blindly aggregate everything in sight (see Achen & Shively, 1995; Piantadosi et al., 1988). On this account, if the causal processes at work in determining group differences in suicide rates were truly located only at some supraindividual systemic level, then how are we to explain the fact that, even when suicide is epidemic, it remains statistically rare, and that the large majority of the members of even the most benighted of such cultural groups somehow solder on, with no actionable thoughts of suicide?

What is principally wrong with all such either/or debates is that all of these assembled combatants participate in the same pernicious, Cartesian-like tendency to dichotomize everything in sight. The real challenge, if students of selves or societies are ever to understand one another, we mean to argue, is to find some countersynthesis that aims to dissolve the traditional dichotomy between, in this case, individual persons and whole cultures. All of this is much easier said than done.

Why Study Youth Suicide?

The research to be reported here began with the wonderment of how it could possibly happen that, with all of life's potential sweetness not yet full upon their lips, so many young people could so frequently undertake to intentionally injure themselves, or, in the extreme, to attempt to end their own young lives? Our earliest research efforts into such matters began, as psychologists are want to do, by studying suicidal individuals, and by working to determine how the occurrence of suicidal behaviors might be related to difficulties in the standard course of identity development (Chandler & Ball, 1990). More particularly, we were interested in working out how, in the face of often dramatic ontogenetic and other changes, young people come to some understanding of how they are meant to remain, in some sense, continuous or self-same. As further detailed later, what the results of our efforts have made clear is that a lack of self-continuity, expressed as failures in constructing a sense of ownership of one's personal past and future prospects, is strongly associated with a dramatically heightened risk of suicide. In short, what these studies are taken to have shown is that, in the absence of a sturdy sense of self-continuity, life becomes cheapened, and the possibility of suicide newly becomes a live option.

From Individual Psychopathology to the Epidemiology of Youth Suicide

However hazardous simply growing up may otherwise be, such risks are obviously magnified when the cultural backcloth against which development naturally unfolds is unraveled by larger-scale social-cultural adversities. Nowhere is this more apparent than in the identity struggles of young Indigenous persons who must construct a sense of selfhood out of the remnants of a way of life that harsh colonial practices have systematically driven to the point of extinction. In the best of circumstances, culture can be counted on to provide young people with a backstop; some measure of sameness while outgrowing childish ways. *If*, instead, one's culture is marginalized, or vandalized, or turned into a laughingstock; and *if* the trustworthy ways of one's community are criminalized, legislated out of existence, or otherwise assimilated beyond easy recognition, *then* woe be upon those transiting toward maturity. This is the fate, we have argued, of many Indigenous youth around the world. Their cultures of origin no longer compute, old ways of achieving self-understanding have been Hollywood-ized, and their paradise has been turned into a parking lot. The predictable consequence of such personal and cultural losses, we have undertaken to show, is often disillusionment, lassitude, substance abuse, self-injury and, most dramatically, self-appointed death at an early age.

To the degree that all that has just been said holds any promise for helping us better understand why the burden of suicide falls so disproportionately on the young, and especially on the youth of certain cultures, but not other, then a network of related hypotheses suggest themselves.

From Self- to Cultural Continuity: Framing the Study of Youth Suicide

If culture ordinarily serves as a critical backstop to the routine foibles of individual identity formation, then it should follow that community-level rates of youth suicide should also vary as a function of the degree to which such communities find themselves bereft of meaningful connections to their traditional past, and otherwise cut off from local control of their own future prospects. More particularly, two testable claims flow from these expectations.

The first claim is that, because different Indigenous communities have differently weathered their typically negative contacts with the non-Indigenous world, their collective responses to such adversities should be equally variable. With particular reference to the problem of youth suicide, it is reasonable, then, to expect that the rate at which youth suicides occur should also vary from one community to the next.

The second claim is that because different Indigenous groups have met with varying levels of success in preserving and rehabilitating their differently savaged cultures, it should also happen that suicide rates will be lower in those communities that have achieved a greater measure of cultural continuity (i.e., success in reconnecting to their traditional past, and in building ties to some shared future). Testing these expectations has been the focus of a program of research that has been ongoing for almost two decades—research that, more often than not, has centered on the study of Indigenous youth.

Youth Suicide: A Proving Ground for Exploring the Interface Between Psychological and Sociological Explanations

As with other hard problems, the difficulties presented by various lingering dualisms continue to be big-picture problems; so big, in fact, that there would seem to be no real alternative to beginning small, or smallish, and avoiding the temptation to try to explore every culture at once. Although only in comparison to those looping philosophy-of-science dilemmas that go on and on, could the problem of youth suicide be counted as small youth suicide is nevertheless potentially more tractable than are other less tractable, generic question concerning whether to dichotomize or not dichotomize. Something like this, then, is responsible for the fact that we, and our immediate colleagues, have chosen as a proving ground this otherwise morbid topic—decisions set in motion primarily because, somewhat fortuitously, history set the problem of youth suicide directly in the path of colliding paradigms. On the one hand, a psychodynamic, mental-health-based tradition continues to accelerate along its own historic explanatory track. Approaching in the opposite direction, at the same speed and on the same rails, is a second oncoming interpretive framework that regularly points to the inescapable fact that, however blue things might get for this or that individual, whole cultural groups either do or do not commit a lot of suicide (Kirmayer, 1994). All of this is reason enough to justify our choosing this particular topic as a place to begin, all in the hope of building a template that holds out the hope of some greater general utility.

Here then is the hard problem. In his 1993 documentary *The Virgin Suicides*, Eugenides reports on the reactions of several teenage boys to the suicides of five sisters. The boys keep a collection of the dead girls' belongings, repeatedly sifting through them in a vain attempt to understand their deaths. As Eugenides put it, "In the end we [that is, the boys] had the pieces of the puzzle, but no matter how we put them together, gaps remained, oddly shaped emptinesses mapped by what surrounded them, like countries we couldn't name" (p. 246). Whole disciplines within the social sciences regularly find themselves in positions no different than the ones facing these boys.

What this quote is meant to help make plain is that, all talk of metatheoretically inspired dichotomies, professional commitments and methodological preferences aside, anything like a satisfactory explanation of youth suicide demands that better ways be found to overcome whatever divisive disciplinary predilections may be at work preventing us from arriving at some more seamless explanatory framework.

Here, then, in the remaining pages of this chapter, we mean to further detail the twinned notions of *self- and cultural continuity*, and to lay out some early developmental and cross-cultural research intended to measure that sense of temporal persistence—that sense of ownership of a personal or collective past and future—that characterizes those individual and those whole cultural communities for which (we now mean to show) suicide is or is not a reasonable option. By contrast, our data also shows, for single individuals and certain whole cultural communities in which such an enduring sense of sameness within change has gone missing, suicidal thoughts and actions are everywhere apparent.

What is demonstrated with such evidence is that, although the explanatory frameworks within which notions of individual selves, on the one hand, and whole societal groups on the other, ordinarily find their meaning are, as advertised, generally split off into separate conceptually watertight compartments, the degree of actual separation imposed by these familiar dichotomies is less than complete. Rather, across both of these distinct domains there exists a degree of overlap sufficient to allow for the operation of a subset of concepts that live with equal comfort within both individualistic and collectivistic spheres of meaning. That is, in much the same way that philosophers of science such as Lakatos (1978) and Ludan (1977) have proposed that, contained on the outskirts of otherwise incommensurable worldviews are to be found bandwidths of assumptions that are mutually open, it is proposed that at least some of our notions, owed to what are otherwise dichotomous conceptions of selves and societies, do, nevertheless, compute equally well in both problem spaces.

The notions of self- and cultural continuity are like that. Without some way of grasping and insuring persistence, some way of identifying and then reidentifying one and the same person, all notions of self- or personhood would become nonsensical. Similarly, any collection of persons without some shared past and common future would utterly fail to meet the constitutive conditions of what cultures are ordinarily taken to be, and would, in consequence, amount to little more than a crowd. In short, failures to achieve a sense of personal or cultural continuity are at least in the running for providing a common accounting system for suicides at both the individual and collective levels. Whether these notions do in fact provide such a shared interpretive frame, equally useful in accounting for suicides in both disciplinary quarters is an empirical question. The evidence that we intend to summarize below strongly suggests that they do.

As a way of making this case, two sets of data are presented, both of which speak to the utility of the notion of continuity as it applies to the thoughts and actions of individual youth, on one hand, and to the culture-preserving efforts of whole Indigenous communities, on the other.

Self-Continuity and Youth Suicide: Study Set I

Over the course of the several years that this program of research has been ongoing (e.g., Ball & Chandler, 1989; Chandler & Ball, 1990; Chandler et al., 2003; Chandler & Lalonde, 1998, 2008, 2009; Lalonde & Chandler, 2004) some 200 young persons (some Indigenous, some not) have contributed data that has afforded us insights into their efforts to claim (and sometimes fail to claim) a measure of personal persistence, or self-continuity, in the face of inevitable change.

As one means of testing these prospects, all of the young persons admitted to an adolescent inpatient psychiatric facility over an 18-month period were first divided into those who were and were not put on active suicide precautions, all before members of both of these groups were yoked with an age-mate from the general community; adolescents known to be free of manifest psychiatric difficulties (Ball & Chandler, 1989; Chandler & Ball, 1990). Each participant was then administered a standardized "self-continuity interview" intended to bring out to what degree they understood themselves to be continuous in time. Some were considerably better at this task than others.

These interviews, which averaged 45 minutes in length, standardly began by asking participants to read two culturally appropriate, comic-book like stories concerning fictional characters whose lives were marked by radical personal change (e.g., Jean Valjean from Victor Hugo's *Les Miserables*). After responding to a series of standardized probes tailored to bring out their best understanding of continuities and discontinuities in the storied lives of these fictional characters, participants were then asked to answer similar questions about sameness and change across several years in their own lives.

The findings that emerged from these measurement efforts made it plain that all but a few of our nonsuicidal participants, whether psychiatrically hospitalized or not, confidently reported that they understood themselves as continuous, self-same, and numerically identical, despite many acknowledged personal changes. In sharp contrast, four out of every five of our participants who were both hospitalized and marked by a history of recent suicide attempts, found themselves wholly unable to provide any coherent account of their own personal continuity. As can be seen in more detail from an inspection of Table 12.1, none of our nonhospitalized controls, but more than 80% of our actively suicidal sample proved unable to offer any personally convincing reasons for why they should be counted as one and the same person across their troubled and changing lives. All of this, we take it, offers a measure of evidence in support of the hypothesis that those who count themselves as cut off from their past and future—that is, those who lack a personal sense of self-continuity—are at special risk to suicide.

TABLE 12.1 Percentage of Self-Continuity Warranting Strategies as a Function of Suicide Risk

Self-Continuity Suicide Risk	Warrant Absent (%)	Strategy Present (%)
High	83	17
Low	7	93
Control	0	100

Note. "High," "Low," and "Control" corresponds with institutionalized participants at a high risk of self-injury, low risk of self-injury, and noninstitutionalized, demographically equivalent control participants.

Individual Data Set II: Cross-Cultural Comparisons

The final bit of evidence regarding the self-continuity warranting practices of individual youth (Chandler & Ball, 1990; Chandler et al., 2003; Chandler & Lalonde, 2009; Chandler & Sokol, 2003; Lalonde & Chandler, 2004) is concerned more with the distinct ways in which youth of diverse cultures proceed in thinking about self-continuity than about suicide per se. Nevertheless, this evidence sets the stage for the subsequent section on cultural continuity.

One sidebar piece of information important in making sense of these data is that although, as suggested above, rank and file young people generally do hold to the view that they are continuous in time, their efforts to justify such claims ordinarily fall into one or the other of two broad categories that we have coded as being either *essentialist* or *narrative-like* in character. The first of these, labeled as *entity* or *essentialist* solutions, relies on accounting systems in which persistent persons are understood as possessing certain more or less abstract, but always essentially defining bits or pieces, said to defy time by remaining relentlessly the same. Alternatively, other individuals, whose responses were coded as more *narrative-like*, undertook the same formal task of vouchsafing their own and others' personal persistence, not by pointing to some imagined something that has putatively remained hidden from the ravages of time, but, rather, by understanding all of the admittedly distinct time slices that make up their own or others' biography as related chapters in what they argued to be one and the same life. Solution strategies of this second *relational* or *narrativist* sort succeed by running a continuous story-like thread of meaning through what are recognized to be substantively different incarnations of the self.

In conducting this study (Chandler et al., 2003), the structured self-continuity interview was once again administered, this time to two matched groups of adolescents. One of these groups consisted of 90 adolescents, drawn in equal numbers from urban and rural Indigenous or First Nations communities located on Canada's west coast. Each of these participants was paired with an age-mate of

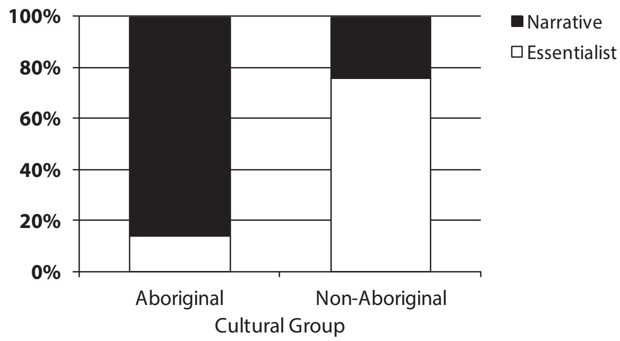

Figure 12.1 Percentage of Aboriginal and non-Aboriginal participants subscribing to a narrative and essentialist form of self-continuity.

the same gender, chosen to be more representative of the province's European American cultural mainstream.

As can be seen from an inspection of Figure 12.1, respondents from the culturally mainstream relied primarily on essentialist strategies for justifying their claims for personal persistence, whereas more than 80% of the First Nations adolescents made exclusive use of more narrative strategies as their default solution to these same continuity problems. There are, as Stich (1990) reminds us, no epistemic virtues, and there is probably no ultimate adaptation advantage to either essentialist or relational self-continuity warranting strategies. At the same time, and for reasons brought out in the sections to follow, it can scarcely be a good thing to rely upon narrative modes of self-understanding if one happens to be a member of some benighted Indigenous community whose cultural story has been dismissed, criminalized, and assimilated almost out of existence.

In summary, what all of these individually oriented bits and pieces of data summarized so far are meant to make clear is that the measured concept of self-continuity does in fact show some real promise in offering up a culturally sensitive conceptual scheme useful in promoting some better understanding of suicide in individual youth. What remains to be demonstrated is the counterpart issue of whether this same conceptual machinery (these same considerations about persistence in the face of change) can also be brought to bear in similarly illuminating our efforts to understand variable rates of suicide in whole cultural communities. To the extent that such an extension proves useful in differentiating whole cultural communities with high and low suicide rates, then some progress will have been made in finding a common denominator bridging the familiar self versus society dichotomy.

Cultural Continuity as a Hedge Against Suicide in Indigenous Youth

The final research effort described here (Chandler et al., 2003; Chandler & Lalonde, 1998, 2009; Lalonde & Chandler, 2004) was predicated on the assumption that distinctive cultural groups, like individual selves, are constituted by identity preserving practices that work to forge links to a common past and future. On this prospect, it was anticipated that Indigenous communities bereft of such culture sustaining ties would be at special risk for suicide, whereas those that had achieved greater measures of success in preserving cultural connections would be better shielded from the slings and arrows that regularly cost whole Indigenous communities appropriate levels of care and concern for their own future well-being.

As before, several guiding principles directed our search for answers to the question of how best to relate community-level measure to individual outcomes. Some of these were technical in nature, such as the need to restrict our search pattern to include only those variables for which band-level data are already available for all or most of British Columbia's (BC) First Nation communities. Other of our reasons were more theory-driven. Put most directly, rather than trolling aimlessly through the mounting seas of *Statistics Canada* data in the blind hope of snagging something that might relate to variable community-level suicide rates, we took our lead from our own earlier research that supports the theoretical prospect that suicide (whether measured at the individual or community level) can be best understood as an outcome of the collapse of those identity-preserving practices that serve to secure some enduring sense of personal and cultural identity through time.

Obviously, a precondition for successfully identifying possible cultural factors that influence the rates of Indigenous youth suicide is that all of Canada's otherwise diverse Indigenous communities do not share a common suicide rate (Chandler et al., 2003). The observations reported here primarily concern the province of BC and its more than 200 distinct First Nation Bands. The observed suicide rate for the entire First Nations population of BC during the period 1987 to 2000 is generally known to be more than double the provincial average (Statistics Canada, 2001). If, against reason, suicide rates were unrelated to culture, then tabulating the suicide rate for each band would have resulted in a more or less rectangular distribution. As shown in Figure 12.2, however, something much closer to the opposite is true. What this saw-toothed picture

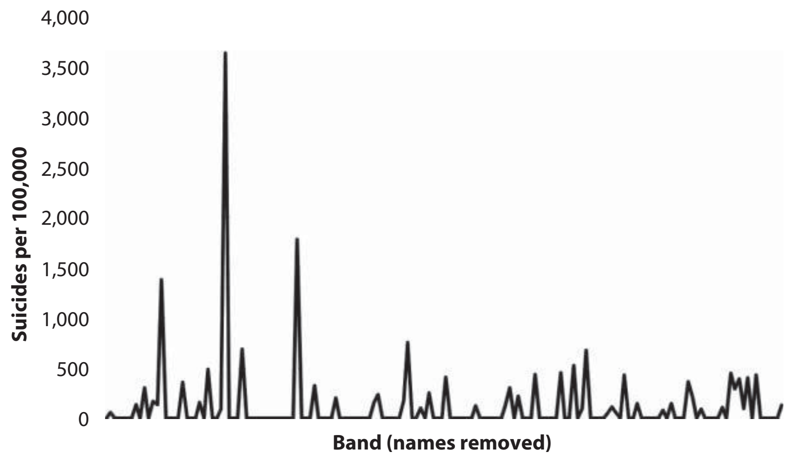

Figure 12.2 Youth suicide rates among First Nation Bands in British Columbia, Canada (1987–2003).

makes clear is that many of BC's Aboriginal communities suffered no youth suicides during the 15-year period (1987–2003) for which data were available, while, for others, the rate was many times higher than the provincial average. Figure 12.3 similarly arrays youth suicide rates, this time by tribal councils—such councils are typically composed of a dozen or more individual bands that share a common history, language, or geography.

Evident from these data is the fact that nearly 90% of suicides occur in less than 10% of these communities, and that in more than half of all bands, and 20% of tribal councils, youth suicide is effectively unknown. Clearly, the "epidemic" of youth suicides regularly reported in the popular press is not a "First Nations" epidemic, but, rather, a tragedy suffered by some Indigenous communities and not others.

Cultural Continuity as a Hedge Against Aboriginal Youth Suicide

Having demonstrated that Indigenous youth suicides are not uniformly distributed across BC's First Nations Bands, but exist instead in epidemic proportion in some but not other communities, we were encouraged to attempt to find ways of indexing what we have called *Cultural Continuity*, a concept that manifests itself at the level of whole Indigenous communities.

In pursuit of solutions to this measurement problem we began our initial 1998 study (Chandler & Lalonde, 1998) by constructing a first-draft *Index of Cultural Continuity* initially made up of six marker variables expressive of the degree to which each of BC's First Nation bands have both managed to preserve ties to their heritage culture,

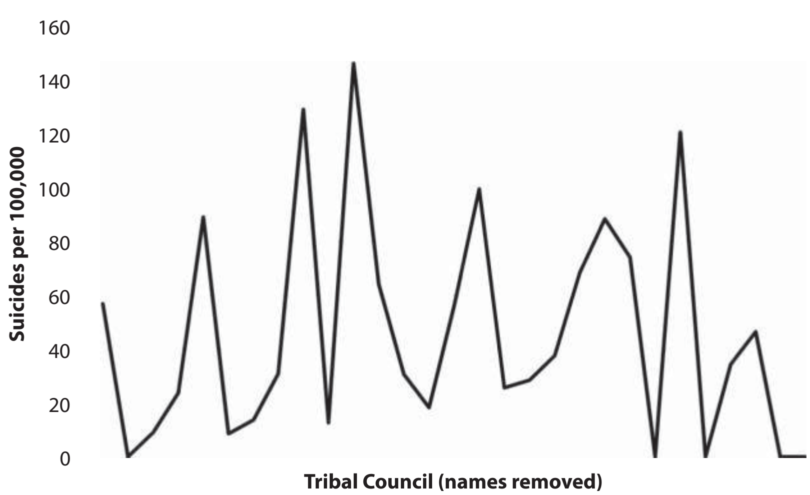

Figure 12.3 Youth suicide rates among Tribal Councils in British Columbia, Canada (1987–2003).

and to secure some enduring control over their own as yet unrealized futures. These proxy measures focused on the degree to which each of the province's more than 200 Bands had already secured: some measure of self-government; some control over the delivery of health, education, policing services, and cultural resources; and were otherwise at work litigating for Aboriginal title to traditional lands. These measures were chosen primarily because each appeared to signal something important about a community's efforts to recover its past and secure a measure of control over its own civic future. Access to information concerning these variables for each of BC's First Nation bands made it possible to locate these communities along a 6-point continuum ranging from low to high levels of Cultural Continuity. Subsequently (Chandler & Lalonde, 2009), three more predictor variables were added, including measure of band-level knowledge of Indigenous languages, the proportion of women in band government, and control of child protection services.

Figure 12.4 concerns the 6-year window between 1987 and 1992, and displays the suicide rates for all of those bands credited with as many as six of our original *Cultural Continuity* markers. As can be seen by an inspection of this figure, every band characterized by all of these *Cultural Continuity* factors experienced no youth suicides during the 6-year window considered, whereas those communities lacking any of these protective factors suffered youth suicide rates often hundreds of times the national average. These data, which were closely replicated in our second-wave of data collection (Chandler & Lalonde, 2009), are seen to make a very strong case that the well-being of First Nation youth, as measured by community-level suicide rates, is strongly associated with the extent to which their cultural community is hard at work both rebuilding connections to its traditional past, and struggling to regain control over its own future.

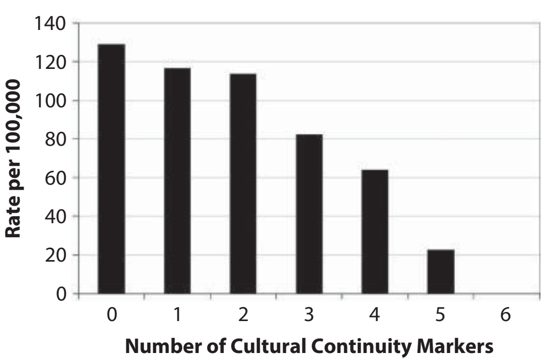

Figure 12.4 BC youth suicide rate displayed by number of continuity factors present within community.

CONCLUSIONS

Selves necessarily depend on relations to things outside of the walls of self-contained individualism; just as cultures are understood to exist in virtue of the integrative relations they afford the individuals that compose them. By these shared lights, selves and cultures, rather than living entirely separate ontological existences, are better seen as contrastive poles of an otherwise common relational dialectic—different vantage-points on outcroppings of the same reflexive project. However self-evident all of this may appear to those who have conceived this volume series, such integrative ideas are far from the usual fare. Rather, and more often than not, the separate disciplines that ordinarily concern themselves with matters of the self and with matters of culture are typically not on speaking terms.

There is, of course, nothing especially new in once again pointing out that any comprehensive account of mental and social life invariably requires descriptions framed at different (and perhaps even incommensurable) levels of analysis (Sterelny, 1990). Everyone from Hobbes (1651/1996), to contemporaries such as Marr (1982) and Dennett (1992) are all clearly correct about just this. As is also widely understood, simply repeating that there is some unbreachable split between all things psychological and everything cultural simply will not do. Where consensus does break down, however, is in deciding whether, in our attempts to move beyond these two solitudes, we should be trying, on the one hand, to develop *similar descriptions of different things*, or, alternatively, to undertake to work out *different descriptions of the same thing*.

Of these two prospects, far and away the first (the dualistic one about achieving similar descriptions of different things) has proven the most popular and enduring. As Hobbes (1651/1996) saw it, for example, the "great Leviathan called a commonwealth or state . . . is but an artificial man, though of greater stature and strength than the natural" (p. 7). On this and similar accounts, the presumed relations between individual and collective events is best worked out through some hierarchical arrangement; some foundational and therefore reductive approach that makes it possible to understand social-cultural affairs within the causal structure of the material world—within what Putnam (1999, p. 138) called the same *causal-subsumptive story*.

Hooking things up in this cause-and-effect fashion is tidy, but it does not come without its own considerable costs. Here is one. Because, and according to such antecedent-consequent accounts, *effects* (more often than not "cultures") are seen to necessarily follow, rather than precede, their *causes* (Lycan, 1981), things that might otherwise result in confusions (e.g., things that are seen to be ontologically distinct—Brand, 1970), are typically kept in separate rooms of our mind (Taylor, 1985). All of this, it would seem, extracts an unsupportably high price for supposedly bridging the usual individual-societal antinomy.

The second and less commonly taken of these competing explanatory routs (the one pursued in this chapter and in our own research) aims instead to supply different descriptions of the same thing. On this account (what Putnam [1999] terms the *analytic alternative*), the different levels taken to mark psychological and cultural life are not imagined to be things literally discovered in the objective relations connecting actual events in the "real" world, but, instead, are understood to be products of human construction and, as such, are imagined to belong to some common, internal, "epistemic corpus" (Putnam, 1999, p. 138). On this view, all straightforwardly causal accounts of supposedly different levels of functioning tend to be dismissed as *technologistic* (Habermas, 1979), or *objectivistic* (Smedslund, 1977), or *automation* models (Flavell & Wohlwill, 1969). These are accounts, which condemn those who employ them to endlessly pawing through the debris of visible effects in search of invisible causes—an enterprise that, as Broughton (1983) points out, is not unlike trying to catch sight of the dark by switching on the lights suddenly. Our own efforts involve a minimum of such "pawing," but are meant, instead, to somehow put persons and their cultures on the same ontological footing.

In the empirical work that has been described here, we aimed to pursue this second and more analytic alternative by viewing matters of both self- and cultural continuity as different in grain or scope, but not different in kind—as different levels of description of the same thing. As such, the relations between the individual and cultural groups, as detailed in our research, are viewed as *relations of identification or correspondence*, rather than imagined *connections of cause and effect*.

Given all of this, the common denominator, the thing that cuts across persistent individuals and persistent peoples, and that, as Heidegger (1953/1996) put it "forms the common horizon for both," is *time*. In just the same way, then, that self-continuity is the name for whatever reflexive personal project that is meant to sustain some coherent account of one's own biographical identity, cultural-continuity similarly needs to be seen as community actions that collectively promote a common past and a common future. What serves, then, to make continuity a common denominator of both personal persistence and persistent people is that the same temporal coherence that serves to constitute individual selves becomes, when elevated to the level of whole cultures, a shared or standardized past and a collective future. If, owing to some train of personal or collective mishaps, single individuals or whole communities lose track of themselves in time, and so suffer some disconnect with their past or future, then it should follow, as our data suggests it does, that old responsibilities and new promissory notes will both fly out the same window, life will become cheap and suicide or something like it a near certainty.

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CHAPTER 13

Moral Development

ELLIOT TURIEL

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Morality is obviously a topic of great importance for humankind as it entails religion, politics, government, societal makeup, and cultural practices. As is well known, morality and its development in individuals has long been a concern in anthropology, sociology, and psychology. Morality has also been a central topic in philosophy, going back to Socrates, Aristotle, and Plato. Those moral philosophic works are still studied and debated, as are the classic works of later moral philosophers such as Immanuel Kant, John Stuart Mill, Adam Smith, and David Hume. One of the continuing debates in moral philosophy carried over to psychological theories has centered on the roles and prominence of reasoning and emotions in moral practices and decisions. As discussed by Brandt (1959) and Frankena (1963), Kant and Hume were influential in their presentations of differing positions on reasoning and emotions. On the one side, the Kantian tradition emphasized principles involving reasoning in guiding moral decisions in ways that are not emotionally determined. On the other side, the Humean tradition regarded moral values as derived from sentiments such as sympathy. Another issue traditionally debated is whether morality is relative to social systems, cultures, and even individuals or, because it involves substantive judgments about how people should treat and relate to each other, it can apply universally across contexts. The debates along these lines occur in contemporary times, as well (Benedict, 1934; Hatch, 1983; Kohlberg, 1971; MacIntyre, 1981; Shweder, 1982).

Although philosophers still engage in debates about the roles of emotions and reasoning in morality, there are several philosophers who propose that morality must be analyzed from the perspective of substantive issues about which people make judgments involving processes of reasoning, but with emotions as significant aspects of those forms of judgments and reasoning. Among the most prominent of those philosophers, to name just a few, are Rawls (1971, 1993), Sen (1999, 2006, 2009), Nussbaum (1999, 2000), Dworkin (1977, 1993), Gewirth (1978, 1982), Habermas (1993), Okin (1989), and Walzer (2007). The substantive moral considerations they identified and analyzed include justice, rights, and civil liberties, with the promotion of human welfare and equal treatment as components. The highly regarded and path-breaking work of Rawls (1971), in his *Theory of Justice*, is foundational in many of the treatises of these philosophers.

It is not that all these moral philosophers present a unified position with no disagreements—far from it. However, there are some fundamental premises they share. One—especially relevant to psychological formulations—is that human functioning involves thought and reasoning. As succinctly stated by Nussbaum (1999), "human beings are above all reasoning beings, and . . . the dignity of reason is the primary source of human equality" (p. 71). In keeping with the emphasis on reasoning, Sen (1999) in his treatise on economic development and human freedom maintained that a sense of justice involves judgment, thought, and inference: "It is the power of reason that allows us to consider our obligations and ideals as well as our interests and advantages. To deny this freedom of thought would amount to a severe constraint on the reach of our rationality" (p. 272). Human reasoning also implies that humans make choices and reflect on social conditions: "Central to leading a human life . . . are the responsibilities of choice and reasoning" (Sen, 2006, p. xiii). It is necessary, however, to mention that emotions are seen to be a constitutive part of the process as evaluative appraisals "in which people . . . survey objects in the world with an eye to how important goals and projects are doing" (Nussbaum, 1999, p. 72). Emotions and ideas are subject to critical scrutiny (Nussbaum, 2001).

THE LIBERAL TRADITION IN MORAL PHILOSOPHY

In emphasizing reason and choice, philosophers like Nussbaum and Sen work with core assumptions in a "tradition of liberalism," which is not meant to refer to a political ideology or movement (as is mistakenly inferred by some psychologists), but rather refers to a philosophical perspective on morality going back to the thought of Greek and Roman Stoics. In this tradition it is presumed (Nussbaum, 1999), "that all, just by being human, are of equal dignity and worth, no matter where they are situated in society, and that the primary source of this worth is a power of moral choice within them, a power that consists in the ability to plan a life in accordance with one's own evaluations of ends" (p. 57). According to Nussbaum (1999), modern thinkers also emphasize, "that the moral equality of persons gives them a fair claim to certain types of treatment at the hands of society and politics" (p. 57). In some respects, these principles were designed to apply to political systems and to the structure of societies (Rawls, 1971, 1993). As stated by Rawls, 1971):

> Justice is the first virtue of social institutions, as truth is of systems of thought. . . . Laws and institutions no matter how efficient and well arranged must be reformed or abolished if they are unjust. Each person possesses an inviolability founded on justice that even the welfare of society as a whole cannot override. . . . Therefore, in a just society the liberties of equal citizenship are taken as settled; the rights secured by justice are not subject to political bargaining or to the calculus of social interests. (pp. 3–4)

However, these principles are intended to apply, as well, to the "lives that people are able to lead" (Sen, 2009, p. xi), which includes concerns with how people are able to reduce injustices and advance fairness.

The types of thinking and emotions espoused in these philosophical perspectives mean that social groups do not simply determine individuals' moral stances or that morality is relative to societies or cultures. Nussbaum (1999), for example, maintained that there is "variety within groups, cultures, and traditions" (p. 8) and that, "traditions are not monoliths. Any living culture contains plurality and argument; it contains relatively powerful voices, relatively silent voices, and voices that cannot speak at all in the public space" (p. 8).

Another contemporary philosopher, Appiah, has incisively captured some of the problems in treatments of culture in stating "It hasn't escaped notice that 'culture'—the word—has been getting a hefty workout in recent years. The notion seems to be that everything from anorexia to zydeco is illuminated by being displayed as the product of some group's culture" (Appiah, 2005, p. 254). Appiah does not discount culture but places it into the context of individual participants who engage in self-development through faculties of observation, reasoning, and judgment. Following John Stuart Mill, Appiah regards autonomy as necessary for human functioning. In his view, individuality and autonomy are central to the formation of identities that do entail collective affiliations. However, identity is not determined by a collective affiliation or participation in a culture:

> I don't say the word "culture" should be banned from our lexicon; I do not claim it is always entirely without utility. But, as we have seen, its weed like profusion can sometimes crowd out analysis. Treating international difference, between what Rorty calls "the West" and the "non-West," as an especially

> profound kind of something called "cultural difference" is, in my view, a characteristically modern mistake. (Appiah, 2005, p. 254)

Appiah further argues that the use of culture as reflecting differences between groups can be a product of a disciplinary artifact because the field of anthropology has a professional bias toward difference: "Who would want to go out for a year of fieldwork 'in the bush' in order to return with the news that 'they' do so many things just as we do?" (Appiah, 2005, p. 254). Appiah also points out that difficulties in cross-cultural dialogue are no more substantial than difficulties of dialogues within societies. Difficulties of dialogues within societies exist not only because there are varying groups within societies, but also more importantly because individuals do not hold one type of perspective on the world determined by a homogenous cultural orientation, an adaptation, or a singular identity. In a similar vein, Sen (2006) argues that individuals always belong to several groups and that they maintain the freedom to determine loyalties and priorities among these different groups. With abilities to make choices and use their powers of reasoning, individuals maintain multiple identities involving social class, nationality, gender, occupation, language, morality, politics, and more. Sen, too, emphasized the importance of diversity within groups or cultures and within individuals: "A person has to make choices—explicitly or by implication—about what relative importance to attach, in a particular context, to the divergent loyalties and priorities that may compete for precedence" (Sen, 2006, p. 19). The propositions put forth by Appiah and Sen have far-reaching implications for thinking about similarities and differences among cultures, which, in turn, bears on debates over moral relativism and universality.

The propositions of philosophers are often aimed at defining, formulating, and justifying moral conceptions. Although such moral philosophies are sometimes meant to apply to political systems, they are also based on the premise that moral judgments are part of the mental makeup of individuals (as in "human beings are above all reasoning beings"). The tradition of liberalism in moral philosophy is, therefore, compatible with the psychological approach I take on moral development and elaborate on in this chapter. More generally, this psychological approach has its roots in what has been referred to as the *structural-developmental* perspective of such theorists as James Mark Baldwin (1896), Heinz Werner (1957), and Jean Piaget (1932, 1970, 1995a). In contemporary terms, the approach is consistent with the Process-Relational and Relational-Developmental-Systems paradigm (Lerner, 2006; Lerner & Overton, 2008; Overton, 2006, 2013, Chapter 2, this *Handbook*, this volume)—a paradigm that is well represented in this volume of the *Handbook of Child Psychology and Developmental Science*.

CHAPTER CONTEXT AND STRUCTURE

Within the context of structural-developmental and relational developmental systems perspectives, discussion of a *social domain* approach—that I and several colleagues developed—constitutes a significant part of this chapter. The framework of Social Domain Theory (Nucci, 1981; Smetana, 1981; Turiel, 1978, 1983a, 1983b; Weston & Turiel, 1980) was influenced by the thinking and research of Piaget (1932) and Kohlberg (1963a, 1969, 1971) on the development of moral judgments. As discussed later, however, social domain theory differs from those of Piaget and Kohlberg in that judgments in the moral domain begin at a very early age and are distinct from the formation of other social and personal domains of judgment. Nevertheless, our position is consistent with structural-developmental and relational developmental systems approaches in that the development of morality and other domains occurs through the active reciprocal bidirectional relationships, in their everyday lives, with adults and other children.

Prior to discussing the structural-relational approach, the chapter considers contrasting approaches to moral development and their associated general psychological assumptions. The structural-relational reciprocal bidirectional view of morality stands in sharp contrast with common positions that were taken in the early part of the 20th century and share some key elements with several contemporary treatments. In these contemporary alternative views (e.g., Greene, Sommerville, Nystrom, Darley, & Cohen, 2001; Haidt, 2001; Hauser, 2006; Kochanska & Askan, 2004), morality is not based on reasoning or substantive concepts such as justice, but on one or another type of deterministic psychological mechanism. Prominent deterministic approaches of the early part of the 20th century are first described followed by an exploration and critique of contemporary deterministic approaches that emphasize intuition, biology, and culture.

Following the critique of deterministic approaches the chapter explores the structural-relational perspective and research on the development of morality. This presentation examines the social domains and describes how *morality* is a domain of judgment and action distinct from the domain of reasoning about the *conventions* and customs of social systems, and distinct from concepts in the *personal* domain. The differentiations that children, adolescents, and adults make among the domains reflect *relational* processes of thought and emotions (Turiel, 2010b; Turiel & Killen, 2010) as well as flexibility of thought (Turiel & Perkins, 2004). The emphasis throughout is that this relational position means that although thought and emotion can be looked at from one point of view or another, the two processes cannot be dichotomized as separate disconnected processes.

Both societal contexts and cultural practices need to be taken into account in explanations of development. However, contemporary analyses of homogeneous cultural orientations need to be questioned in the ways outlined by Appiah and Sen. There are, indeed, contemporary analyses by "cultural psychologists," in which dichotomies or divisions are drawn between types of cultures on their conceptions of persons, social relationships, and morality —especially between the supposedly *individualistic* orientations of Western cultures and *collectivist* orientations of non-Western cultures (Markus & Kitayama, 1991; Triandis, 1990).

Research from the social domain perspective, as well as that of anthropologists (e.g., Abu-Lughod, 1993; Wikan, 1996), has examined the intersection of culture and morality. Subsequent sections of the chapter present research demonstrating that cultures cannot be adequately characterized as entailing homogeneous orientations, that individuals participate in cultural practices but at the same time reflect upon and evaluate cultural practices and engage in social opposition and moral resistance. The argument is developed that moral judgments are not relative to cultural contexts and that commonalities exist across cultures. Moreover, this position on *universality* is not based on any type of moral *absolutism*. Morality may appear absolute because issues of welfare, justice, and rights are not judged as arbitrary, but as obligatory across settings. Yet, morality appears relative because issues of welfare, justice, and rights are not applied in uniform ways in all situations. Moral judgments are not applied in absolutistic or relativistic ways, but instead moral decisions often involve *coordination*, or weighing and balancing, between different moral goals, as well as between moral and nonmoral goals.

HISTORICAL SOURCES OF THINKING ABOUT MORAL DETERMINISM

Positions of moral absolutism and moral relativism have stemmed from observations that morality is usually approached with strong convictions and that it has a seemingly binding quality to it. This binding quality, the sense that it is obligatory and without choice, has led to deterministic explanations based on fixed biological dispositions, disembodied learned conscience, learned traits of character, nonreflective intuitions based on evolution and/or cultural orientations, and unexamined adherence to internalized rules, norms, or cultural practices. An explicit or implicit absolutism or relativism underlies most of these views. In some cases, the genome is understood as being fixed and, therefore, unvarying. In other cases conscience, or traits, once acquired, are considered to be unvarying. And in still other cases, the cultural practices incorporated by individuals in different cultures are assumed to result in different and relative moral systems.

Three Early Deterministic Theories

Three well-known theories from the early part of the 20th century have influenced contemporary deterministic formulations—those of Freud and psychoanalytic theories, Skinner and behaviorist theories, and Durkheim and sociological theories. A hallmark of these deterministic views is that what observationally seems to involve choice, conscious reflection and decision making, deliberate changes in small and large life path ways, and reasoned understandings, are all considered to be illusory. Indeed, the theoretical perspectives of the early part of the 20th century were organized around the search for explanations that were considered hidden, unknown, and in many respects, unknowable, to actors.

An emphasis on unconscious processes was a foundational feature of psychoanalytic theory (Freud, 1923/1960, 1930/1961). Freud attempted to generate a general psychological theory on the premise that the mysteries of psychopathology were different only in degree from nonpathological psychological processes and, thus, there was a continuum between the pathological and the "normal." For Freud and other psychoanalytic theorists of the time, early in life (during the first 5 to 7 years) much of significance moves from consciousness into unconscious processes, which feature a virtual insurmountable resistance to bringing the emotions and thoughts into awareness. Pathological and neurotic symptoms were considered manifestations of that which lies in a dynamic and conflicted unconscious.

Central to Freud's paradigm of morality was the concept of conscience, tied to the idea of a dichotomy, and concomitant tension, between individual and society. The root of this tension was the supposed incompatibility of psychological and biological needs of individuals on the one hand, and strivings for long-term survival of individuals and the species on the other hand. Society largely had the function of ensuring survival and protecting people from each other's aggressive tendencies. Through the influences of society, particularly as reproduced within a family, the individual's needs for instinctual gratification become transformed and displaced in the developmental process to make room for internalized standards (via parents as representatives of society) and internalized emotional mechanisms for regulating behaviors. This transformation—grounded in emotions of fear and anxiety, but also facilitated by positive emotions of love and attachment—largely arose from emotional conflicts. These conflicts were thought to produce psychological transformations through the acquisition of a superego that incorporated moral ideals and guilt as the means of regulating conduct.

In the Freudian view, the acquisition of morality resulted in a dichotomy within the individual, entailing superego forces and instinctual gratification needs. The moral side of the dichotomy involved the duty to uphold societal norms. Although fulfilling this duty entailed deep conflicts (most often of an unconscious nature), it was felt as inexorable and impersonal. The internalized morality was considered to be invariable and applied inflexibly. One part of the individual was thought to be kept in check to adhere to societal norms by another part, namely, guilt (or internally directed punishment) that was part of the agency of conscience.

Although behaviorists regarded their theories to be at odds with psychoanalytic theory, the two shared the proposition that much in people's everyday assumptions are illusory and that the causes of behavior are out of awareness (but differing from Freud's ideas about a dynamic unconscious). In the case of behaviorism, those illusory psychological understandings were reduced to conditioning or learning theory explanations of behavior to the exclusion of internal processes. Watson (1924) dismissed the idea of consciousness, equating it with the superstitious, nonscientific concept of a soul in religious frameworks. Skinner (1971) explicitly excluded most other common psychological constructs in his contention that the science of human behavior needs to abandon terminology pertaining to inner mental states or traits of personality: "Physics did not advance by looking more closely at the jubilance of a falling body, or biology by looking at the nature of vital spirits, and we do not need to try to discover what personalities, states of mind, feelings, traits of character, plans, purposes, intentions, or other perquisites of autonomous man really are to get on with a scientific analysis of behavior" (Skinner, 1971, pp. 12–13).

Skinner (1953, 1971) provided one of the most extensive formulations of a strict behaviorist conception of moral acquisition. He proposed that morality reflects behaviors that have been reinforced (positively or negatively) with value judgments associated with cultural norms. Accordingly, individual actions and thoughts were not the product of an active agent operating in a reciprocal bidirectional fashion with a culture, nor were acts considered intrinsically good or bad. All action and acts were simply behaviors acquired and evoked as a consequence of contingencies of reinforcement. Certain contingencies, consistent with the mores of the group, were considered social in that they refer to relationships with others and were thought to be governed by verbal reinforcers, such as *good, bad, right*, and *wrong*. Moreover, social control over behavior was considered particularly powerful when exercised by institutional forces (e.g., religious, governmental, economic, educational). This is because the reinforcers of *good* and *bad* also take the form, for example, of legal, illegal, pious, or sinful acts, with their associated rewards and punishments. Learned behaviors stemming from the customary group practices were considered invariant insofar as reinforcement contingencies were maintained. For Skinner, however, customary group practices did not constitute duties or obligations, nor did they reflect one's character; rather, they were simply behaviors like any other behaviors, and explained by the arrangement of effective social contingencies. Consequently, the psychological "ought" quality of moral values constituted mere *appearance* or *illusion*; *reality* was taken to reside in the conditioning of habitual behaviors.

The third type of influential early 20th-century formulation comes from Durkheim's (1925/1961) sociological perspective that included psychological assumptions. He maintained that morality entails an *unrecognized* attachment to and sense of respect for society (which can include a sense of sacredness and adherence to rituals in religious life). Durkheim theorized that morality is manifested in an attachment to society, as well as symbolic values, which can take secular or religious forms. Religion, however, was considered a *disguised manifestation* of the attachment to society. In Durkheim's perspective morality is based on emotions about group affiliation, with respect for its rules, authority, and symbols such as flags, kings, and constitutions.

The Cognitive Revolution: A Respite From Deterministic Approaches

In developmental psychology the work on cognitive development conducted by Jean Piaget and many others was part of the cognitive revolution that occurred in the 1960s and 1970s (see Bruner, 1990; Vauclair & Perret, 2003). The cognitive revolution, which extended beyond developmental psychology, came to eclipse the prominence of psychoanalytic and behaviorist theories and their emphases on biological and/or environmental determinism. Research by Kohlberg (1963a, 1971) and a renewed interest in Piaget's (1932) research on children's moral judgments resulted in a large body of research based on a constructivist-relational position. Both Piaget and Kohlberg examined the moral judgments of children and adolescents, proposing sequences of development entailing increasing differentiations of moral judgments from other types of personal and social judgments. Research based on social domain theory (Turiel, 1978, 1983a) built on the constructive-relational approach of Piaget and Kohlberg, but resulted in explanations of development as involving the formation, in early childhood, of distinct developmental pathways within the moral, conventional, and personal domains. These positions are described further after an exploration of several other contemporary perspectives.

Contemporary Deterministic Perspectives on Morality

Although psychoanalytic and behaviorist explanations are no longer part of mainstream psychology, three features of their formulations (including Durkheim's) are evident in contemporary deterministic analyses of moral development: (1) The person's morality stems from the internalization of group values or norms shaped by socializing agents; (2) morality is binding as a consequence of strong emotions. In addition to the prior emphasis on emotions such as fear, anxiety, and guilt, disgust is now also seen as central in moral acquisition and action; (3) conscious choices and conscious reasoning do not play an important role in moral functioning; rather one form or another of unawareness is at work insofar as people believe (falsely) that they act autonomously, with reasoning, and can make rational decisions.

The "People-Are-Stupid" School of Psychology

Many of the contemporary deterministic formulations (e.g., that morality is due to emotions or unexamined intuitions) essentially propose the opposite of Nussbaum's (1999) view that individuals have "the capacity for understanding moral distinctions, evaluating options, selecting means to ends, and planning a life" (p. 71). There has been a reemergence in psychology, well beyond analyses of morality, of views that disparage mind, cognition, and autonomy. In several areas, but particularly some quarters of social psychology and neuroscience (e.g., Liljenquist, Zhong, & Galinsky, 2010; Zhong & Liljenquist, 2006), findings from artificial and contrived tasks in laboratory settings are inappropriately generalized to broad and sweeping assertions about human psychology. Such generalizations are made in assertions that irrationality, determinism, and unconscious processes are the hallmarks of human functioning. This is part of a trend that Kihlstrom (2004; see also Kihlstrom, 2008; Turiel, 2011) refers to as the "people-are-stupid" school of psychology. Kihlstrom refers to a people-are-stupid school because of the proffered argument that many, if not most, judgments and decisions are nonconscious, automatic, and nonrational or irrational. According to Kihlstrom, this school of psychology maintains that "as we go about the ordinary course of everyday living, we do not think very hard about anything, and simply rely on biases, heuristics, and other processes that lead us into judgmental error" and that "the evidence of irrationality only consists also (of) evidence of unconscious, automatic processes" (2004, p. 169). Thus, the people-are-stupid school bases its argument on assumptions that decisions are emotionally driven, not based on thought or rational processes; are irrational in that they involve going against one's own interests, and irrational in that they involve being blinded by one's own interests; do not involve choice or self-determination because they are most often nonconscious and out of awareness (automaticity); and finally that perceptions of deliberative choices in decision making are illusory. In these views, illusions are not equivalent to errors or mistakes that people make in efforts to understand the world. Rather, the claim is that people fool themselves, create a mythical world, and engage in illusions (Ariely, 2008; Iyengar & Lepper, 2000; Simmons & Nelson, 2006; Wegner, 2002).

As mentioned, broad-ranging propositions about thought, consciousness, unconscious determinism, and morality involve generalizations from findings based on experiments that involve contrived tasks and the assessment of simple behaviors far removed from substantive issues of morality. An illustrative example appeared in a *New York Times* op-ed article (Eagleman, 2009). In this article, Eagleman, a neuroscientist, predicted the reactions of the American people and the effects on the "psychology of the nation" to President Obama's decision (announced on December 1, 2009) to send 30,000 more troops to the war in Afghanistan with an announced deadline of 18 months for the start of troop withdrawal from that war. Eagleman argued that President Obama's timetable of 18 months was too long for people to process, and that setting short-term goals would better evoke in the American people the sentiments that President Obama wished to evoke. Eagleman's argument was based on a set of simple and rather contrived laboratory experiments that presented participants with different deadlines for obtaining different sums of money. One experiment made participants an offer of accepting $100 immediately or $110 one week later. Most participants chose the $100 (and presumably offering $100 now and $500 in 18 months would produce the same result). In other studies using brain imaging, when people made similar decisions it was found that the neural networks in short- and long-term decisions appear to be separate. Eagleman's claim was that the results of research of this sort tells us a great deal about how people in general will react to President Obama's decisions on the war in Afghanistan.

This example illustrates the problem of generalizing from highly limited experimental results on artificial tasks to decisions that entail serious and far-ranging concerns and consequences. Further, the experiments illustrate the presumption that, in matters small and large alike, people do not reflect seriously on the decisions they make. That is, the research is presumed to demonstrate that people do not make rational choices (i.e., judging on the basis of self interest by delaying a short period and profiting more). Formulating broad conclusions about the automaticity and irrationality of decisions from research on enormously simplified areas of decision making are common in some circles (hence a "people-are-stupid school").

Other illustrative examples of the problem of unwarranted generalizations from simple contrived tasks include studies that jump from experimental predictions concerning gambling decisions about sporting events with point spreads, to the generalization that decision making is fundamentally intuitive rather than rational (Simmons & Nelson, 2006). Further, following historically on a long line of research on cognitive dissonance, some investigations with simplified tasks have drawn broad conclusions about situational forces determining self-control. In one such study (Iyengar & Lepper, 2000), participants were presented with displays of high-quality products (jams, chocolates) to sample and buy at a $1 discount. More of those exposed to a small number (e.g., 6) of choices purchased the product than those exposed to a large number (e.g., 24) of choices. On this narrow base the conclusion was drawn that having a large number of choices leads to a lack of control due to the forces of the situation.

These types of limited experiments and broad conclusions have also been conducted to generalize to serious moral decisions involving welfare, generosity, trust, and altruism. In a set of studies conducted by Zhong and Liljenquist (2006), the presumed nonconscious and emotive nature of choices and acts associated with "morality" were examined through actions involving cleansing (as in the title, "Washing away your sins"). The general framework this research assumed for an understanding of morality was that morality rests on a sense of purity—not concerns with how people should treat each other—that is, in turn, connected to physical purity. The researchers, thus, set out to demonstrate that when moral purity is threatened, people will experience a need for physical cleansing and reciprocally that physical cleansing will help alleviate threats to moral purity. In the study, participants were first asked to recall an ethical or unethical deed from their past and to describe the feelings and emotions they experienced. Subsequently, they were asked to convert word fragments (e.g., W–H) into words. It was found that those who recalled an unethical deed were more likely to generate cleansing words (e.g., WASH) than those who recalled ethical deeds. Similarly, it was found that those who copied a short story describing an unethical deed rated the desirability of cleansing products (e.g., toothpaste) as greater and were more likely to choose an antiseptic cleansing wipe than a pencil as a gift than did those who recalled an ethical deed. In addition, in one of the studies participants who described an unethical deed and then cleansed their hands were more likely to volunteer for another study than those who had not cleansed their hands.

A second set of studies (Liljenquist et al., 2010) was designed to draw a connection between good smells (symbolic of physical purity) and virtuous behaviors such as trusting others, charity, and altruism. In this case a sense of purity was evoked by placing participants in a clean-scented room (sprayed with citron-scented window cleaner) in comparison with participants placed in an unscented room. The experiments included a supposed game of trust involving exchange of money. Those in the clean-scented room gave more than those in the unscented room. In another experiment it was found that those in the clean-scented room were more likely to profess interest in volunteering for a charitable organization and to donate money to it. The differences were statistically significant, but the effects sizes were small (e.g., 22% versus 6% stating they might donate money). The researchers concluded that there is a nonconscious link between good smell and moral purity: "The current findings suggest that there may be some truth to the claim that cleanliness is next to godliness. Clean scents summon virtue, helping reciprocity to prevail over greed and charity over apathy" (Liljenquist et al., 2010, p. 382).

Do these studies tell us anything of importance about moral development and moral decisions? Do they provide evidence that there is a substantive connection between morality and clean smells or the metaphor of washing away your sins as reflected in choices of cleaning words and products? It is unlikely that they do! Beyond the issue of task simplification, other potential flaws involve, for example, the fact that participants may well be aware of the association made in religious rituals and in the general culture between moral misdeeds and cleansing. Further, participants may have responded to those associations as the perceived expectations of the experimenters in their contrived and unusual laboratory situations. Studies of this sort—including many of those providing evidence for the "people-are-stupid school"—need to be approached with a good deal of caution and with tests of alternative interpretations. For instance, several studies on framing and priming purportedly demonstrate that nonconscious processes produce automatic decisions (see Kihlstrom, 2004; Turiel, 2011). Some examples include findings that participants who read a series of words vaguely related to being elderly (e.g., bingo, Florida) walk more slowly leaving the room than they did coming in (Bargh, Chen, & Burrows, 1996); females who are asked questions about their ethnic affiliations as Asian Americans perform better on a math exam than those asked questions about their gender (Shin, Pittinsky, & Ambady, 1999). Other examples involve probabilistic reasoning, such as, after writing the last two digits of their social security number, those with high numbers make higher bids to purchase products like wine (Ariely, 2008).

The central point of all the illustrative examples, including those on cleansing and clean scents, is that along with the oversimplification of experimental tasks there are a number of other serious potential flaws related to reliability and ecological and construct validity that may impact conclusions drawn from them and especially the generalization of conclusions to broad societal issues. One feature of concern is how readily changes in behaviors occur following very minor manipulations (e.g., walking slowly after hearing Bingo). There is also concern, particularly with respect to the impact of words like *Bingo* or *cleansing*, as to whether experimenters' expectations may in some way have been signaled to participants. Another concern is that in these contrived situations the initial condition induces in participants a mode of functioning that transfers temporarily to the following assessment—with all the attendant expectations of experimental situations. It may take people a little time to shift into more regular modes of operation or more appropriate ones for the new situation. (See Royzman, Leeman, & Baron, 2009, for a study that was designed to avoid the effects of communication of experimenter expectations by administering tasks a few days apart and by obscuring connections between different assessments.)

Kahneman (2011) captured the shortcomings of making predictions based on brief assessments when he discussed his assignment in the Israeli army to evaluate candidates for officer training:

> We were required to predict a soldier's performance in officer training and in combat, but we did so by evaluating his behavior over one hour in an artificial situation. This was a perfect instance of a general rule that I call WYSIATI, "What you see is all there is." We had made up a story from the little we knew but had no way to allow for what we did not know about the individual's future, which was everything that would actually matter. When you know as little as we did, you should not make extreme predictions like "He will be a star." (p. 32)

Clearly researchers need to be extremely cautious about making broad generalizations about modes of human functioning (e.g., that we usually make nonrational decisions, or that morality is based on a sense of purity) based on assessments in artificial and constrained experimental situations. The need for caution is illustrated by the fact that experimental manipulations resulting in higher test scores have not been translated into positive changes in schooling and toward closing the achievement gaps in the United States. It appears that the experimental findings are not applicable to students' learning in actual schools.

However, from the perspective of those who adhere to a binding deterministic view of morality involving nonrational and nonconscious intuitions and emotions, it is, indeed, thought that the cleansing studies reveal a great deal about morality. The following two sections focus on two such examples.

Determinism and Intuition in Morality

The first example of a view of morality as involving nonrational and nonconscious intuitions and emotions comes from Haidt and his colleagues (Graham, Haidt, & Nosek, 2009; Haidt, 2001; Haidt, Koller, & Dias, 1993). Haidt and colleagues propose that moral decisions are based on *intuitions*, which are intertwined with emotional reactions. The claim is that emotions are manifested through intuitions about right and wrong that people maintain without being able to explain why that is the case (it is just so in their minds). Further, reasoning, reflection, and mental scrutiny are claimed to be epiphenomena of rationalization in that they have little to do with the moral decisions; rather, reasoning constitutes after the fact explanations to oneself and to persuade others of what one intuits in the first place. Intuitions themselves are explained by evolutionary adaptations shaped by culture. The claim is that built-in (hardwired?) moral intuitions must be given expression and that it is culture that provides a context for their expression (referred to as *externalization*). Illusions, cognitive blindness (referred to as *moral dumbfounding*) is claimed to be central in the realm of morality. That is, it is claimed people are unaware of what they do or why they think what they think. Immediate and reflexive reactions such as revulsion, disgust, and sympathy are thought to trigger the response that an act is wrong. Key defining features of intuitions are that they occur rapidly, without effort, and automatically. They are also assumed to occur without intentionality and without the use of evidence.

Reasoning, according to Haidt, is used largely for purposes of rationalization; it contrasts with intuitions in that it is slow and requires effort. Whereas moral evaluations and decisions are intuitive, moral reasoning occurs after the fact to justify to self and others why an act is wrong: "when faced with a social demand for a verbal justification one becomes a lawyer building a case rather than a judge searching for the truth" (Haidt, 2001, p. 814). It is also claimed that moral reasoning is used to persuade and to rationalize. Through the use of reasoning and steps of hypothesis testing "people can maintain an illusion of objectivity about the way they think" (Haidt, 2001, p. 823). Moreover, people are understood as largely unable to deal with evidence: "Most people have difficulty understanding what evidence is, and when pressed to give evidence in support of their theories they generally give anecdotes or illustrative examples instead" (Haidt, 2001, p. 821).

Critiques are provided of the type of intuitionist position elsewhere (Turiel, 2010b, 2014a) and in the 2006, sixth edition of this *Handbook*. Here I summarize those critiques and highlight an additional dimension of Haidt's position that has also focused on different types of moral orientations maintained by different groups.

First, to a large extent Haidt has relied on evidence from social psychological studies in nonmoral realms on biases, intuitions, and emotional reactions to support the claim that moral judgments are immediate, nonreflective, and do not account for evidence. He does not consider large bodies of evidence from studies in areas such as number, classification, space, causality, theory of mind, and morality, which demonstrate that people make judgments that are not necessarily immediate, rapid, and categorical, and that can be intentional, deliberative, reflective, and involve reasoning in a fundamental fashion (Gelman & Kalish, 2006; Kuhn & Franklin, 2006; Saxe, 2012). In turn, Haidt does not account for how concepts in these different domains, which may be acquired laboriously over time, can then be applied in rapid fashion (Kohlberg, 1969; Piaget & Inhelder, 1969; Turiel, 2006a). Applying well-developed understandings in an immediate, rapid fashion does not undermine the fact that a complex process of reasoning is involved (see Turiel, 2010a). For example, conceptualizations of number and arithmetic may be acquired laboriously over time but, once acquired, are applied in rapid fashion.

Research on young children's psychological understandings also demonstrates that a quantitative criterion of response speed is inadequate as a means of determining whether reasoning is at work. Many studies of the child's concept of mind (Flavell, Miller, & Miller, 2002) show that cognitive processes of a slow and rapid nature are at work between 3 and 5 years of age. As the research clearly demonstrates, 5-year-old children have an understanding of others' mental states, including beliefs, desires, and intentions. For adults, this is rapidly understood and readily applied—and it appears to be so also for 5-year-olds. Yet, cognitive developmental processes are involved in these understandings as is clear from the fact that 3-year-olds generally do not answer correctly on tasks assessing false beliefs (or other assessments of understandings of mental states). The rapidity of the cognitive processing of 5- or 6-year-old children does not reveal the uncertainties and ambiguities in younger children's judgments, nor the well-established processes of reasoning in the older children. Furthermore, the development of psychological understandings does not stop in childhood or adolescence. Even adults can face difficulties and ambiguities in understanding the psychological states and behaviors of persons (Ross & Nisbett, 1991).

Moral reasoning is multifaceted and can entail ambiguities and uncertainties, and unreflective apprehension, as well as certainties, deliberation, and reflection. Whether moral evaluations and judgments are processed very quickly or slowly, with certainty or uncertainty, with an apparent lack of self-awareness or with reflection and deliberation, depends on the individual's development, the situation or problem confronted, and the points of view of other people. First, how well a moral concept is understood has a bearing on the rapidity of a moral evaluation. A well-understood concept that is perceived as readily applicable to a particular situation may well be used in rapid fashion and give a false appearance to the outside observer that it is intuitive or a habitual practice. The same concept for that individual at an earlier time may have been applied with more uncertainty and less of a sense of being evidently true. That does not mean, however, that a concept, once formed, will be produced rapidly and without self-awareness in all situations. Ambiguities in a situation, as well as awareness that others take a different point of view, can produce deliberation, awareness of ambiguities, and argumentation.

Therefore, rapid, immediate responding is not an adequate criterion for intuition. Rapid responding can be due to several sources. One might be a sense of certainty coupled with an unelaborated understanding of the issue at hand. This form is probably closest to Haidt's use of the term intuition. A very different source comes from developed and well-understood conceptions in situations that appear to the actor as straightforward and unambiguous. In corresponding fashion, responses may be slow because the concept is still not well understood, or because there is an effort to provide an analysis or justification, or because the situation itself has multiple components that require coordination. If, therefore, we eliminate speed of responding as the criterion, the entire concept of intuition becomes ambiguous (see Bruner, 1960, for an illuminating discussion of similarities and differences between intuitive and analytic thinking; see Shweder, Turiel, and Much, 1981, for a discussion of differences between intuitive and reflective thinking).

Haidt and his colleagues ignore large bodies of research that provide a good deal of evidence that children and adults maintain complex forms of reasoning in conjunction with emotional appraisal, in coming to moral and social decisions. Several studies designed from a social domain theory perspective have demonstrated that judgments about acts such as inflicting harm, which may appear on the surface to fit the interpretation of being unreflective and immediate, in fact involve complex judgments and discriminations (Smetana, 2006; Turiel, 2002, 2010b). Although children rapidly judge many acts of physical harm as wrong, they are also readily able to articulate reasons, especially that it is not good to inflict pain, that people do not like experiencing pain. In addition, children distinguish between acts of physical harm that are wrong in some circumstances (e.g., unprovoked acts of hitting) and acts of harm that are justified in other circumstances (e.g., in retaliation for provocations; see Astor, 1994). Children and adults also take intentions into account and, thereby, distinguish between physical pain due to spanking of a child by a father and that due to a father who hits a child for reasons not intended to promote the child's welfare (Wainryb, 1991).

It should be noted that Haidt does not present evidence in support of the proposition that moral reasoning, involving concepts of welfare, justice, and rights, is used instrumentally only after decisions are reached, or that it is used as a means of justifying the decision to oneself. The unsubstantiated and reductionist assertion that reasoning is used after the fact entails a deprecation of human thinking, and a misconstrual of what lawyers do in attempting to convince a jury (see Turiel, 2006b).

While failing to account for large bodies of developmental research, Haidt and his colleagues rely on a set of unrepresentative and highly idiosyncratic actions in drawing generalized conclusions about moral functioning. Participants—primarily college students—in the Haidt group's various studies were presented with these scenarios: incest involving a consensual decision by a brother and sister to once have unprotected sex; eating one's dead pet dog; an act of cannibalism in which an assistant in a medical school pathology lab cuts off a piece of flesh from a cadaver that was to be discarded, takes it home to cook and eat; a person masturbates with a chicken and then cooks and eats it. Responses to these actions were taken to constitute evidence for the conclusion that moral judgments are emotionally driven intuitions devoid of reasoning, as many participants while judging the acts "wrong," could not present a justification for why the acts were wrong.

A fundamental problem in Haidt's work is his generalization from responses to these highly unusual situations to an explanation of morality. The situations chosen were deliberately done so as examples that supposedly did not involve harm, and would pull for intuitions because they were difficult to justify. As discussed by Jacobson (2012), there are several conceptual and methodological problems in the analyses by Haidt and his colleagues.

These include the fact that a distinction is not drawn between not having a reason for a position and incorrect reasons. Judgments about an issue like incest can involve moral decisions based on ideology, conformism, or group identity, but Haidt treats these as nonreasons. In addition, the experimenter's insistence to participants that the act of incest is described as done "without harm," can serve to obscure respondents' assumptions that the act may be risky and violates rules designed to prevent harm or promote welfare; respondents may have thought that the actors in the scenario should have known better than to take the chance of causing harm. Respondents may have been, as another example, concerned with the possibility that the act might result in irreparable harm to their relationship as siblings (including to foreseeable life events such as their future marriages). See also Pizarro and Bloom (2003) and Kasachkoff and Salstzstein (2008) for additional analyses of problems in the types of situations used by Haidt and his colleagues. See Royzman et al., 2009, and Kayyal, McCarthy, and Russell, 2013, for research showing that emotions like disgust do not determine moral evaluations.

Studies from the perspective of social domain theory have not included acts like cannibalism and sex with animals. We have studied judgments about issues like incest, abortion, homosexuality, and pornography, and compared these with judgments about what can be considered straightforward moral issues like taking a life and physical assault (Smetana, 1982; Turiel, Hildebrandt, & Wainryb, 1991). This research revealed that judgments about the straightforward moral issues were the same among age groups, religious groups, and those who made different judgments about the other, nonstraightforward issues (abortion, homosexuality, pornography, and incest). Participants in the different groups made similar judgments about the straightforward issues and reasoned in consistent ways about them as morally wrong. Evaluations and judgments about the nonstraightforward issues did differ among participants in the study—with some evaluating the acts as acceptable and some as wrong. However, individuals' judgments about the nonstraightforward acts were not consistent, involving contradictions and ambiguities. As an example, negative evaluations of straightforward moral acts were combined with the judgment that the acts should be legally prohibited. By contrast, negative evaluations of the nonstraightforward acts were often combined with the judgment that the acts should not be legally prohibited. It was also found that nonevaluative assumptions bearing on judgments differed among participants (e.g., whether the fetus is a life as related to judgments about abortion). This research, therefore, demonstrates that responses to the nonstraightforward acts (likely to include cannibalism and sex with animals) should not be generalized to other moral judgments.

The strategy used by Haidt and colleagues of choosing examples that appear not to involve harm fails to recognize that there are other situations involving, for example, harm (or fairness, or rights, or liberties) that are based on complex understandings, and to which moral evaluations *are* justified. Indeed, the social domain theory research, as cited above, provides evidence for the complexity of moral reasoning. Social domain theory research has included acts such as inflicting physical and emotional harm, theft, violating rights, violating trust, unfairness, social exclusion, prejudice, and discrimination. These are examples of true to life situations that people frequently encounter in their social relationships and they differ fundamentally from the highly unusual and often nonsocial situations of cannibalism, eating dog meat, incest, or sex with animals.

Moreover, moral judgments regarding acts of harm, unfairness, and violation of rights, once formed, involve complex types of reasoning that surely are applied in many situations in immediate, rapid ways. Consider two historical examples of decisions that can be set in a U.S. southern state (perhaps Mississippi, perhaps Alabama) anywhere between the 1920s and 1950s. One is the example of an African-American man and a Caucasian woman who decide to make love. It is likely that large numbers of White people had strong, immediate reactions that these types of acts are wrong. A second example is of an African-American boy who is 15 years old drinks from a water fountain designated "for Whites only." Many African Americans believing racial discrimination to be wrong would have had rapid reactions that such practices are wrong.

I raise these examples to illustrate that moral judgments are often more than seeming intuitions; in these cases, they involve concepts about different groups, social relationships, perspectives on society, and distinctions between when rights should be applied and when they should be denied. This is so, even though many would have reacted in a seemingly rapid way to these examples by claiming that it is not wrong for consenting adults to engage in sex or get married (and that it is wrong to prevent them from doing so). Similarly, an immediate reaction might be that it is wrong to reserve certain restaurants or water fountains for White people. Again, those reactions are complex and involve reasoning about rights, fairness, and welfare—as well as about the injustices of the dominance and power exerted by one group on another.

That people disagree about how to interpret and apply these concepts fails as evidence that the judgments lack thought and rationality—just as disagreements in psychologists' theories of development fails as evidence that the theories are not based on effortful reflective thought. Few, if any, have suggested that different conceptions on the part of different psychological theorists mean that they stem from nonconscious, automatic reactions determined by group affiliations. It is generally recognized that scientists actively think about those aspects of the world they are trying to most adequately explain, and that they attempt to take evidence into account. Nevertheless, in thinking about how to explain the psychology of human beings theorists often propose that people function in fundamentally different ways from their own. Whereas scholars and theorists take what amounts to a structural and relational approach in their explanations, the psychological functioning of those they are studying are not always seen to take such approaches.

Determinism and the Brain and Emotion in Morality

The unusual situations involving matters such as incest, cannibalism, and sex with chickens are in stark contrast with many of the situations that philosophers and other social scientists (and probably laypersons) regard as part of the moral domain—such as preventing harm, promoting welfare, fairness, and rights. Another program of research based on deterministic assumptions about morality (i.e., moral acts and judgments causally determined by psychological and biological mechanisms) explicitly rejects the value of definitional-philosophical considerations. Sociobiologists and evolutionary psychologists have proposed that emotionally based brain functions determine moral choices. Moral choices are considered nonrational, nonconscious, and automatic (for commonalities with the intuitionist approach, see Greene & Haidt, 2002). The study of morality, emotions, and brain functions has it antecedents in sociobiology (Wilson, 1975). Wilson, a leading sociobiologist, asserted that concerns with epistemology are more of a hindrance than help. He proclaimed, "Scientists and humanists should consider together the possibility that the time has come for ethics to be removed from the hands of the philosophers and biologicized" (Wilson, 1975, p. 562).

Wilson's call went largely unheeded at the time. It collided with the efforts of the many philosophers discussed earlier in this chapter who continued to keep their hands on ethics and morality. It also collided with the analyses of influential developmental psychologists such as Kohlberg (1971) and Piaget (1932) before him who attempted to bring philosophical considerations into their theories and research. Kohlberg (1971), for example, made a compelling case that many shortcomings of psychological research were due to the failure to attend to definitional-philosophical formulations in their research on moral development. However, toward the end of the 20th century and beginning of the 21st, some researchers began to "biologicize" morality and study it with methods from neuroscience (Cushman, Young, & Hauser, 2006; Greene et al., 2001; Greene & Haidt, 2002; Hauser, 2006; Koenigs et al., 2007; Mikhail, 2007). Much in keeping with Wilson's view, a number of these researchers have taken—paradoxically in light of their dismissal of philosophical concepts—a philosophical empiricist approach. For example, Greene (2007) dismisses the relevance of philosophical-definitional analysis:

> As an empiricist, I believe that we can study things like life without defining them. . . . This strategy, I believe, works just as well for the aspect of life that we call "morality." For empiricists, rigorously defining morality is a distant goal, not a prerequisite. If anything, I believe that defining morality at this point is more of a hindrance than help, as it may artificially narrow the scope of inquiry. . . . Rather than seeking out morality by the light of a philosopher's definition (Kantian or otherwise), I and like-minded scientists choose to study decisions that ordinary people regard as involving moral judgment.

The justification for Greene's position lies in the proposition that decisions are determined by subconscious brain functions and, hence, are made prior to conscious awareness (Wegner, 2002). In this regard, Koenigs et al. (2007) contrast their neuroscience position with "traditional rationalist approaches to moral cognition that emphasize the role of conscious reasoning from explicit principles" (p. 908).

Interestingly, the situations often used in the research from this biological-empiricist perspective are on the face of it more clearly in the moral realm than those used in the research from the intuitionist perspective as they pertain to matters of life and death. Actually borrowing from one philosophical tradition, neuroscientists have used tasks that entail utilitarian calculations, such as whether it is preferable to sacrifice one life to save a greater number of lives. So-called ordinary people may well regard these issues to involve moral judgments, but contemplating the idea of sacrificing one life to save five others is not likely to be what they regard as everyday moral decisions. The tasks often used in the neuroimaging research are anything but straightforward regarding the value of life because participants are posed with the complex and difficult problem of whether it is permissible for them to endorse taking a life. In addition, the tasks are constructed to maximize the possibility that people will make what appear to be contradictory decisions (the *gotcha* part of proclivities in some psychological research). Participants are presented with what are referred to as trolley car *bystander* and trolley car *footbridge* scenarios while in an fMRI machine. One version of the bystander scenario is as follows: "A runaway trolley is headed for five people who will be killed if it proceeds on its present course. The only way to save them is to hit a switch that will turn the trolley onto an alternate set of tracks where it will kill one person instead of five" (Greene et al., 2001, p. 2105). Participants are asked questions bearing on whether it is permissible to throw the switch. The scenario involves a utilitarian calculation as to whether it is better to sacrifice one life to save more lives. The "trick" part of this research comes with the use of the footbridge version: "a trolley threatens to kill five people. You are standing next to a large stranger on a footbridge that spans the tracks, in between the oncoming trolley and the five people. In this scenario, the only way to save the five people is to push this stranger off the bridge, onto the tracks below. He will die if you do this, but his body will stop the trolley from reaching the others" (Greene et al., 2001, p. 2105). Still acting as utilitarian executioners, participants need to decide if it is permissible to save five lives by sacrificing one, but in this case by actually pushing a man to his death.

The findings support the idea there is a difference between the two scenarios; most participants judge it acceptable to throw the switch to save five people, but most state it is not permissible to push a man even though that act would save the same number of people (Cushman et al., 2006; Greene et al., 2001). These findings form the basis for the claim that the critical difference between the scenarios is that the footbridge version evokes emotions more than the bystander version, and that it is this difference in emotions that accounts for the difference in responses. Presumably, pushing someone to his death is more emotionally salient than killing the person by throwing a switch and that "it is this emotional response that accounts for people's tendency to treat these cases differently" (Greene et al., 2001, p. 2106). The studies also indicate that the two scenarios are associated with the activation of different brain areas generally thought to involve rationality and emotions.

There are several reasons to question the interpretations drawn from the findings of these studies (Killen & Smetana, 2007; Miller, 2008; Turiel, 2009). One problem lies in the idea that because the footbridge scenario evokes emotions greater or different from the bystander scenario the differences in *decisions* are accounted by emotions. Although the idea of physically pushing a person is likely to evoke more intense emotions than throwing a switch, the two situations are not otherwise the same.

For an adequate analysis of these situations it is necessary to take into account the emotions involved in each, why one might evoke more or different emotions, that reasoning does not entail only utilitarian calculations, and the generalizability of these types of decisions to other moral decisions. It is misleading to say only that the footbridge scenario is more emotionally salient because it ignores the emotions likely to be involved in the bystander scenario as well and the unique features of these types of scenarios. Although the researchers treat the trolley car tasks as representative examples of moral problems involving utilitarian calculations, in actuality a decision as to whether to take a life in these ways is highly unusual for most people, poses complex considerations with regard to the problem of whether it is acceptable to take a life, and is particularly charged with emotion because of the very issues that make it moral: The perceived value and sacredness of life and prohibitions against taking a life. The idea of taking an action like throwing a switch that will cause the death of an individual even to save more lives no doubt evokes strong emotions. The researchers largely ignore the emotions likely to be invoked in the bystander scenario. Both types of scenarios are complex and emotionally laden because a strongly held value—the value and perceived sacredness of life—must be violated in order to preserve that very value. These situations are unusual, complex, and involve dilemmas for people because they are forced to repudiate morality with morality.

We need to ask: What is it about the footbridge situation that evokes more intense emotions? If we do not simply split-off emotions from judgments, then the likely answer is that people do make judgments about the act of physically pushing someone to his death. The footbridge scenario constitutes a different context of evaluation from the bystander scenario (what Asch, 1952, referred to as "objects of judgment"). In addition to the dilemma of saving lives by repudiating the prohibition on taking lives embedded in the bystander scenario, the footbridge scenario entails judgments and emotions about actively and physically causing another's death. Unlike the bystander scenario, the footbridge scenario includes the component of what might be interpreted as inflicting physical assault on another person and thereby directly causing death. Along with utilitarian calculations, participants make judgments about the fundamental conflict in values in the situations, and about the means used to achieve ends. People do take into account the different features of social situations and attempt to coordinate different types of judgments relevant to those features.

To a greater extent than the bystander scenario, the footbridge scenario presents a compounded problem involving the saving of lives, taking a life, the natural course of events, the responsibility of individuals altering natural courses, and causing someone's death directly. The emotions and coordination of judgments involved are more complex in one than the other. The diversity of features embedded in social situations can be even more complex, as is evident in a third scenario used in the research. In that scenario, a doctor can save five patients who are dying from organ failure by cutting up and killing a sixth healthy patient to use his organs for the others. It is rare to find participants who judge it permissible for the doctor to use a healthy patient's organs to save five others. Although this scenario also includes the five versus one calculation, it is seldom the case that physicians act this way; it is rarely condoned, and never seems to be contemplated as legitimate medical or social policy. This scenario raises issues about a doctor's duties and responsibilities, the power granted to individuals to make life and death decisions, the legal system, and societal roles and arrangements.

All these considerations are likely to be taken into account in responding to the scenario. However, the experimental conditions are unlikely to allow much in the way of thought and reflection about the trolley car situations because participants are restricted in the fMRI machine. The conditions are likely to pull for less reflective responses. Research is needed to ascertain how participants think about the trolley car situations used in the neuroimaging studies. Preliminary findings from an in-depth interview study indicate that individuals make distinctions among the different components of the situations and that the situations are construed differently from each other (Dahl, Uttich, Gingo, & Turiel, 2013).

The differences among the scenarios used in the studies seem to be designed to confound people by presenting significantly different features in the guise of similar features (i.e., the utilitarian calculation). However, these scenarios constitute what philosophers call extreme, hard cases involving a moral paradox where the right thing to do is also wrong (an often used example is whether it is permissible to torture someone to obtain information that would save many lives from a terrorist attack [Walzer, 2007]). Such cases entail exceptions to rules and principles, and therefore judgments in these situations cannot simply be generalized to most moral decisions. Thus, the trolley car situations are inadequate starting points for psychological analyses of people's moral decision making. These types of situations might be useful for the study of moral decisions in complex and extreme situations with a solid background of data and theory on people's judgments and decisions regarding more straightforward situations. Although that background is available, the neuroimaging research has ignored it. What are taken to be seeming inconsistencies in responses to the presumably similar (i.e., involving utilitarian calculations) situations have been used to assert that morality is due to evolutionary determined emotions, and that reasoning is rationalization for subconscious decisions.

Determinism and Relativism in the Morality of Groups

The evolutionary and biological perspectives are consistent with nonrelativistic deterministic positions on morality, as evolution would be viewed as applying across cultural groups. At an opposite pole of determinism are perspectives that consider morality to be determined by group participation (though, as discussed later, there have been attempts to combine the two as in the intuitionist approach). As mentioned earlier, Durkheim (1925/1961) proposed that morality is a function of an attachment to a homogeneous group, such as the society. Some cultural anthropologists have maintained that children come to identify with a general orientation in their culture and that different cultures can have very different moral values from each other. Such a view was articulated by Benedict (1934), who claimed that there is a great deal of variation in what might be considered fundamental moral values, but that variations are nonrandom because cultures are integrated: "The significance of cultural behavior is not exhausted when we have clearly understood that it is local and man made and hugely variable. It also tends to be integrated. A culture . . . is a more or less consistent pattern of thought and action" (Benedict, 1934, p. 46). Benedict stated the following with regard to development: "The life-history of the individual is first and foremost an accommodation to the patterns and standards traditionally handed down in his community. . . . Every child that is born into his group will share them with him, and no child born into one on the opposite side of the globe can ever achieve the thousandth part" (1934, pp. 2–3).

Benedict (1934) characterized the proposed variations among cultures through an example that many might consider to epitomize moral concerns, transcending time and place:

> We might suppose that in the matter of taking life all peoples would agree in condemnation. On the contrary, in a matter of homicide, it may be held that one is blameless if diplomatic relations have been severed between neighboring countries, or that one kills by custom his first two children, or that a husband has right of life and death over his wife, or that it is the duty of the child to kill his parents before they are old. It may be that those are killed who steal a fowl, or who cut their upper teeth first, or who are born on a Wednesday. (p. 46)

In this way, Benedict encompassed several cultural practices commonly used to illustrate variations in moral codes: parricide, infanticide, and family relationships of inequalities. Observations of variations in social practices, thus, were used to argue for the incomparability of the moralities of different cultures.

In contemporary research by some cultural psychologists it has also been proposed that cultures are cohesive and integrated and that they can be divided by their orientations to either *individualism* or *collectivism* (Markus & Kitayama, 1991; Shweder & Bourne, 1982; Shweder, Mahapatra, & Miller, 1987; Triandis, 1990). Within this perspective, dichotomous distinctions are drawn between Western (e.g., the United States and European countries) and non-Western (e.g., Japan, India, China, and Middle-Eastern and African countries) cultures. In addition to identifying differences in specific social norms and cultural practices, characterizations of individualism and collectivism from this perspective are meant to define respective general orientations to how persons are defined, how they interact with each other, how society is defined, and how the goals of persons and the group are established and met. The person conceived as an autonomous agent, with personal goals, is understood to be central in individualistic cultures, whereas the group as an interconnected and interdependent network of relationships is considered central in collectivistic cultures. A core feature of individualistic cultures is that the highest value is accorded to the person as detached from others and as independent of the social order. People are, therefore, oriented to self-sufficiency, self-reliance, independence, freedom of choice, and autonomy. Morality is understood to be based on rights and justice. Collectivistic cultures, by contrast, are oriented to tradition, duty, obedience to authority, and interdependence. Morality in this situation is understood as based on duties and obligations.

Following the earlier work of Shweder et al. (1987), Shweder, Much, Mahapatra, and Park (1997) modified the individualism-collectivism dichotomy with a proposal that each form of moral orientation is not exclusively used within a culture. They proposed that there exist three main types of *ethics*: the ethics of *autonomy*, *community*, and *divinity*. Although the inclusion of three ethics broadens the scope of the analyses beyond the dichotomy of rights and duties, it is still claimed that the *social order determines the interplay of different types of goods within a worldview*. Thus, in a non-Western culture (e.g., India), community and divinity are dominant, whereas in a Western culture (e.g., the United States) autonomy prevails. In Indian society, therefore, the ethics of autonomy is minimized and is in the service of the ethics of community, which refers to status, hierarchy, and social order, and the ethics of divinity based on concepts of sin, sanctity, duty, and natural order.

According to Shweder et al. (1997) the ethics of community is dominant in India and, thus a person's identity is associated with status and relationships to others to a much greater extent than autonomy. In fulfilling social roles in society, collectivists are said to accept roles of dominance and power for certain groups (e.g., males) and roles of subordination for other groups (e.g., females). Relationships are part of hierarchical orderings, in which people in dominant and subordinate positions are obligated to protect and look after each other's interests. For example, inequality in Indian families is demonstrated in that wives should be obedient to husbands and husbands should be responsive to the needs and desires of wives. Shweder et al. (1997) regard this type of relationship as analogous to feudal ethics, where the feudal lord does for others as much as they do for him (an asymmetrical reciprocity because one person is in a position of dominance and control). Evidence said to support the idea of asymmetrical reciprocity is found in judgments by participants in a study conducted in India demonstrating that sons rather than daughters can legitimately claim most of a deceased father's property, and that it is acceptable for a husband to beat his wife "black and blue" after she disobeys him by going to a see a movie alone (Shweder et al., 1987).

The general idea that cultures can be dichotomized by emphases on the person or the group has been incorporated into Haidt's intuitionist approach. In efforts to combine evolution and culture he borrowed heavily from Shweder et al.'s (1997) three types of ethics, extending the formulations by proposing that moral intuitions (note that Shweder regards, instead, the three orientations to be based on different rationalities) can take five forms associated with cultures or subgroups within cultures (Graham et al., 2009; Haidt & Graham, 2007). In line with Durkheim's emphasis on group affiliation and cohesiveness, Haidt has maintained that the orientations to morality serve to bind groups together. The orientations include (a) harm and care, (b) fairness and reciprocity, (c) ingroup and loyalty, (d) authority and respect, and (e) purity and sanctity. Despite the larger number of orientations, Haidt accepts the idea that in some groups roles and status in the social hierarchy determine moral stances. In keeping with Shweder et al.'s (1997) proposition, Haidt maintains that morality in India is based on the interdependence in social units like the family where males are in positions of dominance over females and where morally derived cultural practices of inequality are more important than the types of equality and rights valued in person-oriented Western cultures (hence in India "beating a wife black and blue" is a moral good when standards of asymmetrical reciprocity are violated). An orientation to authority and hierarchy, including groups stratified by sex, is moral in nature because it serves the function of binding the group and because both those at the top, with greater power, and those at the bottom, with lesser power, presumably accept the system and its practices of inequality. Another way of stating the moral grounds for a highly stratified society is that social rank is managed by the obligation of superiors to protect and provide for subordinates and for subordinates to respect superiors and appreciate that they protect them.

According to Haidt and colleagues, we do not only have to look to differences between nations to find fundamentally different moral orientations. Differences in moralities are found among subgroups within nations–such as in the moralities that serve to distinguish between conservatives or Republicans and liberals or Democrats in the political landscape of the United States (Graham et al., 2009; Haidt & Graham, 2007). The morality of liberals/Democrats presumably is based on intuitions about harm, fairness, freedom, and includes a disdain for authority (they have an "instinctive distrust of institutions and authorities," Haidt & Graham, 2007, p. 117). By contrast, conservatives/Republicans embrace authority and respect. Therefore, subgroups have fundamentally different moral orientations toward respect for authority, hierarchy, and inequalities, on the one hand, and concerns with fairness, liberties, rights, and equal treatment, on the other (as signaled by the title of a manuscript by Graham, Haidt, and Nosek, "Liberals and conservatives rely on different sets of moral foundations").

The group differences and an element of relativism in this position is well illustrated in a discussion by Haidt and Graham (2007) of the different views on gay marriage espoused by the liberal journalist Jon Stewart and the conservative politician Rick Santorum in an interchange on Stewart's TV show. According to Haidt and Graham (2007), "Santorum's anti-gay-marriage views were based on concerns for traditional family structures, Biblical authority, and moral disgust for homosexual acts (which he had previously likened to incest and bestiality)" (p. 111). In what seems an effort to equate the conservative views of Santorum as representative of a morality based on authority and sanctity with the liberal views of Stewart based on fairness, Haidt and Graham (2007), thereby, treat the position of gay people who are regarded with disgust and denied dignity, worth, respect, and freedom of choice as irrelevant to the morality espoused in the conservative orientation of the Republican politician and his group.

This relativistic position is in direct contrast with the observation of the philosopher Vlastos (1962) that: "The great historical struggles for social justice have centered about some demand for equal rights: the struggle against slavery, political absolutism, economic exploitation, the disfranchisement of women, colonialism, racial oppression" (p. 31). Vlastos regarded these struggles to have occurred throughout history and into the time of his writing in the middle of the 20th century. Political discourse in the 21st century in Western and non-Western nations involve such struggles and include demands for universal equality and universal rights.

Examined historically, the position argued by Haidt concerning U.S. politics implies that acceptance of slavery by virtue of a system of thinking based on ingroup loyalty, respect for roles and authority in the social system (including roles of dominance and subordination), and the sanctity of tradition would have been on an equal footing as opposition to slavery by virtue of harm, suffering, compassion, liberty and rights, and fairness. Similarly, examining Haidt's position historically would lead to the claim that at various points in history people held views on racial segregation and gender relationships based on orientations to authority, hierarchy, and sanctity. Thus, for example, some groups have held the positions that racial groups should be segregated in neighborhoods, schools, eating establishments, hotels, public facilities such as bathrooms and drinking facilities; that people of different races should not be allowed to marry; that females should not vote or have equal access to educational and work opportunities; and that women should be subordinate and obedient to their husbands. Haidt's claims suggest that such positions on race and gender reflect moral perspectives on hierarchy, which have equal moral status as those of groups or individuals holding positions that the rights of different racial groups should be respected and treated equally.

CULTURE, HETEROGENEITY, AND ALTERNATIVE PERSPECTIVES

There is now a large literature with compelling research findings bearing on positions regarding characterizations of cultures with general, homogeneous orientations such as individualism and collectivism. These general orientations fail to capture the heterogeneity of competing views and conflicts within cultures and groups (Gjerde, 2004; Oyserman, Coon, & Kemmelmeier, 2002; Raeff, 2006; Strauss, 1992; Turiel, 2002, 2006a; Turiel & Perkins, 2004; Turiel & Wainryb, 1994, 2000), and fail to recognize that people do not typically rely on authority in their moral evaluations (Kim, 1998; Kim & Turiel, 1996; Laupa, 1991; Laupa & Turiel, 1986, 1993).

The homogeneity attributed to political groups also fails to account for the heterogeneity of people's moral and social judgments. For example, the claim by Haidt and colleagues that liberals have an instinctive distrust of authority and that the morality of conservatives includes respect for authority and institutions came in the first decades of the 21st century when in United States political discourse conservatives championed the pronouncement in 1981 by then President Ronald Reagan that "Government is not a solution to our problem, government is the problem." This has been more than a slogan for conservatives as they struggled for many years to enact legislation and policies aimed at shrinking the role of government for purposes of promoting free enterprise and individual freedoms (e.g., to own guns, keep their money from being taxed, make individual decisions on health care and medical insurance, to freely contribute to political candidates). In the election cycles of 2008 and 2012, liberals countered conservatives with a reliance on governmental authority and initiatives that would restrict freedoms in order to promote general welfare and community interests (including on guns, taxes, and health care). Conservatives invoke respect for the authority of the U.S. Constitution (the Second Amendment) in support of the freedom and right to own guns, but disdain the Constitutional ruling in *Roe versus Wade* that supports the freedom and right to abortion. Liberals invoke respect for *Roe versus Wade* to support the right to abortion, but disdain the Second Amendment as a basis for gun ownership. Conservatives have shown disdain for the authority of the presidency of the United States (as in their attitudes toward President Barack Obama from 2008 to 2013), just as liberals showed disdain for the presidency (as in their attitudes toward President George W. Bush from 2000 to 2008). Both groups are concerned with freedoms, restrictions, the role of authority, and the welfare of people and the community. For instance, liberals/Democrats have often espoused communitarian positions that rely on the moral force of the group and they value democratic institutions without instinctive distrust of authority (Bellah, Madsen, Sullivan, Swidler, & Tipton, 1985; Putnam, 2000). In turn, on the conservative/Republican side antiabortion positions are strongly guided by commitments to avoiding harm and the value of life—as are liberal positions on abortion (Dworkin, 1993; Smetana, 1982; Turiel et al., 1991). Stereotyping the orientations of one or the other does not capture the differences between them.

Distinctions between individualism and collectivism, with the presumption that those at different positions on social hierarchies readily accept their roles, status, and power have a serious shortcoming; those in subordinate positions were not adequately studied.[1] Instead, there was a reliance on those who are in positions of authority and

[1]Events in India that occurred at the end of 2012 and beginning of 2013 shed a different light on so-called asymmetrical reciprocity in the family and relations between males and females. A brutal rape and subsequent death of the woman resulted in massive nationwide demonstrations and protests. The demonstrations were in part over the rape and killing. They were also about the inadequate responses of the police and the courts to such events, as well as about discrimination and the unfair treatment of girls and women perceived to be widespread. Women from India writing op-ed pieces in *The New York Times* discussed the lives of females who are subjected to these conditions. In one such telling a woman from Delhi (Faleiro, 2013) wrote about the regularity of sexual harassment and the "steady thrum of whistles, catcalls, hisses, sexual innuendos, and open threats" that occur in public spaces, offices, and house parties. She wrote that to prevent sexual harassment teenage and adult females must often take steps like carrying safety pins and makeshift weapons. A 50-year-old woman who had been raped when she was 17 concluded that, "We have spent generations constructing elaborate systems of patriarchy, caste, and social and sexual inequality that allows abuse to flourish" (Abdulali, 2013).

power in the culture to inform investigators about the culture. As noted by several critics, by excluding those in positions of lesser power, published research presents a one-sided view. For example, the cultural anthropologist Wikan (1991) noted that: "looking mainly at culture's spokesmen . . . at the exclusion of the poor, the infirm, women, and youths . . . [has resulted in] the concept of culture as a seamless whole and of society as a bounded group manifesting inherently valued order . . . that effectively masked human misery and quenched dissenting voices" (p. 290). Making a similar point, the philosopher and political scientist Okin (1989) argued that: "Oppressors and oppressed—when the voice of the latter can be heard at all—often disagree fundamentally. Contemporary views about gender are a clear example of such disagreements; it is clear that there are no shared understandings on this subject, even among women" (p. 67).

A consequence of the failure to study the critical perspectives of those of lesser power is that groups are erroneously described as neatly bound together in harmony. However, groups placed in the collectivist camp do not fit stereotypes of homogeneity, harmony, and acceptance of cultural practices. As discussed later, psychological and anthropological research conducted over the past 20 years or so also documents that in non-Western cultures there are concerns with subjugation, unfairness in cultural practices of inequality, and efforts to affect social change through opposition and resistance. All of these considerations make for a morality as an ongoing part of social relationships, which entails active concerns in everyday life with how people should treat each other. The research also demonstrates that non-Western cultures experience conflict, social struggle and present significant variation in perspectives on social relationships. Wikan (1996) summarized findings from her ethnographic research in Cairo this way: "these lives I depict can be read as exercises in resistance against the state, against family, against one's marriage, against the forces of tradition and change, against neighborhoods and society" (pp. 6–7).

Where do these conflicts and struggles originate? They arise from human reflections on social relationships including judgments about dignity, welfare, fairness, and rights, and they arise from conscious human values of freedom and equality. A number of studies in patriarchal cultures have shown that opposition and resistance to cultural practices extends well beyond the infliction of physical harm. A set of psychological studies have assessed the thinking of adolescent and adult males and females about designated roles and how females evaluate cultural practices that grant much control to males over females in many activities. These include studies conducted in Turkey (Guvenc, 2011) and among Druze Arabs in Northern Israel (Wainryb & Turiel, 1994)—as well as studies in India (Neff, 2001), Colombia (Mensing, 2002), and Benin (Conry-Murray, 2009). Common to these patriarchal cultures are restrictions on females regarding educational and work opportunities, recreational pursuits, social affiliations, and choices of dress. More generally, restrictions are placed on the decisions females can make, with males granted decision-making power when disagreements occur. One finding bearing on characterizations of such cultures is that the ideas of autonomy, independence, and personal choice (supposedly minimally present in collectivist cultures) are recognized to be part of the culture. Males assert their independence; females are aware that males are granted autonomy, independence, and power. However, females also value independence and freedom of choice, but believe that they have to struggle to accomplish such ends. Females are aware of the pragmatics of social relationships in the family and sometimes grant decision-making authority to males because males have the power to inflict serious negative consequences to those in subordinate positions (e.g., abandonment and divorce). Nevertheless, in the studies that assessed females' judgments as to whether the practices are fair or unfair, it was found that the large majority judged cultural practices of inequality to be unfair.

Consistent with general findings in this body of research, the following example of a response from an adult woman in the study conducted among Arab Druze villagers living in Northern Israel (Turiel, 2002) provides an illustration of how people in non-Western, nonliberal cultures make judgments of unfairness in group norms and do not simply accept authority and hierarchy. She said:

> A man's life is simple. He works, he comes back home; he has no other responsibilities. I work too and I have kids and a home. He knows that when he comes back, everything will be ready for him. That's such a pleasure. When I come home I have more work to do at home. So, who do you think deserves to get out a little and enjoy life? (p. 249)

Another example comes from a woman in a study conducted in villages in eastern Turkey (Guvenc, 2011): "Everybody has rights and you have to see this. A woman and man are equal" (p. 21).

Findings consistent with these psychological studies were obtained in studies by Abu-Lughod (1993) and Wikan (1996) using ethnographic methods, with the researchers living in the communities for lengths of time observing events and interviewing females. In her research in the Bedouin community in the northwest coast of Egypt, Abu-Lughod (1993) found a good deal of opposition and resistance in daily life among girls and adult women. Acts of opposition and resistance occurred in the context of a patriarchal system in which many cultural practices are designed to allow males to control the activities of females and for males to have greater access to activities fulfilling their autonomy and achievement of personal choices and entitlements. Abu-Lughod reported that there are disagreements and conflicts among group members, efforts to alter existing practices, and struggles between wives and husbands, and parents and children. Women develop strategies, often hidden from men, to assert their interests. These strategies, which include deception, allow women to avoid unwanted arranged marriages and polygamy, assert their will against restrictions imposed by men, attain some education, and engage in prohibited leisure activities. Therefore, women do not simply accept the situation imposed by authority and embedded in cultural practices.

Wikan's (1996) studies of people living in poor areas of Cairo revealed a predominance of social struggle, conflict, and disagreement. These struggles and conflicts are multifaceted since they involve conflicts within society, as well as within the family. As in the research with the Bedouins, there is opposition on the part of females to the restrictions imposed on them by males (for more details on the psychological and anthropological studies, see Turiel, 2002, 2006a).

Their findings can be illustrated through the response of a woman in Wikan's (1996) study of people living in conditions of poverty in Cairo—sentiments resembling those of the Druze woman quoted earlier:

> I tried to make Mustafa understand that we must be open with each other and mutually adjust—that we must tell each other what each of us liked and wanted from life, so we could make each other happy. But he just scowled and said, "I do as I please!" and "I am free." Of course, the man should have his freedom, but not at the woman's expense! (p. 31)

As an example pertaining to the cultural practice of polygamy in the Bedouin village, one woman regarded the practice of polygamy to be unfair:

> And this business of marrying more than one wife—I wish they'd change their views on this. It is the biggest sin. The Prophet—it is not forbidden but the Prophet said only if you treat them fairly. But a man can't, it can't be done. Even if he has money, he can't. As a person in his thoughts and his actions, he can't be fair. He'll like one more than another. (p. 238)

Cultural Practices, Relativism, Absolutism, and Universality

The findings of the psychological and anthropological research indicate that universal values of freedom, autonomy, and rights are very much part of "traditional" cultures. They are highly valued by and for males and desired by women. The findings are in contradiction with cultural analyses that focus on specified duties and roles, and the submergence of self into a network of interdependence. The other side of the coin of social hierarchies is that there is a strong sense of independence and personal entitlements embedded in social hierarchical arrangements. Examples of where such entitlements hold are for those in higher castes and social classes relative to those in lower castes and classes (Turiel, 2002, 2003; Turiel & Wainryb, 2000), and in relationships between males and females. Whereas practices revolving around social hierarchical arrangements convey duties and role prescriptions, they also convey that those in dominant positions have personal autonomy and entitlements—especially due to them by those in subordinate positions.

The findings also demonstrate that cultural practices promoting inequalities and unfair treatment are not uncritically accepted—even though the practices are traditional and supported by those in positions of power and authority. This is because through the development of moral judgments about welfare, justice, and rights, individuals can step back—*reflect*—and *evaluate* existing social conditions. The findings indicate that there are multiple perspectives within cultures, and that the perspectives of those in different positions in the social hierarchy can vary. On the one hand, people actively participate in their culture and share much with each other, but, on the other hand, they have disagreements and conflicts with each other.

The research showing opposition to cultural practices of inequality within social hierarchies, as well as the different domains of judgment, has implications for how we think about social and moral dimensions of cultures and for comparisons between cultures. The existence of different and distinct domains of social judgments means that members of a culture have heterogeneous orientations and, therefore, a culture cannot be defined through a homogeneous orientation. In addition, there are complex patterns of commonalities and differences between cultures. There are commonalities in the moral judgments people make in different cultures, but there are also differences in the ways moral judgments are applied. In turn, the different perspectives on cultural practices held by those in lower and higher positions of power and status means that there are differences within cultures. It is also the case that those in a particular position in the social hierarchy (e.g., lower status groups) have some similar perspectives as those of the same status in other cultures, but have perspectives that can be different from groups in other positions (e.g., those of higher status) in their own culture. Consequently, it is important to consider multifaceted relations between and within cultures, with areas of between and within culture agreements and disagreements.

All of these considerations regarding differences and similarities within and between cultures have implications for how we think about relativism, absolutism, and universality. I have discussed positions that take a universalist/absolutist stand on morality. Proposals of a biological or genetic origin to morality (e.g., sociobiologists and evolutionary psychologists) implicitly assume that morality is universal because the brain processes on which they are assumed to be based are unlikely to vary by culture. When these researchers describe areas where people do display different moral evaluations in different situations (as in different responses to the bystander and footbridge trolley car situations), these differences are explained as failings of consistency due to interference from emotional reactions. Normatively, according to these researchers, there should be consistency in moral evaluations—a consistency reflecting an underlying absolute fixed biological base (see the idea of a universal moral grammar put forth by Hauser, 2006; Mikhail, 2007).

Philosophers have frequently debated the question of relativism. In the social sciences, however, there are those who maintain that morality differs by cultures in ways that they are incomparable with each other, but also maintain that they are not taking relativistic positions (e.g., Shweder et al., 1997). The justification for the assertion of nonrelativism is that they do not see morality as arbitrary, but rather as entailing obligations holding moral weight within a culture. Whether it is labeled relativism, it is clear that differences between cultures in morality are posited and that they are based on the assumption that cultures form cohesive integrated patterns of organization of fundamentally different types (as in the propositions regarding individualism and collectivism).

Both absolutism and broad cultural differences fail to account for the development of social and moral judgments that constitute different systems of individual thought, the flexibility of mind in coming to social and moral decisions, the heterogeneity in judgments about persons and groups, and important commonalities across cultures and variations within cultures. As discussed in a subsequent section, decision making involves processes of coordination whereby moral goals regarding rights, social inclusion, and honesty can be subordinated to other moral goals or nonmoral goals. Those types of decisions speak against moral absolutism. The studies involving coordination in decision making show that particular moral values or concepts are not applied in either categorical or arbitrary ways. A failure to draw a distinction between moral concepts and how they are applied leads to viewing variations in social decisions as evidence of fundamental moral differences.

Another dimension of moral and social decision making that has to be added to the mix is informational assumptions or judgments about reality, which have to do with perceived consequences in a system of beliefs about reality (Asch, 1952; Hatch, 1983; Turiel et al., 1991; Turiel, Killen, & Helwig, 1987; Wainryb, 1991). Conclusions about group differences in the morality of cultural practices should not be drawn without considering assumptions about reality (of this world or otherworldly). This point was spelled out by Hatch (1983) through the example of the practice (a practice Hatch reports existed in some places in the past) for a son to leave parents to die when they reached a certain age and were still in good health:

> [such practice] may reflect differences in existential beliefs and assumptions, rather than morals. . . . Judgments of values are always made against a background of existential or factual beliefs and assumptions, consequently what appears to be a radical difference in values between societies may actually reflect different judgments of reality. . . . Let us say that a society which has the custom of putting parents to death at an early age reasons in doing so that people are better off in the afterlife if they enter it while still physically vigorous. Both they and we presumably agree on the moral principle of looking out for our parents' interests, and our disagreement is really over the nature of the afterlife, and hence about what their interests are. This is a matter of factual beliefs, not values. (pp. 66–67)

The distinction between moral concepts (e.g., concern with the welfare of others) and assumptions about reality applies to many other practices as well. It applies to practices bearing on dress and food, for example, when those are tied to assumptions about the afterlife and actions on earth that are assumed to have consequences for the souls of the deceased (e.g., a son's action after the death of his father is assumed to affect the father's soul; see Turiel et al., 1987). As another example, assumptions about the status of the fetus as a life have a bearing on judgments as to whether abortion is right or wrong (Turiel et al., 1991). If practices do differ in these ways, it is not adequate to take absolutist or relativist positions on associated acts or practices. The examples illustrate that alternative acts seemingly different from each other (such as putting parents to death or not) can be motivated by similar moral concepts (such as furthering the parents' welfare).

Moral Thought, Reciprocal Social Interactions, and Constructive-Relational Processes

The illustrative examples of responses by adult women, which reflect the evidence from the research literature, indicate that moral and other social judgments are not inflexible reactions due to emotions, brain processes, disembodied conscience, or the incorporated, habitual, psychologically fixed values or standards shaped by society. The critical stances to cultural practices and the implied differences in perspectives between those in different positions on social hierarchies indicate that individuals in so-called collectivist cultures do not treat societal roles or associated practices as sacrosanct. Moreover, their moral judgments, and conceptions of social relationships and self do not reflect a commitment to a supposedly cohesive, integrated, and shared cultural orientation. In addition to the perceived unfairness of aspects of the system ("who do you think deserves to get out a little and enjoy life"), there are understandings of the importance of mutuality, as well as autonomy and freedoms ("we must be open with each other and mutually adjust," "the man should have his freedom, but not at the expense of the woman").

The studies from which the women were quoted and other studies conducted in several cultures also indicate that demands for social justice and equal rights are not restricted to the great historical struggles referred to by Vlastos (1962). Concerns with equal rights and unfair treatment are not only part of political movements, but are also part of people's everyday lives in Western and non-Western cultures alike (Turiel, 2003). This is because individuals, starting early in life, are *reasoning beings*. As *constructive and relational processes* (see Overton, Chapter 2, this *Handbook*, this volume, for an extensive general discussion of constructive and relational processes in developmental science), there is questioning of privileges, control, and decision-making power granted only some groups in the social system. As already discussed, such a perspective is part of a long liberal tradition in moral philosophy. It is also consistent with a tradition of theory and research on the development of moral judgments (Kohlberg, 1963a, 1969, 1971; Piaget, 1932). The connection between philosophy and psychology is not only due to a consistency in approaches to morality. Most importantly, *philosophical-definitional analyses* are necessary for adequate psychological research (Chomsky, 1979; Piaget, 1970; Turiel, 1983b).

Writing at a time when many adhered to behaviorism and logical positivism, Kohlberg (1971) noted that "The critical defect of this epistemology for child psychology was that it did not allow the psychologist to think about cognitive processes as involving knowledge" (p. 151). He also stated that those traditions worked with the assumption that "processes of learning truths" are the same as the processes of learning lies or illusions. "It explains the learning of logical operations of 'truths' in terms of the same processes as those involved in learning a social dance step (which is cognitively neutral), or those involved in 'learning' a psychosis or a pattern of maze errors" (p. 152). Kohlberg observed that much research from the 1950s to the 1970s had attended only to psychological constructs in attempts to explain the acquisition of vaguely defined values, standards, or behaviors (research usually based on psychoanalytic and/or social learning theories). He provided cogent analyses of the shortcomings of psychological research that ignored philosophical-conceptual analyses, which would include the type of research strategy advocated by Wilson (1975) and Greene (2007). In arriving at the conclusion that the study of morality could not be restricted to the narrow confines of psychological analyses, Kohlberg's (1963b, 1964) extensive reviews of research also led him to the conclusion that the data did not lend support to the propositions that environmental variables such as parental childrearing practices, positive and negative reinforcements, and processes of identification and imitation could adequately explain the development of morality. In addition to the problems that such research was not based on sound conceptual frameworks concerning the moral domain, nor sound associated assessments of moral evaluations, judgments, decisions, or, actions, the research operated from the perspective that development is largely adult driven. Within that framework, it was presumed that adults shape, guide, and, thus determine, the child's behavior and development.

Like Piaget, Kohlberg proposed that the development of social judgments involves a constructive process stemming from children's interactions in a multifaceted social world.

Children's experiences in such complex and multifaceted interactions often entail confronting social problems, conflicts, and struggles. The role of children's interactions and development was well-summarized by Piaget (1951/1995), who emphasized the reciprocal bidirectional complex causal nature of social interactions:

> Socialization in no way constitutes the result of a unidirectional cause such as the pressure of the adult community upon the child through such means as education in the family and subsequently in the school. Rather, . . . it involves the intervention of a multiplicity of interactions of different types and sometimes with opposed effects. In contrast with the somewhat academic sociology of the Durkheim school which reduces society to a single whole, collective consciousness, and its action to a unidirectional process of physical and spiritual constraint, the concrete sociology which the personal and social development of the child obliges us to construct must be wary of sweeping generalities if it is to make sense of the systems of relations and interdependencies actually involved. (p. 270)

Piaget, therefore, proposed that society (or culture) is not homogeneous (as in Durkheim's analysis of society as a single whole), that social interactions are of varying kinds (multiplicity of coactions of different types), and that development is not caused by the environment (pressure of the adult community). Thus, Piaget proposed that development does not involve the shaping of children to internalize the norms or standards of society (see Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume, for a similar dialectic perspective on socialization processes). He also maintained that moral development is not innately or biologically determined, even if moral judgments and emotions emerge early in life. For instance, in his volume on children's moral judgments, Piaget criticized assertions by Antipoff (1928, as cited in Piaget, 1932) that a sense of justice was "innate and instinctive" and that its emergence did not require social experiences. Antipoff's conclusions derived from findings that a sense of justice could be observed in early life. However, Piaget noted that Antipoff's research was with children from 3 to 9 years of age, and that by the age of 3 years children have experienced a good deal of social interaction that influences their development.

Piaget and Kohlberg maintained that there is an interweaving of thought, emotions, and actions. Actions constitute the foundation of thought and the development of thought, and thought in turn feeds back on actions (Kohlberg, 1969: Piaget, 1932, 1954/1981; Overton, 2006, Chapter 2, this *Handbook*, this volume; Turiel, 2006b, 2008a, 2010b). Thought and emotions are relational in nature, that is, they are interdependent parts of a system. Emotions are not so powerful and thinking so weak that emotions dominate reasoning. Emotions do not drive thought and behavior and individuals do not simply act nonrationally or irrationally because of unconscious or unreflective emotional reactions. Emotional appraisals are part of reasoning that involves taking into account the reactions of others and self (Nussbaum, 2001; Turiel & Killen, 2010). Moreover, the primary emotions associated with morality are positive ones such as sympathy, empathy, and respect; they are not negative or aversive emotions such as fear, anxiety, disgust, and guilt. In fact, numerous research studies have demonstrated that young children display these positive emotions in their social relationships (Arsenio, 2010; Arsenio & Fleiss, 1996; Dunn, 1987, 1988; Dunn, Brown, & Maguire, 1995; Eisenberg & Fabes, 1991; Hoffman, 2000; Zahn-Waxler, Radke-Yarrow, Wagner, & Chapman, 1992).

In pioneering theory and research from the perspective of the development of morality as a constructive process, Piaget and Kohlberg each proposed age-related sequences of transformations in moral judgments. In their formulations, the development of moral judgments is characterized as a process of a series of differentiations leading to "autonomous morality" (Piaget) or "post-conventional morality" (Kohlberg). Piaget proposed that at the highest level moral judgments are autonomous in that individuals participate in the elaboration of norms; they construct judgments, with understandings of fairness, equality, and the need for cooperation. However, prior to autonomous morality children form heteronomous moral thinking of adherence to fixed rules and obedience to adult authorities perceived as infallible. At the heteronomous level, moral obligation is tied to a one-way or unilateral respect for adults. In that way of thinking, young children presumably do not oppose or defy authority. As put by Piaget (1960/1995): "From this it follows, for example, that if distributive justice is brought into conflict with authority . . . the youngest children will believe authority right and justice wrong" (p. 304). In forming moral understandings of justice in the autonomous orientation, Piaget thought that children differentiate the moral from the nonmoral. One of the salient confusions supposedly resolved with the developmental shift from heteronomy to autonomy is the differentiation of "what ought to be from what is" (Piaget, 1932, p. 350). Heteronomous thought identifies "what is with what ought to be" (p. 347).

For Piaget the development of autonomous moral thinking involved a differentiation of justice from adult authority and the force of custom. Although Kohlberg's 6-stage sequence of moral judgments differed in its details from the sequence proposed by Piaget, he, too, proposed that development entails progressive differentiations of what ought to be from what exists (first from punishment and prudence, then from authority and convention). In the sequence proposed by Kohlberg distinct moral understandings do not emerge until the highest stages, when there is a clear differentiation of "moral values and judgments from other types of values and judgments" (Kohlberg, 1971, p. 216).

In this type of differentiation model, distinct moral judgments emerge through a lengthy process of distinguishing issues of welfare, justice, and rights from other judgments. Moreover, in these formulations it is implicitly assumed that decisions are bounded within the moral domain, without consideration of how domains are coordinated. This is because embedded in the idea of progressive differentiations of domains is the idea that moral judgments displace other and developmentally lower types of judgments. The types of moral understandings that characterize the highest stages involve overarching principles that serve to organize priorities in decisions. At the highest stages, moral principles are given priority over other domains because the process of development is said to involve the formation of judgments out of prior confusions. Because development entails a disentanglement of morality from other social considerations, it is presumed that morality will then be given priority over the "less adequate" forms of judgment represented in the lower stages.

As discussed in the section that follows, research since the mid-1970s in the area of social domain theory, on the one hand, lends strong support to the *constructivist-relational* approach to morality put forth by Piaget and Kohlberg, but, on the other hand, it disagrees with their development sequences as entailing progressive differentiations between moral and nonmoral concepts. Social domain theory proposes and documents that children form distinct concepts of welfare, justice, and rights in the various categories analyzed by the philosophers discussed at the outset of this chapter. This is not to say that children's moral judgments possess the features of thinking evident in the academic philosophical analyses (Shweder et al., 1981). It is to say that children make judgments about welfare, fairness, and rights, which reflect issues such as inflicting harm, taking another's property, unequal treatment, and violating rights. The claim and empirical documentation is that the young child does not confuse morality with the conventions and customs of social systems, or adherence to rules, or reverence for authority, or with the needs and interests of self and others.

SOCIAL DOMAINS AND SOCIAL INTERACTIONS

Well over 100 published studies based on the distinctions among the social domains—*moral, social conventional, personal*—have demonstrated that children form moral judgments about welfare—and in more rudimentary ways about justice and rights—and that they form judgments about other domains, including the social conventional and personal (comprehensive reviews are provided by Nucci, 2001; Smetana, 2006; Smetana, Jambon, & Ball, 2014; Tisak, 1995; Turiel, 1998, 2002, 2006a). Many of the studies document that the domain distinctions are formed by at least 4 to 6 years of age. Distinguishing morality from other domains demonstrates that individuals think about social relationships, emotions, social practices, and social order, and that thinking about morality has features distinctive from thinking about other aspects of the social world (hence the idea of *domain specificity*). Making the distinctions among domains also demonstrates that judgments about the social world include nonmoral domains of importance. Individuals form judgments within the *personal domain* that pertain to actions considered outside the jurisdiction of moral concern or social regulation and legitimately within the jurisdiction of personal choice in arenas that do not involve impinging on the welfare of others (Nucci, 2001, 2014). Individuals also form judgments about social systems, social organization, and the conventions that further the coordination of social interactions within social systems (Turiel, 1983a). *Conventions* are a constitutive part of social systems and these entail shared behaviors (uniformities, rules) whose meanings are defined by the system in which they are embedded.

The *domain of morality*, as with the other domains, operates within the context of social systems. The domain of morality, however, contrasts with the domain of convention in that morality is not conditioned by or defined by existing social arrangements. From the social domain perspective on morality, prescriptions are characterized as obligatory, generalizable, and impersonal insofar as they stem from concepts of welfare, justice, and rights (Turiel, 1983a). The distinctions among domains do not entail simple discriminations made by individuals among categories; each domain constitutes a complex whole.

Although much of the research on domain distinctions has been conducted in the United States, there are a number of studies conducted in non-Western cultures that demonstrate that children and adolescents make judgments about welfare and justice that differ from their judgments about social conventions. These non-Western studies have included research in India (Bersoff & Miller, 1993; Madden, 1992; Miller & Bersoff, 1992), Korea (Song, Smetana, & Kim, 1987), Hong Kong (Yau & Smetana, 2003), Indonesia (Carey & Ford, 1983), Nigeria (Hollos, Leis, & Turiel, 1986), Zambia (Zimba, 1987), Brazil (Nucci, Camino, & Milnitsky-Sapiro, 1996), and Colombia (Ardila-Rey & Killen, 2001).

An important methodological feature of the early research on domains was the experimental presentation to participants of situations that did not depict conflicting features from several domains (nor with competing claims within the moral domain). Research studies that potentially obscure the child's ability to make moral judgments have presented children with situations that are overly complex in the sense that they have included competing considerations and goals. This problem has already been discussed with reference to the use of the trolley car test situations in the neuroimaging studies (Greene et al., 2001). In Kohlberg's research (1963a) children were also presented with multifaceted problems requiring them to weigh and coordinate competing moral, as well as nonmoral considerations. One example is the often-cited situation of a man who must decide whether to steal an overpriced drug that might save his wife's life. This situation includes considerations of the value of life, property rights, violating the law, interpersonal obligations, and personal responsibilities in each of these.

Another example from Kohlberg's research is a story in which a doctor is deciding whether or not to adhere to the request of a dying woman in pain that he give her drugs to make her die sooner. Although this situation raises moral issues regarding the value of life, the responsibilities of doctors to patients, and legal issues, it also raises questions about personal choices with respect to the quality of life, and when it is legitimate for an individual to end her life in the context of a terminal illness and great pain. The responses of a 10-year-old boy in Kohlberg's study illustrate how these issues are entangled and how they might be disentangled. The boy recognized that the decision has pragmatic consequences for the doctor in stating, "From the doctor's point of view, it could be a murder charge" (Kohlberg, 1963a, p. 23). Recognizing that the situation confronted the dying woman with personal choices about the quality of her life and the great pain she was experiencing, he said, "From her point of view, it isn't paying her to live anymore if she's just going to be in pain," and "It should be up to her; it's her life, not the law's life" (p. 23).

Kohlberg analyzed these responses solely in terms of judgments of a moral kind: That morality for the 10-year-old is instrumental, hedonistic (pleasure and pain), and based on a person's ownership rights (which fit into his second stage of moral judgments). An alternative interpretation is that the boy viewed the woman's wishes in terms of her legitimate realms of personal jurisdiction and the doctor's choice, which the boy assumed to be one of helping her or putting himself in legal jeopardy. It may well be that the 10-year-old was making judgments about what he judged to be nonmoral features of the situation which he attempted to coordinate with moral considerations. Although we cannot know if this boy was making differentiations between the moral and personal domains, studies that separated different considerations provide strong evidence that even younger children make moral judgments different from their judgments about conventions, rules and laws, authority, and personal choices.

In the early research on domains children were typically presented with a series of social acts or transgressions classified in accord with distinctions among the domains (e.g., Davidson, Turiel, & Black, 1983; Nucci, 1981; Smetana, 1981; Tisak & Turiel, 1984, 1988; Turiel, 1978, 1983a; Weston & Turiel, 1980). Thus, moral actions entail physical harm (e.g., hitting others, pushing them down), psychological harm (e.g., teasing, name-calling, hurting feelings), and fairness or justice (e.g., failing to share, stealing, destroying others' property). These acts were depicted to study participants as intentional and as resulting in negative consequences to others. A few studies also included prosocial moral actions (e.g., Kahn, 1992; Smetana, Bridgeman, & Turiel, 1983; see also Damon, 1977, 1980, 1988; Eisenberg, 1986; Eisenberg, Miller, Shell, McNalley, & Shea, 1991; Eisenberg-Berg, 1979; Turiel, 2014b). Subsequent research examined in greater detail moral issues of psychological harm (Helwig, Hildebrandt, & Turiel, 1995; Helwig, Zelazo & Wilson, 2001), fairness with regard to social exclusion (Killen, Lee-Kim, McGlothlin, & Stagnor, 2002), and rights (Helwig, 1995a, 1995b, 1998). By contrast, the conventional issues presented to participants in the studies pertained to uniformities or regulations serving functions of social coordination (e.g., entailing modes of dress, forms of address, table manners, forms of greeting). In turn, research has included presentation to participants acts that do not involve inflicting harm or violating fairness or rights and that are not regulated formally or informally—that is, actions in the personal domain. The personal issues, within Western culture include choices of friends, the content of one's correspondence, and recreational activities.

Two important dimensions of judgments in these domains have been studied: (1) the criteria according to which thinking within domains is identified (referred to as *criterion judgments*), and (2) the ways individuals reason about courses of action (referred to as *justifications*). In examining these features of domains, assessments of criterion judgments have included questions about whether the actions would be right or wrong in the absence of a rule or law, if the act would be all right if permitted by a person in authority (e.g., a teacher in a school context), whether an act would be all right if there were general agreement as to its acceptability, and whether the act would be all right if it were accepted in another group or culture. Studies on the *moral domain* (for reviews see Smetana, 2006; Turiel, 2002, 2006b) consistently show that children and adolescents judge that moral issues are obligatory, that they are not contingent on authority dictates, rules or consensus (e.g., that the acts would be wrong even if no rule or law exists about it), or on accepted practices within a group or culture (e.g., the act is wrong even if it were acceptable practice in another culture). Judgments about moral issues, based on these criteria, are structured by concepts of welfare, justice, and rights. Examinations of the justifications given for these judgments have involved preventing harm, promoting welfare, fairness, and rights (Turiel, 1983a, 2002).

However, not all social actions and regulations are judged according to the criteria and justifications of the moral domain. Acts in the *conventional domain* are conceptualized as linked to existing social arrangements, and contingent on rules, authority, and existing social or cultural practices. Justifications for judgments about conventional issues are based on understandings of social organization, including the role of authority, custom, and social coordination. Even when conventional transgressions are deemed very important, children still judge them by conventional criteria and justifications (Tisak & Turiel, 1988). Furthermore, insofar as nonmoral actions are not part of the conventionally regulated system, they are judged to be part of the *personal domain*, which defines the bounds of individual authority and establishes distinctions between the self and group (Nucci, 2001, 2014).

The research on domains, therefore, demonstrates that the social judgments of people are multifaceted. Starting in early childhood, differentiations are made among moral, conventional, and personal concepts, whose origins appear to be based in early social experiences. Several studies were conducted with young children. In one group of studies, criterion judgments were assessed among children ranging from approximately 2 to 5 years of age (Crane & Tisak, 1995; Nucci & Turiel, 1978; Smetana, 1981; Smetana & Braeges, 1990; Smetana et al., 1999; Smetana et al., 2012; Smetana, Schlagman, & Adams, 1993; Tisak, 1993; Yau & Smetana, 2003). These studies have demonstrated that the distinction between moral and conventional transgressions becomes increasingly consistent and focused across these years. Two-year-olds do not distinguish the domains, however, during their third year children judge moral transgressions to be generally wrong to a greater extent than conventional transgressions. By the end of the third year, children also judge moral transgressions independently of rules or authority (Smetana & Braeges, 1990). Although 6- or 7-year-old children generally make the distinction on several dimensions, it has been found that they apply it readily to familiar but not unfamiliar issues (Davidson et al., 1983). By the ages of 9 or 10 years, children apply the distinction to both familiar and unfamiliar issues.

Research on domain distinctions has also shown that young children do not base their moral judgments on authority. Although the children judge conventional domain acts to be contingent on the dictates of persons in positions of authority, this is not the case in the moral domain. These findings suggest that, in itself, authority is not a moral orientation for many and that young children do not believe authority right and justice wrong when in conflict. Research in the United States and Korea has directly examined children's conceptions of authority relations and moral judgments (Braine, Pomerantz, Lorber, & Krantz, 1991; Damon, 1977; Kim, 1998; Kim & Turiel, 1996; Laupa, 1991; Laupa & Turiel, 1986, 1993; Tisak, 1986) and the findings indicate that when they evaluate commands made by either adults or peers in positions of authority, young children take into account the type of act commanded and the boundaries of the authority's jurisdiction in a social context. Damon (1977) found that young children do not accept the legitimacy of a parent's directive to engage in acts judged to violate moral injunctions, such as directives to steal or cause another harm. Other studies (Kim, 1998; Kim & Turiel, 1996; Laupa, 1991, 1994; Laupa & Turiel, 1986, 1993) examined how children account for the type of act commanded and the attributes of persons giving commands (i.e., adult or peer, social position in a school, and attributes like possessing knowledge about rules or an event). For moral acts entailing theft or physical harm to persons, children (4 to 6 years) give priority to the act rather than commanding person's authority status. Children's judgments are not based on respect or reverence for adult authority but on an act's harmful consequences to persons. By contrast, for conventional acts like turn-taking and the application of game rules, the children give priority to commands from adult authority over children or other adults who are not in positions of authority (for a more general discussion of concepts of authority, see Laupa, Turiel, & Cowan, 1995; for a discussion of religious authority in the context of moral and conventional acts, see Nucci, 1985, and Nucci & Turiel, 1993).

Social Interactions and Emotional Appraisals

The development of domains of moral, social, and personal judgments is associated with the various types of social interactions experienced by the child; these include interactions with parents, other adults, siblings, and peers (Youniss, 1980).

Research has demonstrated that the child's social interactions differ in the moral, conventional, and personal domains depending on the context of the events the child encounters. In one set of studies observations were made of children's interactions with other children and adults in the context of moral and social conventional transgressions. This research, conducted with preschoolers (Nucci & Turiel, 1978; Nucci, Turiel, & Encarnacion-Gawrych, 1983; Nucci & Weber, 1995) and older children (Nucci & Nucci, 1982a, 1982b; Turiel, 2008a), demonstrates that interactions around moral transgressions are different from interactions taking place when conventional transgressions occur. Interactions around moral transgressions typically do not involve commands or communications about rules and expectations of adults (which do occur for conventional events). Interactions around moral transgressions are about feelings and the perspectives of actors, as well as communications about welfare and fairness. Interactions and communications about moral issues revolve around the effects of acts on people, the perspectives of others, the need to avoid harm, and the pain and emotions experienced, whereas with regard to conventional events, they revolve around adherence to rules, commands from those in authority, and an emphasis on social order.

Further, the distinction between morality and social conventions applies to situations actually experienced. The most extensive study showing that this is the case was conducted in the context of social interactions in elementary and junior high schools, where observations were made in classrooms, periods of recess, during lunch, and during transitions from one activity to another (Turiel, 2008a). The detailed recording of observations included events or incidents entailing moral or conventional issues and events that involved combinations of the two domains. As in prior observational studies, social interactions and communications were, in important respects, different for the moral and conventional events. In reaction to moral events, participants responded with statements about the injurious effects on others, the unfairness of actions, and at times with physical or verbal retaliation. By contrast, reactions to the conventional events focused on rules, sanctions, and commands to refrain from the acts.

In this research, participants' judgments about the events were assessed shortly after the events had occurred. For the most part, participants negatively evaluated the moral and conventional transgressions, and accepted as valid rules prohibiting the actions. Nevertheless, judgments about the actual moral events differed from judgments about the actual conventional events in ways consistent with previous findings in studies conducted in nonbehavioral contexts. Acts in the moral domain were judged independently of rules, institutional context, or authority dictates. As examples, generally it was judged that moral acts should be regulated, and that moral acts would be wrong even if a rule did not exist in the school or in a school in another city. It was judged that conventional acts were acceptable if rules did not exist. It was also found that transgressions in the moral domain, in contrast with conventional transgressions, would be wrong even if the teacher dictates that they are acceptable. In turn, justifications for judgments about moral events were mainly based on welfare and justice, whereas for conventional events justifications were mainly based on considerations of social organization, rules, authority, and tradition. Moreover, participants made similar judgments and justifications when responding about one month later to comparable hypothetical situations.

In sum, the observational studies of children's social interactions demonstrate that they perceive features of events they experience and scrutinize other people's judgments, emotions, and actions. Children's everyday social experiences involve participating in and observing events of several types, including what people say to each other, concerns with feelings, and concerns with how others will react. Children participate in events that involve, as examples, people harming or helping each other, sharing or failing to share, excluding or including others, treating people equally or unequally. Their observations and reflections of events in the moral, conventional, and personal domains are major sources of formation and changes of children's moral and social judgments.

Another set of studies indirectly provides information about how children's experiences influence their moral judgments (Wainryb, Brehl, & Matwin, 2005; Wainryb & Recchia, 2012). In a study by Wainryb et al. (2005), children and adolescents were asked to narrate events in which they had inflicted harm on others and ones in which they were victims of acts of harm. The analyses of the narratives provided by even the youngest children in the study (4-year-olds) document that they are aware of their social interactions, verbal exchanges between individuals, actions taken, the effects of verbal exchanges and actions on self and others, and feelings evoked. The narratives also illustrate that young children think about their experiences. Illustrative of children's attention to emotional reactions is the following statement by a 4-year-old boy talking about his experiences as a victim, recalling the physical and emotional hurt involved (from Wainryb et al., 2005):

> Well, I remember one thing about um someone, um a friend hurting me. I, it was just little bit. He was a friend, his name was William, he hit me with his hammer in the middle of the head and it really hurt. (p.54)

A 4-year-old girl stated her experience as a victim as follows:

> My friend Sydney, . . . when I came inside her house, she said she really didn't want to play with me and she um she hit me and um and I felt bad and so I asked her mom . . . if I could go home and she said yes. (p. 54)

Similarly, a 4-year-old boy recollecting a time he was a perpetrator, was aware of the harm his actions caused and expressed regret about it:

> I was playing with my friend Adam and I said something that really hurt him and he said, "I don't like that." And I stopped. I also pushed him. And I said, "I'm sorry." Because he told me he didn't like it. (p. 55)

Older children reflected on the feelings involved and showed awareness of the nature of relationships and mutual expectations. These characteristics were evident in the comments of a first-grade girl discussing a time she felt slighted by someone she regarded as her best friend who referred to another child as her best friend:

> And I kind of thought to myself that was kind of making me feel bad. So I wonder if I can go over there and tell her that I that that kind of hurt my feelings. . . . She's a best friend of mine and I just can't get it out of my mind because she, because, because whenever I walked home from her house at night time she would always give me a hug and I would always do that and we would and I would never want to leave her house. Then at the birthday . . . I'm wondering if he's really her um best friend. (p. 56)

These types of concerns and reflections on social relationships were expressed by many children of various ages. Another example from the research by Wainryb et al. (2005) comes from a 10th-grade girl who talked about the time she avoided a planned evening with one of her best friends in order to spend time with other friends:

> And I remember uh I kind of lied to her but I mostly like avoided her one night . . . and then she figured it out and found out and she felt really bad and was hurt and so it wasn't good. Cause I bet she felt betrayed maybe even she thought I don't care about her but I do um I didn't want to hurt her feelings because she was one of my best friends and so I know sometimes being honest is hard but it would definitely be worth it, but it was hard just because I felt so pressured like it happens a lot I know it happens to a lot to people my age especially that you feel so pressured that you want to do something with one person but then you promised to another person and uh I don't know you want to be everywhere and you want to be everyone's friend and you don't want to hurt anybody but you also really just want to do what feels good, and that definitely was part of the situation I wanted her to feel like okay. But I mean she got over it we're friends and everything. (pp. 59–60)

Another example comes from a study by Wainryb and Recchia (2012). In this case, an adolescent girl reflects on an interaction that involved hitting. The adolescent girl recognized the reasons leading to a fight with her sister, appraised the associated emotions, as well as her emotional reactions of regret for an act in a relationship she valued:

> I remember the first time I punched Rita. . . . she hit me first and then I really hurt her, punching her, and I felt so bad after hurting her, like I was like crying, I was like "I didn't mean to hurt you!" but she wouldn't talk to me and I remember going to my parents' bathroom and locking myself in there so that so that they couldn't find me because I felt so bad. . . . I remember she started crying and that's when I felt really bad, cuz I didn't really mean to hurt her but I was just so mad. (pp. 18–19)

These examples point to the dynamics of social interactions in childhood and beyond, which include a large measure of scrutiny of events that are experienced, what people say to each other, concerns with feelings, and concerns with how others will react. The examples of children's responses from the Wainryb et al. (2005) and Wainryb and Recchia (2012) studies also illustrate how emotions involve evaluative appraisals (Nussbaum, 2001). Emotions are not simply distinct from judgments; usually they do not in themselves, motivate or drive judgments or actions. Emotions involve evaluative appraisals such that they are guided by ways of judging social relationships, can be part of people's aims, purposes, and goals in life, as well as their understandings of other people and events. As stated by Nussbaum (2001), "emotions always involve thought of an object combined with the thought of the object's salience or importance" (p. 23). In Nussbaum's formulations, emotions have an object (i.e., they are about something in the world); the object is intentional, in that the person experiencing the emotion perceives and interprets the object; and the emotions are connected to complex beliefs about the person.

Consider the emotions that are often labeled as *guilt* and associated with moral transgressions. From the perspective of emotions as evaluative appraisals, guilt is not simply an unreflective negative emotion in reaction to a moral transgression. Guilt can have both nonmoral and moral features. An example of feeling "guilty" about a nonmoral event might be in reaction to having violated a diet or to failing to study for an exam. More generally, what is frequently referred to as guilt in reaction to moral transgressions can involve reflections on social relationships, the effects of one's actions on others, and the expectations of people involved in relationships. These types of evaluative appraisals are evident in the following responses of a female adolescent (from Wainryb and Recchia, 2012) discussing a time she had made fun of an old friend:

> And . . . was like thinking about it and I was like, "How could I do that to my former best friend," you know. Cause she was a person too and just cause I wanted to fit in with other people, I shouldn't have done that. So . . . this went on for awhile. And after that I apologized to her and she accepted my apology although, I don't think I would have if someone would have done that to me. I would have been really hurt. And I found out she cried all the time. And that just made me feel really bad that I did that. So ever since then, I don't make fun of people anymore. (p. 18)

The adolescent's reactions do not represent guilt as an unexamined emotion triggered by an event. We see, instead, reflections on the interactions, the nature of the relationships, the effects of actions on others and self, intentions and consequences, and lessons for future actions.

As already noted, even young children experience and observe in others positive emotions such as affection, sympathy, and empathy associated with moral issues. It has also been found that emotions associated with moral judgments are differentiated from those associated with other types of social judgments. For example, in a study by Arsenio (1988) children from 5 to 12 years of age were presented with descriptions of events involving several different types of acts. The children were asked to assess the emotions that would be experienced by different participants (actors, recipients, and observers). For events entailing positive moral actions, such as helping and sharing, children generally attributed positive emotions, like happiness, to the actors. For conventional transgressions, children attributed neutral or somewhat negative emotions (sadness, anger) to the participants. In the case of moral transgressions entailing one person victimizing another (e.g., a child stealing a toy from another), children attributed very negative emotions to the recipients and observers, and attributed somewhat positive emotions to the perpetrators of the acts. The research also showed children could use information about emotional responses to infer the types of experiences that would lead to the emotional reactions. Children, who were presented with descriptions of the emotional reactions of actors and alternative events that may have elicited the emotions, associated different emotions to the different actions; older children were able to do this more accurately than younger ones.

The reasons children provided for why characters in the events experienced the attributed emotions varied by domain of event and role of participants (Arsenio & Fleiss, 1996). The negative emotions expected of victims of moral transgressions were thought to occur because of the harm, loss, or injury resulting from the acts. For victimizers, however, it was thought that the material gains obtained by them would result in some feelings of happiness. In addition to the specific emotions (e.g., affection, sympathy) associated with moral judgments, there could well be general sentiments that are central features of moral judgments. On the basis of philosophical analyses and a limited amount of psychological research, we have hypothesized (Turiel & Killen, 2010) that the two general sentiments of *sanctity of life* and *respect for persons* have such organizing features. Sentiments that people hold regarding the sacredness of life is a topic addressed in detail from a philosophical perspective by

Dworkin (1993), who proposed that the intrinsic value of life includes the strong emotional-conceptual sense of the sacredness or inviolability of life. He maintains that people everywhere are concerned, in one way or another, with preserving lives, act to save lives when they can, make strong judgments about the loss of life, and experience intense emotions like grief at the loss of a loved one (Dworkin, 1993). However, the dynamics of the issue of life are complicated because people do take lives in war and for reasons of self-defense, and it is one of the condoned ways, through capital punishment, of responding to murder.

Dworkin's treatise is specifically aimed at demonstrating that the sacredness of life is central to debates about abortion and euthanasia, but he also intends to provide a general formulation of "a fundamental idea that almost all share in some form: that the individual human life is sacred" (Dworkin, 1993, p. 13). Within the context of differences among people as to whether abortion and euthanasia are right or wrong, Dworkin argues that in order to understand the differences between "liberal" (pro-choice; abortion is generally acceptable) and "conservative" (pro-life; abortion is generally unacceptable) positions it is necessary to account for their common views that life is sacred and inviolable (the term *sacred* has religious connotations and the term *inviolable* has secular connotations). Although for some there may be religious underpinnings to the sense of the sacredness of life, it is also a secular view (in the form that life is inviolable). The sense of sacredness or inviolability of life is also maintained by those who judge abortion and euthanasia as acceptable. In Dworkin's view, those who take a pro-choice stance on abortion nevertheless almost always regard it as a "grave decision" because it does mean the extinction of human life already begun.

Dworkin's purpose in elaborating the nature of debates about abortion and euthanasia, even in the context of differences about their permissibility, is to demonstrate the force of the sacredness and inviolability of life. It becomes clear that most people hold to the sanctity and inviolability of life when we consider their common positions on the taking of life immediately after birth (or late in pregnancy). Debates do not occur as to whether it is acceptable to take an infant's life after birth with regard to any of the reasons or justifications (or any others) evident in the controversies over abortion (Turiel et al., 1991). Research into moral judgments needs to better account for people's sense that lives have intrinsic value and how the sentiment develops (Turiel & Killen, 2010). This should be viewed as a general sentiment because people feel highly emotional about maintaining their own lives, the lives of close others (family, friends, etc.), and, in a general way, of human life (including those one does not know).

A related general sentiment, respect for persons, was part of the analyses of development in Piaget's (1932) research on moral judgments. For Piaget, respect for persons in relationships of mutuality and reciprocity is essential for moral concepts of equality and justice. In Piaget's formulations, morality entailing mutual respect includes concerns with justice and fairness in serving the needs of persons and adjudicating competing interests.

Coordination: Its Importance in Decision-Making and Development

The distinctions evident in thinking about moral, social-conventional, and personal domains must be taken into account in explaining the decisions people come to in situations they face. Many social situations include features associated with the different domains, as well as differing features within the moral domain. Therefore decision making can involve coordination of different and sometimes conflicting moral considerations and goals and other social considerations and goals; decision making can also involve coordination between different moral goals. The process of coordination involves weighing and balancing the different considerations when drawing conclusions within the parameters of social situations (Turiel, 2008b). More broadly, coordination reflects the fundamental flexibility of thought and its relational nature.

A failure to attend to multiple but separable features of social situations has sometimes led to inadequate explanations of decisions regarding authority, helping behaviors, and conformity (Turiel, 2002). As an example, Milgram's (1974) experiments in which participants were instructed to administer supposedly painful electric shocks to another are frequently regarded as studies of obedience to authority. However, the experiments included much more: Participants were posed with a choice between avoiding inflicting pain on another person or adhering to conventional authority relations in what was presented as a scientific setting—conflicting choices that involved resolutions through processes of coordination. In Milgram's (1963) initial experiments the majority (about 60%) of participants did continue to administer the electric shocks. It is this finding that is interpreted in terms of obedience to authority. However, even in those experimental conditions most who administered the shocks displayed conflict between their desire to avoid inflicting pain and adhering to the conventional expectations of the situation. In addition, most of the experimental conditions in the studies (as summarized in Milgram, 1974) resulted in defiance of the authority dictates, with participants eventually giving priority to avoidance of infliction of pain to another (Turiel, 2002; Turiel & Smetana, 1984). Several other well-known social psychological experiments, such as on bystander intervention (Latanée & Darley, 1970) and conformity (Asch, 1956), have also yielded variations of acts in different experimental conditions reflecting coordination of moral, social, and psychological considerations (Asch, 1952; Turiel, 2002).

Explanation of the development of concepts of rights also necessitates analyses of coordination of different situational features. On the basis of findings from several large-scale public opinion surveys of adult Americans, some philosophers, psychologists, and political scientists (e.g., Protho & Grigg, 1960; Sarat, 1975) have asserted that most Americans do not adequately understand the concept of rights. This is because the surveys found that rights are endorsed in some situations and not in others (Hyman & Sheatsley, 1953; McClosky & Brill, 1983; Stouffer, 1955). In their view, an adequate understanding of rights involves consistently upholding rights across situations.

However, some philosophers have put forth the alternative view that rights constitute one type of moral norm that, even when well understood, is weighed and balanced (i.e., coordination) against other competing moral and social norms in particular situations (Dworkin, 1977; Gewirth, 1982). Adequate understandings of rights can lead to sometimes subordinating rights to other goals. As an example, the right to free speech may be judged in relation to the harm to persons' physical welfare that might result from its exercise (Helwig, 1995a). In coordinating different considerations, individuals sometimes uphold rights and at other times subordinate rights toward the goals of preventing harm or promoting community interests.

Developmental research has been conducted on the coordination of concepts of rights with other moral and social considerations. In his program of research, Helwig (1995a, 1995b, 1997) examined the judgments of American and Canadian children, adolescents, and adults, about freedoms of speech and religion, in general, and about a series of situations entailing conflicts between the freedoms and other moral considerations. In response to general questions (e.g., should people be allowed to express their views or engage in their religious practices; would it be right or wrong for the government to institute laws restricting the freedoms), most endorsed the freedoms and judged them as moral rights independent of existing laws that are generalizable to other cultural contexts. The study participants based these judgments on psychological needs (e.g., self-expression, identity, autonomy), social utility, and democratic principles. Along with the general judgments, however, individuals accepted restrictions on the freedoms when in conflict with other moral considerations (i.e., physical harm, psychological harm, or equality of opportunity). At younger ages, however, there was a greater likelihood of acceptance of restrictions than at older ages (see also Helwig, Ruck, & Peterson-Badila, 2014; Ruck, Abromovitch, & Keating, 1998).

Concepts of rights and democracy are also evident among adolescents in rural and urban settings in China (Helwig, Arnold, Tan, & Boyd, 2003). The pattern of varying application of rights is also found in Costa Rica, France, Italy, and Switzerland (Clémence, Doise, de Rosa, & Gonzales, 1995; Doise, Clémence, & Spini, 1996), as well as among Druze Arabs (Turiel & Wainryb, 1998). The findings from China and the Druze stand in in contradiction to the proposition that concepts of rights are not part of the social makeup of non-Western cultures.

Another area of moral judgments involving coordination is in decisions about social inclusion and exclusion (Horn, 2003; Killen & Cooley, 2014; Killen et al., 2002; Killen, Pisacane, Lee-Kim, & Ardila-Rey, 2001). This set of studies, which included preschoolers, children, and adolescents, examined judgments about social exclusion based on gender (e.g., in doll play, truck play) and race (e.g., in a basketball team, in a math club). A central finding is that exclusion based on gender and race is judged as wrong in straightforward situations; such evaluations are based on reasons of fairness and equality. For instance, children negatively evaluate the exclusion of a boy from a group of girls engaging in activities associated with female norms (e.g., playing with dolls) or a girl from a group of boys engaging in activities associated with male norms (e.g., playing with trucks). However, when judging situations that involve other considerations (e.g., there is only room for one more person in a group; qualifications for a group activity), then fairness is weighed against contributions to group goals—goals used as a basis for the decision even if it means giving preference to someone on the basis of gender or race.

Honesty and deception are other topics of moral consideration that have yielded data on coordination in decision making. Honesty is particularly interesting in this regard because it is often assumed that it is an obviously moral good that ought to be unwaveringly maintained. Many regard honesty as an important virtue or character trait that children must learn in ways that they always will follow. However, matters of honesty and trust are not straightforward and do not always dictate the moral course of action. One forceful illustration of the nuances of the application of honesty comes from philosophical discourse regarding Kant's contention that it is always wrong to lie (Bok, 1978/1999). Philosophers have posed the scenario of someone who must decide whether to tell the truth upon being asked by a murderer where his intended victim has gone. It has been pointed out that in such a situation the moral prescription to save a life should take precedence over the moral prescription to tell the truth and that there is a moral obligation to engage in deception.

In the situation of the murderer asking where his intended victim has gone, the moral goal of trust is in conflict with the value of life. Giving priority to physical welfare over honesty is evident in evaluations of physicians who responded that it is legitimate to deceive an insurance company when it is the only way to obtain treatment for a patient with a serious ailment (Freeman, Rathore, Weinfurt, Schulman, & Sulmasy, 1999). Several studies with children, adolescents, and adults have shown that processes of coordination are salient in decisions regarding honesty and deception. In one study (Perkins & Turiel, 2007), the large majority of adolescents (ages 12 to 13 and 16 to 17 years) judged it acceptable to deceive parents about demands considered morally wrong (e.g., regarding a parental directive to hit another) on the grounds of preventing injustice or harm. The majority of adolescents also judged that deception was justified when parents directed personal choices (e.g., which club to join), although the older adolescents were more likely to judge deception of parents regarding personal choices acceptable than the younger ones (92% versus 62%). However, there are situations in which adolescents judge deception of parents as wrong. The majority judged that it is not right to deceive parents when they give directives about prudential activities (e.g., completing homework). Such directives were seen as within parents' legitimate authority to place restrictions bearing on the welfare of their children. These findings illustrate how adolescents make discriminations among different situations: between ones involving directives to engage in morally wrong acts or to control personal choices and those involving directives about prudential matters.

In the study with adolescents (Perkins & Turiel, 2007), it was also found that fewer of them judged deception of peers acceptable than deception of parents for the morally relevant and personal issues. Although the adolescents thought that the restrictions directed by peers were not legitimate, they were less likely to accept deception of peers than of parents. The difference between how adolescents perceive the acceptability of deception of parents and friends points to another element of the coordination of different considerations in social and moral decision making. The reason that deception of friends is considered less acceptable is that such relationships are seen as based on equality and mutuality, whereas relationships with parents involve greater inequality in power.

The findings on deception among adolescents (Perkins & Turiel, 2007) are in accord with commonly found adolescent-parent conflicts around issues in the personal domain (Smetana, 2011). However, the coordination of honesty or trust in decision making also occurs in childhood. Gingo (2012) conducted a study with children from 7 to 12 years of age, assessing judgments about deception in reaction to directives from parents and teachers of acts in the moral, personal, and prudential domains. The situations presented to the children were designed to be age-appropriate (e.g., cutting in line, choice of friends, climbing a wall at a park). Age differences were found in judgments about deception of parents for the acts in the moral and personal domains. Most of the youngest children (90% of the 7- to 8-year-olds) judged deception for the acts in the moral domain unacceptable, with increasing acceptance of deception among the older children (30% of the 9- to 10-year-olds and 50% of the 11- to 12-year-olds). Similar patterns held for acts in the personal domain. Consistent with the judgments of adolescents (Perkins & Turiel, 2007), the majority of children in each age group judged deception unacceptable for the prudential acts (for each of the domains, similar patterns were found in judgments of deception of teachers but with greater acceptance of deception of teachers than parents).

In Gingo's (2012) study, assessments were made of children's evaluations of the directives from parents and teachers and of depictions of noncompliance with those directives. Gingo also found that the large majority of children negatively evaluated the directives in the moral domain and positively evaluated noncompliance. These findings indicate that, unlike adolescents, children give priority to honesty even though they evaluated the directives not to be legitimate. In turn, the majority of children who had negatively evaluated deception, positively evaluated directives regarding the prudential acts and negatively evaluated noncompliance. Age differences were obtained only for evaluations of adult directives and noncompliance in the personal domain—with younger children giving more positive evaluations of the directives and more negative evaluations of noncompliance than the older children.

As suggested by the study with physicians (Freeman et al., 1999), decisions about the legitimacy of deception also occur among adults. Another study (Turiel, Perkins, & Mensing, 2009) examined the judgments of young adults of college age and older married adults regarding deception in hypothetical situations in marital relationships involving power differences (with either a working husband in greater power or a working wife in greater power). In a situation posing a conflict between honesty and a person's physical and emotional welfare (attending meetings of a support group for a drinking problem), the results were unambiguous in that the large majority gave priority to welfare over honesty—whether the deception was by a husband or wife. Other situations depicted a spouse who engages in deception for personal aims (maintaining a secret bank account; seeing a friend disliked by the spouse; shopping for clothes). Judgments in those situations appear to take into account the general structure of power in society that grants entitlements to men over women. Participants in the study were more likely to judge it acceptable for the wife than a husband to engage in such deception even when the wife works and has greater power and control within the family.

Common patterns are, therefore, evident in the studies on deception—as well as other moral concerns such as rights and social exclusion. Starting at young ages, flexible judgments are made about matters regarded as morally important. Acting honestly is important because maintaining trust is judged a necessary moral goal. However, maintaining and promoting physical or emotional welfare and combating injustices are also important moral goals. The findings show that across ages these goals are not pursued in mechanistic or emotionally driven ways. Individuals recognize that conflicts between moral goals need to be addressed and reconciled by drawing priorities in the context of other considerations. Moreover, the findings of these studies should not be interpreted to reflect a failure to apply abstract judgments in concrete situations. Individuals do hold judgments in the abstract about rights, fairness, honesty, and harm—as well as abstract judgments in the conventional and personal domains. The studies on coordination show that more than one of these judgments are brought to bear in concrete situations and that decisions involve drawing priorities between those different judgments. Therefore, to understand how components of thought are related to each other, it is first necessary to understand the distinctions among those components.

Coordination and Development

Processes of coordination are also relevant to explanations of development within the moral domain. Because the domain distinctions are made at very young ages and maintained through childhood, adolescence, and adulthood, we would expect age-related changes to occur within each of the domains. Cross-sectional and longitudinal research has led to the identification of a series of changes in conceptions of social systems and the role of conventions in social interactions (Turiel, 1983a). In turn, Nucci (2001) identified age-related levels of thinking in the personal domain.

Some studies indicate that young children's moral judgments are grounded in concepts of physical harm and welfare and that older children form greater understandings of psychological harm, fairness, justice, and equal treatment (Davidson et al., 1983; Kahn, 1992). Systematic research was undertaken to directly examine age-related changes in moral judgments (Nucci & Turiel, 2009). The research was designed to assess the hypothesis that development of moral judgments involves processes other than straightforward or linear changes with age. This hypothesis was based on the research showing that moral decisions involve coordination. Previous research has also indicated that not all acts in the moral domain (such as inflicting harm, taking another's property, or acting to benefit others) are necessarily the same since they may differ within different situational contexts. In this research on the development of moral judgments, children and adolescents (7 to 16 years of age) were presented with hypothetical situations involving *three types of acts*: (1) helping another in distress (helping a child who had fallen and hurt himself or herself), (2) inflicting physical harm (a child hitting another), and (3) taking another's property (taking money a child had unknowingly dropped). These three acts were *depicted in different contexts*:

1. In one context there were no competing goals (such as helping would not involve any cost to the actor, or hitting for no reason).
2. In a second context there was a conflict with the goals of the actor (such as stopping to help another would result in a loss, or hitting for self defense).
3. A third context involved a conflict with the goals of a third person (such as hitting to protect a third child).

An additional feature of the situations is that the characteristics of persons involved in the acts were varied, with victims described as a generic child, a vulnerable child (e.g., a child who has emotional or physical handicaps), and a child who had previously teased the actor (referred to as antagonist).

The variations across acts and context were included to address the propositions that moral judgments are applied in flexible ways, that contextual variations would result in different decisions, and that there would be continuities across ages in some moral judgments and discontinuities in judgments that required coordination of different aspects of the situations presented. The findings support these propositions. First, it was found that the younger and older participants made similar judgments about the importance of helping others in need, avoiding harm, and respecting another's property when there were no competing interests of self and others. In the unconflicted situations with a generic child as the recipient of the act (e.g., the child being helped or hit) the majority in each age group judged it wrong not to help, to hit, and to keep the lost money. Therefore, the findings show that there are continuities in moral judgments. Some aspects of moral decisions develop at an early age and are maintained across ages.

The study also found variations in judgments, including variations related to age. For example variations were found by contexts when the situations depicted conflicts with the goals of self or another. This was most evident with regard to hitting to defend oneself or another—with fewer evaluating hitting as wrong in these contexts (though this was not the case when the child was described as vulnerable). These contextual variations were not age-related.

Age-related differences were found in several situations. This is illustrated by the findings on judgments about helping when there is a conflict with desired goals for self or another (e.g., stopping to help will prevent the actor or a younger brother from attending an important event). In this context 14-year-olds were less likely to judge a failure to help as wrong than the other age groups, including the 16-year-old group. The younger children (8- and 10-year-olds) did not attend to different features of the situation and made one-dimensional or straightforward applications of their judgment that one should help another in distress. The 14-year-olds, by contrast, attended to different features of the situation, including nonmoral or personal goals. However, they had some difficulty in coordinating or weighing and balancing the moral and personal considerations in coming to decisions. As a consequence, they sometimes judged that the actor had the right not to help the other because of the costs to the self. The oldest participants in the study (16-year-olds) attended to the different considerations and goals and coordinated them by drawing priorities in coming to decisions. They more adequately coordinated the different situational features than the younger adolescents.

CONCLUSIONS

In an earlier section of this chapter I discussed the positions taken by cultural psychologists (Markus & Kitayama, 1991; Shweder & Bourne, 1982; Triandis, 1990) who propose that cultures can be divided by their orientations to individualism and collectivism. Haidt and Graham's (2007) position of moral differences in orientations of members of different political parties implies a relativism according to which supporters of gay rights and those who have "moral disgust for homosexual acts" are treated as different but equal. But it was also pointed out that Haidt and Graham's views stand in sharp contrast to Vlastos' (1962) observation that the great historical struggles for social justice have centered on demands for equal rights. In this respect I argued that struggles for justice and equal rights are not restricted to periods of upheaval or rebellion or to so-called individualistic cultures in the West. In support of this argument I pointed to findings of conflicts within non-Western patriarchal cultures and presented a few examples of women's responses that reflected on cultural practices and by which they judged as unfair aspects of social organization granting greater power, control, and entitlements to males over females.

The process of *reflection* on social organization and cultural practices is consistent with the *constructivist-relational* approach to moral and social development. More specifically, the findings on rights, social inclusion and exclusion, and honesty and deception provide strong support for the proposition that individuals do not simply accommodate to or unquestioningly accept the norms, standards or values of their group. As the *relational developmental system perspective* suggests, people are "*active agents*, . . . relational, spontaneously active, complex adaptive systems" (Overton, 2013, p. 53). Indeed, the research on honesty and deception demonstrates that adolescents and adults oppose certain relationships involving power differences and accept acts of subversion. The processes of coordination also reflect a *flexibility of thought*, by which persons differentially take into account various features of social situations, weigh and balance them against each other, and establish priorities in arriving at decisions.

These features of social thought and emotional appraisals also need to be taken into account in order to better understand cultural differences and similarities—which, in turn, bear on questions of relativism, absolutism, and universality. I have presented excerpts of judgments made by females of unfairness in cultural practices drawn from research that included those in positions of lesser power in social hierarchies. Social hierarchies, with their social inequalities, seem to be common among cultures all over the world. As noted, to adequately understand cultural frameworks it is necessary to consider the possibility that people in such different positions might have different perspectives on the social system and on certain cultural practices. I also discussed the findings from the psychological and anthropological studies showing that individuals do not always accept authority-dictates, cultural practices of inequality, or hierarchies in systems of social organization. Opposition and resistance to cultural practices stem from reflections, based on moral judgments of welfare, justice, and rights, on existing social conditions. Such opposition and resistance occur in everyday life and even in close relationships of the family. Social opposition to cultural practices indicates that moral development is a process of construction of judgments about what ought to exist rather than acceptance of what exists. In addition to the commonalities in moral judgments across cultures, social opposition indicates that within cultures we do not see general acceptance of existing practices.

The research findings on judgments and actions on the part of females with regard to cultural practices of inequalities are in direct contradiction with propositions of cultural differences as a function of differing cohesive orientations. For some cultural psychologists (e.g., Shweder et al., 1987; Shweder et al. 1997) and those taking an intuitionist approach (e.g., Haidt & Graham, 2007) power differences and inequalities are seen to reflect sharp cultural differences because people in some cultures supposedly accept power differences and inequalities as part of their prescribed roles and duties. As we have seen in this chapter, however, in non-Western patriarchal cultures people do not uncritically accept cultural practices promoting inequalities and unfair treatment—even though the practices are part of tradition and supported by those in positions of power and authority. We have also seen that concerns with autonomy, independence, and personal choice are recognized to be part of those cultures and are not solely the province of supposedly individualistic Western cultures. Conflicts and social opposition occur in Western cultures, too, over gender and social class inequalities (Hochschild, 1989; Okin, 1989, 1996; Turiel, 1996; Willis, 1977).

The evidence strongly supports a view of humans as reasoning beings with connections to evaluative appraisals of emotions. Moral judgments involving welfare, justice, and rights develop in different cultures alongside social-conventional, and personal judgments. Variations exist in judgments within individuals and within cultures. Variations stem not from the incorporation of different values or standards, but from the construction of distinct domains of social reasoning, processes of coordinating these different domains, informational assumptions about reality, and evaluative standpoints on social organization and cultural practices. Reasoning, reflection, and evaluative scrutiny of the ways people relate to each other are very much a part of the ways people function. The idea of moral relativism is inadequate because it fails to account for the commonalities across cultures in moral understandings. The evidence also speaks against the idea of moral absolutism insofar as absolutism means that particular moral values or concepts must be categorically applied. Concepts of trust, harm avoidance, and rights, as examples, all coexist in a relational context. Social life is such that one moral good can conflict with another. In most cultures, choices must be made that can result in variations in the application of a moral good so as to maintain a moral good.

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CHAPTER 14

Development and Self-Regulation

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"When you rule your mind you rule your world."

—Shanklin, 1929, p. 22

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Self-regulation has received heightened attention as a key mechanism that predicts a variety of outcomes including school readiness (Blair & Razza, 2007; McClelland et al., 2007; Morrison, Ponitz, & McClelland, 2010), academic achievement during childhood and adolescence (Cameron Ponitz, McClelland, Matthews, & Morrison, 2009; Duckworth, Tsukayama, & May, 2010; Li-Grining, Votruba-Drzal, Maldonado-Carreño, & Haas, 2010; McClelland, Acock, & Morrison, 2006), and long-term

We are very grateful to Fred Morrison for his thoughtful and constructive comments on a previous draft of this chapter.

health and educational outcomes (McClelland, Acock, Piccinin, Rhea, & Stallings, 2013; Moffitt et al., 2011). Although researchers have studied self-regulation from a diverse set of perspectives, the literature clearly suggests that self-regulation has important implications for individual health and well-being starting early in life (Geldhof, Little, & Colombo, 2010; McClelland, Cameron Ponitz, Messersmith, & Tominey, 2010). In the fields of child psychology and developmental science, an emphasis on Relational-Developmental-Systems (RDS; Overton, 2013; Overton & Lerner, 2012) illuminates how self-regulation may impact individual development.

This chapter reflects the RDS theoretical orientation and explores major issues in the study of self-regulation in childhood and adolescence. The chapter starts by situating the study of self-regulation within a RDS context and discussing conceptual issues, such as relative plasticity, that guide researchers' understanding of the development of self-regulation. Next, the chapter defines self-regulation and reviews research on important correlates of self-regulation including academic achievement, motor processes, intelligence, and risk factors. It then discusses cross-cultural variation in these skills, and person-context relations. The chapter concludes by discussing self-regulation from the perspective of RDS and next steps for the field of self-regulation including studying self-regulation in context, improving intervention efforts, and advancing analytical and measurement methods.

HOW RELATIONAL-DEVELOPMENTAL-SYSTEMS INFORMS RESEARCHERS' UNDERSTANDING OF SELF-REGULATION

Relational-Developmental-Systems (RDS) rejects the mechanistic notion that a person's development can be separated into additive components such as genes or elements of the context in which a person lives (Lerner, 2006; Overton, 2006, 2011, Chapter 2, this *Handbook*, this volume). All development represents a bidirectional (←→) and dynamic process of person–context relationships and these are mutually regulating. Self-regulated action represents the processes through which a person regulates his or her environment, whereas the context provides conditions that similarly regulate the person's development. Due to their coregulatory nature, these bidirectional relations have been called developmental regulations (Brandtstädter, 2006). Developmental regulations occur in multilevel contexts and involve mutually coacting relations among genetic, epigenetic, cellular, neural, behavioral, and contextual levels of influence (Gottlieb, Wahlsten, & Lickliter, 2006; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume). Related to this is the concept of *probabilistic epigenesis*, which holds that individual development is a result of dynamic and continuous bidirectional coactions between such different levels of influence. A set genotype can result in a probabilistically distributed array of phenotypes due to contextual processes that can occur at multiple levels of the developing person ←→ context system. Similarly, theories have emphasized the probabilistic and indeterminate nature of self-regulation, which has especially important implications for the understanding of how self-regulation develops in childhood and adolescence (Blair & Raver, 2012b; McClelland et al., 2010).

The RDS perspective arises from a relational metatheory that follows in a long line of integrative epistemologies such as Kant's efforts to reconcile rationalism and empiricism and Hegel's dialectical synthesis of the knower and the known (Overton, 2013). Relational perspectives emphasize cohesive integration (i.e., *holism*) as a fundamental guiding principle. Holism stands in direct contrast to atomistic approaches that imply an immutable reality composed of elements that preserve their identity regardless of context (Overton, 2006, Chapter 2, this *Handbook*, this volume). Under holism, the whole exists as an organized and self-organizing system of parts, each defined by its relations to other parts and to the whole itself (Overton, 2006). Key empirical issues for developmental scientists interested in describing, explaining, and promoting positive human development are therefore composed of five interrelated questions, which can be directly applied to the study of self-regulation:

1. What is the nature of self-regulation?
2. How is self-regulation expressed differently in different people?
3. How is self-regulation implicated in positive human development?
4. Self-regulation supports positive human development in relation to what contextual/ecological conditions?
5. At what points during ontogenetic, generational, and historical time does self-regulation support positive development?

Considering these five related questions has direct implications for empirical research on the development of self-regulation across the life span.

Core Issues Related to the Development of Self-Regulation

RDS consider living organisms to be *active agents*, "that is, as relational, spontaneously active, complex adaptive systems, that are self-creating (i.e., enactive; autopoetic), self-organizing (i.e., process according to which higher level system organization arises solely from the coaction of lower-level components of the system), and self-regulating" (Overton, 2013, p. 53). The core concepts of RDS and related perspectives (e.g., dialectical systems, Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume; dynamic systems, Witherington, Chapter 3, this *Handbook*, this volume) inform how self-regulation and its development are presented in this chapter. The fundamental RDS concepts that frame the understanding of self-regulation development include *relative plasticity, multifinality, equifinality*, and *canalization*.

Relative Plasticity

Relative plasticity reflects a person's capacity for change. Intervention research (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Raver et al., 2011) and theoretical perspectives (Bateson, Chapter 6, this *Handbook*, this volume; Bateson & Gluckman, 2011; Lerner, 2006) suggest that self-regulation shows plasticity throughout the life span. The relative plasticity of self-regulation is affected by biological, behavioral, and contextual factors, such as when temperamental predispositions and aspects of the context influence a child's ability to regulate his or her thoughts, feelings, and behavior. These self-regulated actions can alternatively increase or constrain the child's potential for change over the life span, depending on the degree to which his or her self-regulated actions align with the strengths and resources found in his or her context (Lerner, 2006). For example, a child who has a difficult temperament but who has sensitive parents who modify their parenting to fit with her temperamental style may exhibit greater plasticity in the development of her self-regulation compared to a child whose difficult temperament fit poorly with her parents' parenting style.

The RDS view of development reflects conceptual and theoretical shifts away from problem-focused views of development toward views that focus on optimizing development and the possibility of change throughout a person's life. On the one hand, this suggests that there are many opportunities for children to develop strong self-regulation skills. In fact, researchers have identified windows of opportunity during early childhood and adolescence that represent sensitive periods for the development of self-regulation (Diamond, 2002; Zelazo, Carlson, & Kesek, 2008). On the other hand, the notions of relative plasticity and sensitive periods imply that the potential for change is not limitless and that the degree of plasticity may vary across the life span (McClelland et al., 2010). Although a child may have the potential to strengthen his or her self-regulation skills throughout childhood and adolescence, contextual factors such as parenting style and quality of the home and school environments can also limit plasticity. For example, children who grow up in the context of sociodemographic risk are more likely to face difficulties developing the regulation skills that would enable them to function adaptively in broader society. Such limited skills may in turn exacerbate developmental constraints related to the increased stress, chaos, and instability often found in these children's contexts (Blair, Granger, et al., 2011; Blair & Raver, 2012a; Sektnan, McClelland, Acock, & Morrison, 2010). However, contextual factors such as safe neighborhoods, high-quality schools, and strong teachers can also provide important buffers against the constraints inherent in adverse environments, which would work to strengthen plasticity in a child.

In addition to contextual factors, person characteristics such as temperamental reactivity and emotionality can work to strengthen or constrain the child's capacity for self-regulation (Lengua, 2002; Rimm-Kaufman & Kagan, 2005). Together, contextual and person factors that lead to developmental constraints or opportunities can limit or strengthen the potential for the development of adaptive self-regulation as children grow. Further, early experiences establish the foundation for later experiences (Entwisle, Alexander, & Olson, 2005; Heckhausen & Schulz, 1999), implying that the ability to regulate one's behavior may continue into later periods of the life span (McClelland et al., 2010). In sum, the plasticity of self-regulation is a positive feature of human development, but it is not without limits. Plasticity varies across development, and the potential for plasticity is a function of the many contextual and individual factors that coact to affect development (Heckhausen & Schulz, 1999; Lerner, 2006).

Multifinality and Equifinality

Along with relative plasticity, the concepts of multifinality and equifinality (Cicchetti & Rogosch, 1996; Overton, 2010) inform the field's understanding of the development of self-regulation. Here, *multifinality* describes developmental processes that share a similar starting point (e.g., similar backgrounds, attending the same schools), but reach diverse outcomes. According to multifinality, the same set of self-regulatory skills may result in different outcomes for different people who develop in different contexts. Inversely, *equifinality* suggests there are multiple ways of attaining any given outcome, especially when that outcome requires aligning a person's unique strengths with the unique opportunities afforded by his or her context.

To illustrate multifinality and equifinality, imagine two children, Sophia and Lucy, who are best friends in preschool. Sophia and Lucy both come from families with highly educated parents who live in the same neighborhood. Yet despite these similarities, the two friends experience quite different pathways of development. Sophia has a fairly easy and nonreactive temperament, does well in school and goes to college. She eventually becomes a successful doctor who is passionate about her work. In contrast, Lucy has a more reactive temperament, dislikes school, and gets by with Cs. Although her parents send her to a local college, she does not find anything that interests her. She ends up with a low-wage job at a factory where she remains for many years. When the factory relocates overseas, Lucy decides to go back to school and earn a master's degree. She becomes a career counselor and goes to work at her old high school, which she finds very satisfying. Sophia and Lucy experience similar environmental conditions in early childhood but different paths early in adulthood (multifinality). Later, however, both obtain satisfying careers, suggesting equifinal outcomes that emerge from very different experiences in early adulthood. Thus, by taking a life-span perspective, seemingly incompatible concepts such as multifinality and equifinality may prove useful.

Self-regulation research, in fact, supports both multifinality and equifinality. For example, in one cross-sectional study of twins (Deater-Deckard, Petrill, Thompson, & DeThorne, 2005), characteristics of the family and early environment predicted children's task persistence in early childhood (an aspect of self-regulation). For older twins, however, child factors such as an intelligence measure and observer ratings of problem behaviors were relatively stronger predictors of task persistence compared to characteristics of the family and early environment (Deater-Deckard et al., 2005). In other words, results with older children suggested a greater influence of individual characteristics and mulifinality in outcomes compared to younger children.

In a study supporting equifinality, children who were rated as having strong attention when they were 5 or 6 years old were more likely to graduate from high school regardless of their socioeconomic background, compared to children who were viewed as having attention problems (Vitaro, Brendgen, Larose, & Tremblay, 2005). Another study found that children who were rated as having strong attention and persistence at the age of 4 had nearly 50% greater odds of completing college by the age of 25, after controlling for a host of background variables (McClelland et al., 2013). This research suggests that self-regulation may be a key developmental factor that helps children reach similarly positive outcomes even if they come from diverse backgrounds (equifinality). Taken together, these studies suggest that self-regulation shows multifinality and equifinality, depending on person and contextual factors.

Canalization

Equifinality and multifinality are closely related to the concept of experiential canalization (Blair & Raver, 2012b; Gottlieb et al., 2006). *Experiential canalization* refers to the coaction of biology and experience, which together influence behavior over time, and thus shape development. Taken in terms of Waddington's epigenetic landscape (Waddington, 1942; see Bateson, Chapter 6, this *Handbook*, this volume), the coaction of biology and experience therefore influences the channels dictating which developmental outcomes are most likely to occur. This can be seen early in life, when dynamic and bidirectional coactions with different aspects of children's environments (e.g., parents, siblings, peers, school and social contexts) lead them to develop differing self-regulatory skills, even when their temperamental characteristics are similar at birth. For example, a temperamentally reactive child may experience more difficulty regulating himself early in life but may develop strong self-regulation because his parents teach and model strategies to manage his reactivity. This child may continue to be generally more reactive as he grows older, which can develop into an asset that enables higher levels of enthusiasm and engagement.

Together, the core issues of relative plasticity, equifinality, multifinality, and experiential canalization suggest that the development of self-regulation fits well within a Relational-Developmental-Systems framework (Lerner, 2006; Overton, 2010). The next section discusses the action theoretical perspective, which falls under the larger umbrella of RDS, and focuses directly on self-regulation.

How Action Theory Models Inform Approaches to Self-Regulation

Action Theory is one of the most prominent approaches currently subsumed under the RDS perspective. Action Theory targets active agents and how they affect their contexts in ways that meaningfully regulate their own development. Action theoretical models thus represent a class of RDS theories that focus on self-regulated action and its role in developmental regulations.

Action and Agency

Action theories all approach action from the perspective of personal agency (Sokol, Hammond, Kuebli, & Sweetman, Chapter 8, this *Handbook*, this volume). For example, Brandtstädter (1998, 2006) defines "actions" as necessarily related to intentional states such as goals, and under at least partial personal control. Because self-regulation encompasses both conscious and nonconscious phenomena (see Baumeister & Vohs, 2004), action theories are primarily concerned with what Gestsdóttir and Lerner (2008) call intentional self-regulation. An admittedly arbitrary demarcation, intentional self-regulation requires a degree of conscious intention that more automatic forms of self-regulation do not (Gestsdóttir & Lerner, 2008; see, however, Overton, 2013, for the role of conscious, but non-self-conscious acts and intention in action theories). For example, organismic self-regulation represents largely physiological processes that lie outside of one's conscious control (e.g., hypothalamic control of body temperature). Automatized aspects of self-regulation similarly include actions and action-related processes that occur subconsciously through internalization (see Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001). In contrast to these less-conscious forms of self-regulation, intentional self-regulation represents explicitly conscious actions such as resisting the temptation to eat a fattening dessert by reminding oneself of the importance of maintaining a healthy weight.

By emphasizing intentional self-regulation, action theories highlight the person's active control over developmental regulations. Action theories therefore speak directly to the now-common notion that people actively produce their own development through intentional person ←→ context relations (e.g., Lerner, 1982). Action theories thus emphasize personal control over development while acknowledging that self-regulated actions occur within a fully relational integrated person-context system.

Action Is Broadly Defined

As noted by Brandtstädter (1998, 2006) action-theoretical approaches are largely concerned with the role that conscious actions play in developmental regulations, but consider a heterogeneous array of action components. For example, Baltes and colleagues' Selection, Optimization, and Compensation model (e.g., Baltes & Baltes, 1990; Freund & Baltes, 2000) delineates between actions that have different functions. Their model separates goal selection from actions that optimize already-selected goals, and differentiates selection and optimization processes from the compensatory behaviors that allow people to implement a dynamically changing set of means to bypass obstacles and reach their goals. The SOC model therefore hypothesizes that qualitatively distinguishable, yet simultaneously related, self-regulatory processes have an impact on behavior during different stages of the goal pursuit. For instance, imagine Brian, an adolescent who has just transitioned to high school. During middle school Brian participated in a number of different sports, but he finds that these same sports require a greater time investment in high school. Because his after-school time is limited, Brian must therefore choose which sport(s) he will continue playing and which he will discontinue. The ability to weigh the pros and cons of each sport and to make a decision to pursue some, but not all, of his athletic goals requires Selection skills as hypothesized by the SOC model. The skills required for goal selection differ from the self-regulatory skills that allow Brian to optimize his athletic performance (e.g., following a daily training regimen), and these optimization skills differ still from the self-regulatory strengths that Brian will rely on when something does not go according to plan. For instance, regular practice failed to improve Brian's batting skills and he compensated for this failure by consulting an outside hitting coach.

Brandtstädter and Renner's (1990) dual process model alternatively delineates between assimilative actions that directly influence the external context through, for example, requesting that another student stop talking so one can work, and accommodative actions such as deciding to do one's work at home, which directly influence a person's own cognitive processes. Although both models are distinctly action theoretical, they approach self-regulated action from different angles and are somewhat complementary. Aspects of goal selection can alternatively be considered as assimilative (e.g., selecting the goal to acquire a new resource) or accommodative (e.g., restructuring one's goal hierarchy in response to some external demand), for instance.

The above models differentiate different types of self-regulated actions based on qualitative characteristics, but action theoretical models encompass a much broader swath of research than this example may imply. For example, Brandtstädter (1998, 2006; Geldhof et al., 2010) describes four general categories of action theory. Structural theories focus on the structural analysis of actions and cognitive operations, such as Piaget's emphasis on the development of cognition's foundational components (e.g., transitivity, conservation; Piaget, 1970). Motivational theories instead highlight factors that motivate action such as expectancies for and the estimated value of success (see Eccles, 1983), control-systems theories draw from cybernetic and systems-theoretical models (e.g., Norman & Shallice, 1986), and social-constructivist theories emphasize cultural symbols, such as the meaning of specific words and hand gestures, and the roles these symbols play in the development of actions (e.g., Vygotsky, 1978).

ACTION AND DEVELOPMENT OCCUR IN A RELATIONAL INTEGRATED PERSON-CONTEXT SYSTEM

RDS in general, and action theories in specific, emphasize cohesive integration at all levels of science. Of particular interest to research on self-regulation, this integration suggests that researchers can only approach developmental regulations as occurring through the gyrations of a unified person-context system. Many authors have heuristically described this unity of person and context by emphasizing the completeness and bidirectionality of person-context coactions. This chapter adopts the completeness of this integration, and underscores that the person can only be truly defined as a subset of the larger contextual whole; the context exists as a set of multiple coacting parts, some of which exist as developing persons. When it comes to measurement, it may be virtually impossible to assess every factor that contributes to developing self-regulation. Yet using the RDS lens means acknowledging the relational and holistic nature of the person ←→ context system in the design and selection of measures, and in the interpretation of results.

This dynamic picture of individual development characterizes the present discussion of self-regulation across the life span and specifically, across childhood and adolescence. For example, Emily is an active, happy baby, with a relatively easy temperament. She adjusts easily to routines and calms down once upset. She can self-soothe (i.e., self-regulate) by sucking on her pacifier when she gets scared or distressed. One of her parents also has an easy temperament and may have passed this to Emily in part by responding calmly to Emily even when Emily is very upset. Emily's parents are consistently warm and responsive, which creates a good fit between her temperament and her parent's parenting style. This creates a positive set of coactions between Emily and her parents that sets the stage for strong regulatory skills throughout Emily's life.

In contrast, imagine Noelle, a baby who is often fussy and has a more difficult temperament. Noelle has difficulty adapting to routines and novelty easily distresses her. She also has trouble calming down when she is upset. Research suggests that the development of Noelle's self-regulation skills will be facilitated by parenting that fits well with her temperamental style. In other words, Noelle's self-regulation is likely to be strengthened if her parents are patient, warm, and responsive, and also model adaptive and positive self-regulation skills. However, if Noelle has parents who have difficult temperaments themselves or who live in chronic poverty, Noelle may be less likely to receive the quality of parenting needed for her to develop strong self-regulation skills (Blair & Raver, 2012a; Evans & Rosenbaum, 2008; Wanless, McClelland, Tominey, & Acock, 2011). Moreover, without additional support, Noelle may have difficulty with self-regulation as she moves through childhood and adolescence.

The complete fusion of person and context has two immediately salient implications for self-regulation research. First, the fusion of person and context suggests that self-regulation cannot exist as a person-level characteristic. Instead, self-regulation can be demonstrated by direct and indirect processes by which the person affects his or her surrounding context. For example, a child can directly resist the temptation to hit another child and also use self-talk and calming strategies to indirectly control the surrounding environment (e.g., helping to maintain a peaceful classroom climate by avoiding aggression). Any aspect of self-regulation can therefore only be measured—and indeed exist—as a specific component of the relational person ←→ context system. From this view, global measures of self-regulation thus can be considered heuristic proxies that estimate generalities that exist across many contexts.

As such, summary measures of self-regulation prove especially useful when predicting similarly domain-general measures of positive development that aggregate information about multiple contexts (see Geldhof et al., 2010; McClelland et al., 2010). Lerner and colleagues, for example, have consistently shown positive relations between a domain-general measure of self-regulation and a similarly broad measure of positive youth development (e.g., Bowers et al., 2010; Lerner et al., 2005). Here, the domain-general measure of self-regulation measured goal-directed behaviors without referencing any specific context (e.g., "I make every effort to achieve a given goal"), whereas the domain-general measure of positive development aggregated information about multiple contexts such as academic and social skills (e.g., being good at school work, having a lot of friends), as well as connection to participants' families, peers, and social institutions (e.g., feeling important and useful in a family, having adults in the community listen).

Because domain-general measures either aggregate information across contexts or ask for information without specifying a specific context, such measures necessarily gloss over the highly idiographic nature of real-world self-regulated behaviors. Observing self-regulation means observing people with unique sets of self-regulatory strengths coacting with their equally unique contexts. Examining the relations among self-regulation and context-specific outcomes may accordingly require more nuanced measurement tools as well as more idiographic study designs (Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2010). For example, studies have suggested that domain-specific indices of positive development, such as academic competence, may be more strongly related to same-domain indices of self-regulation, such as the ability to select academic goals that align with one's personal strengths and skill level, than to domain-general indices of self-regulation such as inhibitory control (e.g., Geldhof, Little, & Hawley, 2012).

The utility of the domain-general/domain-specific distinction, however, is under debate for measurement as well as theoretical conceptualizations of self-regulation (Garon, Bryson, & Smith, 2008; Lewis & Todd, 2007; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Wiebe et al., 2011). This shift parallels neurological evidence that move theories away from the notion of specific brain locations that are linked to specific skills, and toward the idea that networks of brain areas are activated in any given task, albeit with the origin of activation fixed for a given task (Dehaene, 2011). Further, more complex and less automated tasks activate a greater number of neurological areas, especially in the prefrontal cortex (Colom, Jung, & Haier, 2006; Floyer-Lea & Matthews, 2004). The issues of measurement are discussed later in the chapter, focusing first on conceptual and definitional issues related to self-regulation.

Nonrelational Systems Theories and Perspectives of Self-Regulation

The relational developmental systems perspective offers a broad theoretical framework that integrates disparate approaches to human development. Doing so requires that relational models account for the unity of outwardly contradictory constructs and ideas (i.e., the identity of opposites; Overton, 2010), while simultaneously acknowledging their very real and practically meaningful uniqueness (i.e., the opposites of identity; Overton, 2010). However, fully relational approaches can result in highly complex theories, models, and analyses. Research goals certainly exist that do not necessarily require a high degree of complexity for parsimoniously examining inter- and intraindividual differences in self-regulation. In fact, a great deal of the self-regulation literature does not explicitly acknowledge the fusion of person and context.

For example, other perspectives place more emphasis on the relative stability and genetic contributions of the executive function components of self-regulation (Miyake & Friedman, 2012; Miyake et al., 2000). According to the unity/diversity framework of executive function proposed by Miyake and colleagues (Miyake & Friedman, 2012; Miyake et al., 2000), self-regulation reflects both common and separate underlying cognitive processes. Moreover, this framework argues for substantial genetic contributions to and relative stability in children's self-regulation. In contrast, others such as Blair and Raver (2012a, 2012b) use Gottlieb's (Gottlieb, 2007; Gottlieb et al., 2006) psychobiological theory and concept of experiential canalization concept to describe self-regulation as the complex and dynamic interplay among multiple levels of influence. This view also acknowledges the malleability of self-regulation in young children. Similarly, a relational perspective is used to frame and integrate the discussion of self-regulation in this chapter. However, it is important to note the diversity of theoretical perspectives inherent in self-regulation research and that not all research in this area stems from this view.

DEFINITIONS OF SELF-REGULATION AND RELATED CONSTRUCTS

The theoretical *concept* of self-regulation refers to taking in information, weighing choices and consequences, and making adaptive choice(s) to attain a particular goal. Beyond this broad definition, which is generally agreed on, there are debates about the scientific *constructs* that represent self-regulation. These include the nature and type of information that is relevant in the decision process, the process(es) by which a person weighs choices and consequences including the role of emotion, what constitutes "adaptive," what is meant by "goal," and what to call these different components.

What Is Being Measured?

There is considerable debate concerning the definition of the construct of self-regulation and the terminology used when discussing its associations with developmental outcomes. This is partly due to the importance of self-regulation for a diverse number of fields, all of which use different methods to examine phenomena related to self-regulation in childhood and adolescence. Table 14.1 shows some examples of how different fields adopt different terms to describe the complex construct of self-regulation and its subcomponents. For example, executive function (EF) originated in clinical and neuropsychology and includes the components of attentional switching and working memory; and developmental psychologists have studied delay of gratification in normative samples of children (Duckworth & Kern, 2011; Mischel et al., 2011). *Effortful control* was coined by personality scholars to describe the early-life precursor to the conscientiousness trait of the Big Five model of personality in adulthood (Rothbart, 2007).

Construct differences have diminished as methodological approaches incorporate measures from multiple disciplines (Wolfe & Bell, 2007). This also highlights the utility of using domain-general and domain-specific measures of self-regulation, depending on the research question. In an attempt to clarify constructs and measures, researchers sometimes use different levels of analysis (e.g., neurological activation, physiological responses, observed behavior, or self-report). Low to moderate correlations, however, are typically observed for self-regulation tasks across raters, settings, and demand characteristics of tasks (Duckworth & Kern, 2011). For example, in a meta-analysis of 282 samples including more than 30,000 participants, Duckworth and Kern (2011) examined correlations among diverse measures of self-regulation and self-control. Studies assessing executive function, delay of gratification tasks, and observer and self-report measures were included. Given that all studies purported to measure

TABLE 14.1 Examples of Variation in Terminology in the Study of Self-Regulation

Field	Terms	Component(s)	Time Span
Clinical psychology	Signal detection	Perceptual sensitivity	<Seconds
		Drift rate	<Seconds
		Reaction time	<Seconds
Neuropsychology	Executive function	Attention/switching	<Seconds
		Working memory	<Seconds
		Inhibitory control	<Seconds
Cognitive psychology	Fluid cognition	Perceptual speed	<Seconds
		Processing speed	<Seconds
		Manual dexterity	<Seconds
Developmental psychology	Delay of gratification	Thought suppression	<Seconds <Minutes
	Behavioral self-regulation	Attention/switching	<Seconds
		Working memory	<Seconds
		Inhibitory control	<Seconds
		Distraction	<Seconds
		Impulse control	<Minutes
Personality psychology	Temperament	Conscientiousness	<Minutes
		Effortful control	<Minutes
		Grit/self-control	<Weeks/years
Educational psychology	Engagement	Time-on-task	<Hours
		Flow	<Hours
		Persistence	<Minutes
Life-span psychology	Goal-attainment	Selection, optimization, and compensation	<Weeks/years
		Primary versus secondary control	<Weeks/years

self-regulation or its analogues, the authors found fairly low effect sizes of associations, averaging 0.27, but with substantial variability. Somewhat encouragingly, the source of the information (e.g., published article, chapter, dissertation, or e-mail to authors) did not suggest a publication bias where stronger effect sizes appeared in the published literature more often than did weaker effect sizes. The year of study was also not a predictor, which suggested that convergent validity in the measurement of self-control has been consistent for the past 45 years. These results therefore indicate that self-regulation measures are substantially distinct from one another and this has been the case for most of the time the construct has been studied.

Research has also supported the notion that common measures of self-regulation likely suffer from substantial levels of measurement error. For example, one study found that one-fifth of the variance in teachers' ratings of 3- to 5-year-olds' self-regulation (defined as social competence and problem behaviors) was due to nonchild characteristics such as teachers' ethnicity, their self-reported self-efficacy for teaching, and whether their preschool classroom was located in a school or in an early childcare center (Mashburn, Hamre, Downer, & Pianta, 2006). In another study, Crane and colleagues found that teacher and parent ratings were more disparate for children of low and high directly assessed language and cognitive ability level, compared to children of average ability (Crane, Mincic, & Winsler, 2011). When children had low abilities, parents rated their children's social competence (initiative, self-control, and behavior problems) better than did their teachers. In contrast, when children had high abilities, teacher ratings were higher than parent ratings of social competence (Crane et al., 2011).

Finally, a study of 4- to 6-year-olds showed that the amount of assessor variance in child assessments administered by independent assessors was negligible but that the assessor variance for teacher assessors was substantial (Waterman, McDermott, Fantuzzo, & Gadsden, 2012). This suggests that large amounts of variability in teacher-administered measures were not related to children's own performance but rather to the teachers who administered the assessments. These studies illuminate potential sources of "error variance" in children's scores on an observer-reported measure. They also illustrate how a child's self-regulation is not necessarily inherent to the child but is a function of many other variables including the adult giving the rating and aspects of the social context.

Sources of variance are especially important to consider when studying self-regulation. However, the low to moderate effect sizes observed in Duckworth and Kern's (2011) meta-analysis suggest that self-regulation may encompass multiple oblique factors rather than standing alone as a unitary construct. Even if a generous amount of measurement error is allowed in the operationalizations of self-regulation considered (i.e., $\alpha = .60$), the average interitem correlation in the above meta-analysis adjusts to $.27/(\sqrt{.6}\sqrt{.6}) = .45$. A disattenuated correlation of .45 suggests that the items share approximately 20% of their total variance and does not indicate unidimensionality.

Duckworth and Kern (2011) suggest approaches to dealing with this issue such as using multiple methods, both domain-general and domain-specific, to assess self-regulation or relying on observer-report when only a single measure of self-control can be collected. For example, the 10-item classroom self-regulation subscale from the Child Behavior Rating Scale (Bronson, 1994) is related to both directly assessed self-regulation and academic achievement (e.g., Cameron Ponitz, McClelland et al., 2009; Wanless, McClelland, Acock, et al., 2011), and was adopted by the state of Oregon as part of their kindergarten assessment battery. When multiple measures are possible, Duckworth and Kern also advise using aggregate or latent scores of these measures to result in a single score with stronger reliability (Willoughby, Blair, Wirth, & Greenberg, 2012). Such analytic workarounds treat the lack of measure convergence as "error variance," that is, idiosyncrasies in children's responses that are unique to the person being tested as well as aspects of the setting (Duckworth & Kern, 2011). Examples might include the child's mood on the day of testing, whether the task was interrupted, whether the child was motivated by the particular rewards offered for doing the task, and who assigned the rating.

The diversity of self-regulation theories and the corresponding operationalizations suggest that the study of self-regulation lacks a cohesive framework. Nevertheless, such diversity is also a strength. This diversity provides a richness and depth of information regarding the development of self-regulation across childhood and adolescence. For example, infancy researchers often examine temperamental aspects of self-regulation, including activation and inhibition levels, and refer to the influence of effortful control and surgency for children's ability to self-regulate (Wolfe & Bell, 2007). Researchers who study self-regulation in early childhood are more likely to refer to a child's impulse control depending on specific task demands, such as teachers asking a child to wait while her peers line up at the classroom door (Smith-Donald, Raver, Hayes, & Richardson, 2007).

Several key aspects of self-regulation have proven especially useful to the study of children and adolescents. The purpose of the ensuing section, however, is not to provide an encyclopedic review of all self-regulation research. Instead, it shows how research from different perspectives can converge on an understanding of self-regulated action. It specifically considers the case of intentional self-regulation, which describes the person's deliberate regulation of his or her own attention, emotion, or behavior. Emotional and behavioral aspects of regulation are also included in the discussion (McClelland et al., 2010).

Executive Function

Cognitive researchers often examine the underlying components of executive function (EF), which is a complex construct thought to underlie self-regulated action (Best & Miller, 2010). Executive function subsumes several disparate processes, suggesting that cognitive aspects of self-regulation can themselves be decomposed in numerous ways. The following cognitive processes are thought to be especially relevant to executive function and, in turn, self-regulated action: (a) attentional shifting, also referred to as cognitive flexibility and control, (b) inhibitory control, and (c) working memory (Best & Miller, 2010; Garon et al., 2008; McClelland & Cameron, 2012; Willoughby et al., 2012; Zelazo et al., 2008; Zelazo & Müller, 2002).

Attentional Flexibility and Control

Attentional flexibility and control are implicated in the infant's transition from simple arousal to fully endogenous attention in the first few years of life (e.g., Colombo, 2001), and the subsequent development of attentional capacities (e.g., Posner & Rothbart, 1998; Rothbart & Bates, 2006; Rothbart, Sheese, & Posner, 2007). Attention plays a major role in self-regulation as a gestalt phenomenon (e.g., Norman and Shallice's Supervisory Attention System; Norman & Shallice, 1986), and aspects of attention are especially intertwined with emotion regulation in infants and children (Sheese, Rothbart, Posner, White, & Fraundorf, 2008).

Attentional flexibility refers to the ability to voluntarily focus on a task and shift attention when needed (Rothbart & Posner, 2005). Attentional control and flexibility help children selectively emphasize goal-relevant environmental inputs, implicating attention in most developmental regulations. Furthermore, the role of attention in self-directed intentionality and responsiveness especially implicates attentional control as mediating agent-driven coactions between persons and their contexts. Attentional control thus serves as a key lynchpin of self-regulation throughout the life span.

Inhibitory Control

Attentional flexibility and control are strongly related to *inhibitory control*, which includes interference control of thoughts, attention, and memories; and response inhibition of behaviors (Diamond, 2013). Inhibitory control refers to the ability to inhibit a prepotent response and activate another, usually more adaptive, response (Diamond & Kirkham, 2005; Rothbart & Bates, 2006; Zelazo, Müller, Frye, & Marcovitch, 2003). Research suggests that children begin to display inhibitory control by approximately Age 3 (e.g., Posner & Rothbart, 1998), a period that also corresponds with the development of endogenous attention. Inhibitory control develops throughout childhood (e.g., Jones, Rothbart, & Posner, 2003), increasing throughout adolescence and into early adulthood (e.g., Hooper, Luciana, Conklin, & Yarger, 2004).

In terms of RDS, inhibitory control enables children to proactively optimize coactions with their contexts. Inhibitory control allows individuals to time their actions in ways that maximize adaptive development and allows them to inhibit immediately gratifying actions that may nevertheless lead to negative distal outcomes. Moreover, inhibitory control implies an increased level of personal effort and future-orientation and accordingly enables individuals to be more active producers of their own development. Inhibition also plays a major role in other conceptualizations of self-regulation such as effortful control and delay of gratification.

Working Memory

Working memory is another aspect of executive function and is closely related to inhibitory control (Best & Miller, 2010). Working memory includes actively working on and processing information and is demonstrated by a child who can remember and follow instructions in a multistep activity (Gathercole, Pickering, Ambridge, & Wearing, 2004; Kail, 2003). Working memory relates to academic success in young children (Gathercole & Pickering, 2000; Kail, 2003), and develops rapidly in childhood and adolescence with a substantial increase in capacity seen during these periods of the life span (Gathercole et al., 2004). Moreover, working memory constitutes a skill set that is related to intentional self-regulation. It enables children and adolescents to hold information in mind while they work and consider the best solution or strategy.

Complex and Combined EF Components

Research has differentiated responses that require inhibition only (children must stop or control motor activity) from relatively more complex responses that require inhibition of a dominant response *plus* activation of another, nondominant response (Blair, 2003; Dick & Overton, 2010; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; Müller, Baker, & Yeung, 2013; Sokol, Müller, Carpendale, Young, & Iarocci, 2010). For example, measurement research has examined conflict inhibition tasks such as the Head-Toes-Knees-Shoulders (HTKS) that requires stopping a response and initiating a new response, while also tapping working memory and attentional flexibility (McClelland & Cameron, 2012). In the task, children are asked to remember up to four paired rules for behavior (e.g., "Touch your head" or "Touch your toes") and then asked to do the opposite in response to the given command. The task also increases in complexity as children progress through the items, requiring children to utilize working memory and attentional flexibility to remember new rules and switch attention from the old rule. The task has demonstrated strong interrater reliability, construct, and predictive validity in diverse samples in the United States, Asia, and Europe (Cameron Ponitz, McClelland, et al., 2009; McClelland et al., 2007; von Suchodoletz et al., 2013; Wanless, McClelland, Acock, et al., 2011; Wanless, McClelland, et al., 2013). Future work must disentangle which cognitive components contribute most strongly across different ages and the different complexity levels of the task. For example, early in the task, when there are only two rules, inhibitory control may be most relevant; but later in the task, working memory and attentional flexibility may become more important because there are four rules to remember and the rules switch.

There is empirical evidence that the degree that each EF component relates to children's overall self-regulation skills may vary with age and skill level. In one study, Willoughby, Wirth, and Blair (2011) studied more than 1,000 children involved in the Family Life Project who were given measures of working memory, inhibitory control, and attention shifting. All tasks showed variability regardless of whether the child was from a low-income background or not. However, the attention-shifting task was better at distinguishing EF skills for low-ability children, the inhibitory control measure was best for children of average self-regulation ability, and the working memory task was the best for high-ability children. These results are interesting given developmental differences in how the underlying EF skills are thought to develop. Although all aspects of EF improve in the early childhood years, the developmental trajectories of skill components may be somewhat different. For example, research suggests that there is relatively more rapid development in inhibitory control in early childhood, which may influence the later development of attentional shifting and working memory (Best & Miller, 2010).

Further, EF appears more unitary for younger children but emerges as distinct components for older individuals (Best & Miller, 2010; Miyake et al., 2000). This finding is reflected in the unity/diversity framework by Miyake and colleagues (Miyake & Friedman, 2012; Miyake et al., 2000), which describes how components of EF show both unity (e.g., they correlate with each other and may tap common underlying processes), and diversity (e.g., they also are separable). This framework also aligns with the developmental trajectory of EF. For example, the latent, relatively stable nature of distinct EF components has been established for adult subjects across cultures (Best & Miller, 2010; Miyake et al., 2000), but is less differentiated in young children (Hughes, Ensor, Wilson, & Graham, 2010; Wiebe et al., 2011). The younger the children in the sample, the more likely that factor analyses will reveal one or two factors. Some research suggests that findings may be somewhat dependent on relatively subtle variations in tasks and performance indicators (Miller, Giesbrecht, Müller, McInerney, & Kerns, in press). A developed "EF Scale" for children aged 2 to 6 years begins with an inhibitory control demand only, then adds a switch demand, then adds increasing working memory demands (Carlson & Harrod, 2013). Children's performance increases gradually with age, aligning with the developmental progression of EF skills (Best & Miller, 2010).

Effortful Control

Rothbart and Bates (1998) defined effortful control as "the ability to inhibit a dominant response to perform a subdominant response" (p. 137). Although this definition is difficult to distinguish from inhibitory control, effortful control is instead considered an aspect of children's temperament that develops in tandem with the development of endogenous attention. Research on infant temperament has not found a complete analogue to effortful control, for example, with factor analyses instead uncovering a factor called *Orienting/Regulation* (e.g., Gartstein & Rothbart, 2003). Orienting/regulation contains many "regulatory" components similar to effortful control (e.g., orienting, soothability), but lacks a truly effortful component.

RDS emphasizes person and contextual relative plasticity as well as stability, which is compatible with the temperamental view of effortful control. Although temperament exhibits stability, it is also malleable especially early in life, and the two approaches are highly compatible in many respects. Temperament represents aspects of the individual (e.g., organismic prenatal epigenesis) that influence actions and behaviors in ways that produce cross-context cohesion. That is, temperamental characteristics such as effortful control align with RDS by representing a relatively stable characteristic of individuals that are otherwise highly malleable. Rather than an either/or distinction, the contribution of temperament to self-regulation is a good example of the tradition of the RDS perspective: Temperament is *both* individual (organismic) in origin, *and* is malleable depending on contributions from the external environment. Similarly, effortful control has links to both temperament and to context.

Delay of Gratification

Delay of gratification is a separate approach to self-regulation with close ties to both inhibition and endogenous attention. Mischel and colleagues (e.g., Mischel & Ebbesen, 1970) originally studied delay of gratification using their now-famous marshmallow task with children. In this task, a child must choose between eating one marshmallow now or waiting for an unspecified period of time and being rewarded with two marshmallows. The time that a child delays his or her immediate gratification (eating the marshmallow) to obtain the larger future reward (two marshmallows) is taken as an index of that child's ability to self-regulate. Subsequent research has adapted this task for adults by varying the value of the rewards—sometimes making them hypothetical—and by extending the delay time to a month or longer (e.g., Duckworth & Seligman, 2005; Forstmeier, Drobetz, & Maercker, 2011).

Mischel's research links the ability to delay gratification to endogenous attention and effortful inhibition through what he and his colleagues have called the *Cognitive-Affective Processing System* (e.g., Mischel & Ayduk, 2002). This work has shown that children who distract their attention away from visually salient rewards are able to delay gratification longer than children who do not self-distract (Mischel, Ebbesen, & Zeiss, 1972). Similarly, children who direct their attention to the nonmotivating features of a reward are able to delay for longer periods of time than children who do not (who presumably focus on motivating aspects of the reward such as a marshmallow's sweet taste; Moore, Mischel, & Zeiss, 1976).

Self-Control

Experts do not consistently distinguish between the concepts of self-regulation and self-control, with many authors using the terms interchangeably. Some authors, however, consider self-regulation and self-control as distinct processes. For example, Kopp (1982) describes self-control as including the ability to behave according to a caregiver's requests and to adhere to social expectations in the absence of external monitors. She distinguishes this from self-regulation, which specifies a degree of flexibility not present in self-control. The flexibility of self-regulation allows children to meet the changing demands of a dynamic context, such that the distinction between self-control and self-regulation is, "a difference in degree, not in kind," (Kopp, 1982, p. 207). Self-regulation is, in other words, an internalization of self-control that allows for flexible adaptation to contextual demands. Under this definition, self-control allows for agent-driven coactions between persons and their contexts, but only to a limited degree. Control over developmental regulations increases exponentially with the onset of self-regulation. This control permits much greater flexibility and, therefore, the compensatory enactment of alternative, yet equifinal, means of goal attainment.

Kopp's distinction between self-regulation and self-control is not completely agreed on. Other researchers, for example, tend to differentiate between self-regulation and self-control on the basis of proactivity and the role of metacognitive processes. For example, McCullough and Willoughby (2009) specify self-regulation as the process by which a person uses information about his or her current state to change that state. In contrast, self-control represents a more reactive response to immediately salient urges. Similarly, Kuhl (2000) describes self-regulation as a largely implicit process that facilitates chosen actions. He defines self-control as conscious processes that inhibit alternative action tendencies that might "jeopardize the enactment of a difficult intention" (p. 115). The distinction between self-regulation and self-control therefore may vary from researcher to researcher and is somewhat arbitrary. For practical reasons, the two terms can be seen as functionally interchangeable, with both representing the multidimensional concept of self-regulation described in this chapter.

Engagement

Engagement overlaps with the conceptualization and measurement of self-regulation, and is often used by education and personality researchers especially with regard to the persistence of behavior (Boekaerts, 2006; Eccles et al., 1993; Fredricks, Blumenfeld, & Paris, 2004; Pintrich, 2000; Trommsdorff & Cole, 2011; Zimmerman, 1989). Engagement can be defined as conscious involvement in school and related activities, and includes three theoretical components: (1) *cognitive engagement* includes a child's willingness to dedicate effort to learning; (2) *emotional engagement* refers to a child's feelings about school and school-related activities; and (3) *behavioral engagement* includes the degree to which a child actively participates in school and learning activities, such as class work and homework (Fredricks et al., 2004). Similar to EF components, Fredricks et al. (2004) note that the components of engagement are not always distinguishable empirically. What is clear, however, is that children's motivation, interest, value, and self-efficacy (e.g., feeling that "I can do this") are important predictors of how they regulate their behavior in school (Marinak & Gambrell, 2010). Many young children have high levels of motivation but as they grow older, and especially in middle elementary school, declines in motivation and increases in problem behavior are more common, especially for boys (Marinak & Gambrell, 2010; Wigfield, Battle, Keller, & Eccles, 2002). Children's engagement in school depends on their own characteristics and attitudes about school, which depend in turn on their interactions with teachers and peers (Patrick, Ryan, & Kaplan, 2007). For example, adolescents' behavior and ability to self-regulate may be influenced by the fact that they may physically look like adults but base their decisions on neurological and hormonal processes that deemphasize negative long-term consequences and emphasize situation-specific, socially relevant goals such as fame, shame avoidance, and immediate gratification (Steinberg, 2004).

Emotion Regulation

Because of its importance across the life span, the study of emotion regulation constitutes an area of research unto itself. Emotion regulation refers to children's ability to appropriately regulate their emotions (e.g., fear, anxiety, joy) as well as the behaviors influenced by such emotional reactions (Bridges, Denham, & Ganiban, 2004). Further, emotion regulation is thought to develop as a function of multiple dynamic processes that occur at all levels of the relational person ←→ context system, from the neuronal to the societal (Sokol et al., 2010). For example, work in neuroscience suggests a gene known as MAOA can change the presence of a regulating neurotransmitter, called MAO-A (Buckholtz & Meyer-Lindenberg, 2008). In male children (and rats) who are behaviorally aggressive, the MAOA gene is essentially "turned off" and results in MAO-A neurotransmitter imbalances that are thought to contribute to the aggression (Buckholtz & Meyer-Lindenberg, 2008). Rat studies indicate that pharmaceuticals can attenuate the negative neurotransmitter effects, but only within a specific developmental window. These lines of work have growing significance for the use of pharmacological treatments for children with problems regulating anger, anxiety, and other emotions, as well as for youth who encounter the justice system because of these problems.

Calkins (2010) describes emotion regulation as a process that becomes more automatic and improves with practice, which enables the child to manage increasingly complex and stressful environments. Emotion regulation emerges within early social relationships and takes different forms at various points in development (Calkins, 2010). In infancy, early regulatory tasks are tied to regulating children's attention and affective, temperament-based reactions to stimuli and information in the environment. These actions most clearly relate to emotion regulation in early childhood when children must exert considerable effort to regulate their overt behaviors (Eisenberg, Smith, Sadovsky, & Spinrad, 2004). Different types of emotion regulatory strategies have been proposed to help young children effectively manage their affect and emotions (Stansbury & Zimmermann, 1999). These include *instrumental* strategies, which are involved with trying to change a situation (such as trying to get a parent's attention); *comforting* strategies, which include or calming oneself by sucking on a pacifier without changing the situation; *distracting* strategies such as redirecting attention by looking away; and *cognitive* strategies, which include negotiating or reframing the situation into a better perspective. Cognitive strategies are considered the most difficult, especially for young children, who are limited in their metacognitive abilities.

The use of these strategies also reflects the RDS perspective because the person ←→ context is viewed relationally. Consequently children employ different self-regulatory strategies depending on the relational coactions of child and context characteristics (Zimmermann & Stansbury, 2003). This can be seen in a study where shy children, when approached by a stranger in a laboratory, were more likely to use instrumental strategies compared to bold children, who relied more on comforting and distraction strategies (Zimmermann & Stansbury, 2003). In another stranger situation in the same study, children with stronger attentional focusing (an aspect of self-regulation) were more likely to use comforting strategies compared to those with weaker attention skills. Other research corroborates that children who use planful strategies to focus their attention away from a stressful situation tend to have fewer externalizing and other behavior problems later in the school trajectory (Morris, Silk, Steinberg, Terranova, & Kithakye, 2010). In sum, different strategy choices reflect the relational coacting factors of person and context, and attention plays a key role.

Despite the frequent separation of behavioral and emotion regulation in research, the two have strong conceptual and empirical ties. As noted, attention moderates the association between negative emotionality and later outcomes, although often in complex ways (e.g., Belsky, Friedman, & Hsieh, 2001). The empirical overlap found with respect to these constructs may partially reflect the differences in how the constructs have been operationalized by researchers from a diverse set of perspectives (McClelland et al., 2010). For example, the role of attention in regulating negative reactivity is of particular theoretical interest and some, but not all, evidence suggests that strong attention can make up for negative emotionality. Such inconsistencies in findings may reflect variations in measurement, sample, and outcome studied.

As one example, using the relatively advantaged sample of children from the NICHD Early Child Care Research Network (NICHD ECCRN), Belsky et al. (2001) attributed a complex pattern of research findings to the study's observed, laboratory-style measures of infant attention and negativity. These authors found that, for low-attention infants, negative emotionality displayed in a strange situation context at 15 months predicted negative social outcomes when the children were between 3 and 5 years old (Belsky et al., 2001). Emotionality and social competence were not related for infants with strong attention. Conversely, and contrary to hypotheses, greater observed negative emotionality at Age 15 months predicted *better* school readiness (assessed with simple academic concepts such as colors, numbers, and shapes) only for *high*-attention infants; emotionality did not predict school readiness for low-attention infants. Moreover, early attention did not moderate the association between negative emotionality and later problem behaviors. The authors attributed the complex pattern of findings in part to the laboratory measures. For attention, they noted that the play task did not explicitly challenge or frustrate the child in a way that would require emotion regulation. For negativity, they posited that infants' Strange Situation behavior may have been better described as fearfulness rather than anger, and might have been an indicator of infants' more watchful approach to the world (which would presumably help them learn academic concepts later on).

A later longitudinal analysis with children from the same study (Kim & Deater-Deckard, 2010) used different measures of attention, emotionality, and behavior outcomes. For children who had poor attentional focusing measured with teacher- and parent-report, parent-rated anger was more strongly associated with parent-rated externalizing problems. In contrast, anger and externalizing problems were more weakly related for children with strong attention. Of note, these relatively more straightforward and theoretically consistent results emerged when using observer-report data only. These results from two studies utilizing the same sample illustrate how measurement discrepancies may be implicated in conflicting results for the same underlying constructs of attention, emotion, and behavior.

Sample discrepancies may also contribute to inconsistent conclusions. Whereas the NICHD ECCRN sample is considered relatively advantaged, and strong attention appeared protective for children with high levels of emotionality, analyses of low-income children revealed the opposite pattern. In a study of low-income children transitioning to formal schooling (Marcynyszyn, 2007), strong parent-rated attention at 3 years predicted later achievement only for children ages 5 to 6 years who were *low* in parent-rated negative emotionality. Finally, a third study with rural, low- to mid-SES children in early elementary school (Wilson, Petaja, & Mancil, 2011) found that strong attention was only significantly related to children's school achievement for students who did not struggle with aggression. Instead, aggressive children were more likely to have attention problems, which predicted lower reports of children's school achievement.

In sum, although attention, proneness to negative emotions—such as frustration—and regulatory failures are related, how they relate, and for whom, is not yet clear. More comprehensive consideration of measurement and sample contributions to results may be helpful. For example, a meta-analysis of the associations among attention, emotionality, and behavioral and academic outcomes in early childhood is needed. For low-income children in home environments with numerous financial, health, or interpersonal stressors, research indicates that the child's neural development and subsequent behavioral patterns of difficulty may reflect their need to constantly respond to intense negative and stressful stimuli (Blair & Raver, 2012a). Negative environments are thought to overuse the developing brain's "fight or flight" responses and may result in withdrawal or reactive behaviors that can contribute to deficits in processing social information. Thus, children in stressful environments may develop qualitatively different ways of coping with the world and regulating themselves within those contexts.

Given the impossibility of randomly assigning children to stressful environmental conditions, the work in this area is necessarily correlational. Burke, Hellman, Scott, Weems, and Carrion (2011) demonstrated that children who had been exposed to four or more developmental traumas such as emotional or physical abuse or parental incarceration are 17 times more likely than children who experienced no traumas to have learning and behavior difficulty. The consequences of early adversity are thought to have cascading effects after children enter school. Masten et al. (2005) found that children with externalizing problems in childhood had significantly worse academic outcomes by adolescence, which was then related to significantly more internalizing problems in early adulthood.

In an effort to understand the processes that can lead to this developmental cascade, Ladd, Birch, and Buhs (1999) found that children's early behavioral style (e.g., prosocial styles that include cooperative play, or antisocial styles that include aggressiveness) contributed to their peer acceptance or rejection at 5 to 6 years. Acceptance versus rejection was related to the level and quality of classroom participation, which predicted academic achievement. This study raises a key question about the factors that contribute to whether a child establishes a prosocial, problem-solving approach to the world or an antisocial, aggressive, and hostile approach. For example, to decide how to react to a peer who just took his toy, a young boy might need to inhibit yelling or hitting. He may then need to decide to offer to play, tell the teacher, or find a new toy. These self-regulating choices in turn require language facility and planning what to say in the midst of an emotional stressor. Thus, successful self-regulation relates to other processes and skills when influencing children's development.

Bringing Together the Separate Aspects of Self-Regulation

Self-regulation includes both top-down (e.g., executive functions) and bottom-up regulation of thoughts, feelings, and behavior (Blair & Raver, 2012b; Zelazo & Cunningham, 2007). For example, executive function includes attentional flexibility, working memory, and inhibitory control and is used to plan, organize, and problem-solve as well as to manage the regulation of emotions and behavior. This model of self-regulation includes relational bidirectionality between the top-down effortful regulation and the more automatic, bottom-up, aspects of regulation. According to this view, self-regulated behavior includes relations between executive functions associated with the prefrontal cortex (PFC) and emotional and stress responses associated with the limbic and brainstem areas of the brain (Blair & Raver, 2012b). This bidirectional coaction between the top-down and bottom-up aspects of self-regulation enables a child to manage his or her thoughts, feelings, and behavior, which lays the foundation for successful behavior in all areas of that child's life.

Children benefit when educational practices and policies reflect the scientific understanding of school readiness as indicative of the relationships, processes, and contexts within which the child is expected to function (Pianta, Cox, & Snow, 2007). A child's regulatory difficulties may signal a mismatch between environmental demands and available regulatory resources. In line with the RDS perspective, Ursache, Blair, and Raver (2012) frame children's self-regulation as emerging from executive, "top-down" control of "bottom-up" emotional reactivity. For some children, especially those operating within predictable, supportive environments, this emergence produces contextually relevant responses that are adaptive over the long term and that facilitate EF. In contrast, for other children, using EF to make choices may become "derailed" because they must constantly respond to stressful events and short-term consequences.

IMPORTANT CORRELATES OF SELF-REGULATION

Given the conceptualization of self-regulation as occurring within a relational developmental system, it is necessary to describe significant codeveloping skill sets and constructs. In the following section, the relations between self-regulation and several key related constructs are discussed. Given the consistency of such findings, they suggest areas where future research is likely to be especially fruitful.

Self-Regulation and Academic Achievement in Childhood and Adolescence

Although self-regulation and related constructs have been studied by researchers in a variety of fields, it is clear that components of self-regulation are critical for long-term social and academic success (McClelland et al., 2013; Moffitt et al., 2011). An emerging area considers how underlying EF processes are integrated and translated into children's self-regulated behavior especially in contexts such as school and classroom settings (McClelland & Cameron, 2011). Consistently strong relations have been found between children's self-regulation and their academic achievement in early childhood (Blair & Razza, 2007; Cameron Ponitz, McClelland, et al., 2009; Duncan et al., 2007; McClelland et al., 2006; McClelland et al., 2007) throughout adolescence (Duckworth & Seligman, 2005; Duckworth et al., 2010), and into adulthood (McClelland et al., 2013; Moffitt et al., 2011).

Links among self-regulation, school readiness and academic achievement begin to emerge in early childhood. Many studies now document that self-regulation measures, either as a composite construct or through measures of attentional flexibility/control, inhibitory control, and working memory, are robustly associated with both short- and long-term social and academic success (Blair & Razza, 2007; Duncan et al., 2007; Gathercole & Pickering, 2000; Howse, Lange, Farran, & Boyles, 2003; Kail, 2003; NICHD Early Child Care Research Network, 2003; Trentacosta & Izard, 2007). Strong self-regulation and its underlying components indicate that children can manage their emotions, cognitions, and behavior so they can take advantage of instruction and learning activities in schools and classrooms.

Work by McClelland and colleagues (e.g., Cameron Ponitz, McClelland, et al., 2009; McClelland & Cameron, 2012; Wanless, McClelland, Acock, et al., 2011) has examined a direct assessment of self-regulation called Head-Toes-Knees-Shoulders (HTKS), which taps inhibitory control, attentional flexibility, and working memory. In these studies, children's performance on HTKS predicts emergent literacy, vocabulary, and math skills between the ages of 3 and 6 years (Cameron Ponitz, McClelland, et al., 2009; McClelland et al., 2007). These results have also been replicated in international studies with Asian (Wanless, McClelland, Acock, et al., 2011) and European (von Suchodoletz et al., 2013) samples. In one study, gains in self-regulation predicted gains in emergent literacy, vocabulary, and math skills over the school year in 4- to 5-year-olds after controlling for fall achievement scores and demographic variables (McClelland et al., 2007).

In a follow-up study, fall self-regulation scores in children ages 5 to 6 years predicted fall and spring academic achievement skills, although gains in self-regulation predicted gains only in early math skills (Cameron Ponitz, McClelland, et al., 2009). This suggests that self-regulation may be important for a range of developing academic skills prior to formal schooling, but domain-specific relations may emerge as children enter more structured academic settings (McClelland et al., 2007). This notion is supported by the strong relations that have been documented between self-regulation and early math skills by a number of researchers and studies (Blair & Razza, 2007; Bull, Espy, Wiebe, Sheffield, & Nelson, 2011; Bull & Scerif, 2001; Cameron Ponitz, McClelland, et al., 2009).

The associations between self-regulation and math appear particularly strong during early childhood and may reflect the importance of both inhibitory control and working memory in processing and completing math problems (Blair & Razza, 2007; Cameron Ponitz, McClelland, et al., 2009). Moreover, the term *math* is general and includes skills like number sense that are heavily language-based, and skills like approximation and comparison that are more spatially based (LeFevre et al., 2010). Little has been done to unpack the domains within mathematics and to link aspects of self-regulation to specific skills under the math umbrella. Some research however, is emerging. For example, in a sample of Chinese and American children aged 3 to 5 years, performance on the HTKS was related to counting aspects of math but not calculation in both cultures (Lan, Legare, Cameron Ponitz, Li, & Morrison, 2011). Individual EF components, however, showed cultural differences. Chinese children with better working memory and attentional control had higher achievement outcomes across the board (reading, counting, and calculation), whereas neither working memory nor inhibition were associated with reading for American children.

In another study, self-regulation measures were differentially related to counting and calculation (Miao, Diaz, & McClelland, 2013). Specifically, when children were assessed at school entry at 4 to 5 years, measures of inhibitory control (Day-Night task) and working memory (Woodcock-Johnson Auditory Working Memory test) predicted children's counting, whereas the relatively more complex HTKS predicted calculation skills. At the end of the school year, inhibitory control (on the Day-Night task) was associated with counting, working memory predicted calculation, and the HTKS predicted both counting and calculation. Over the school year, early performance on HTKS predicted calculation at the end of the year, with weaker relations for initial working memory predicting end-of-year calculation. These results suggest that different aspects of self-regulation show domain-specific relations to counting and calculation skills even before formal school entry.

Counting is considered a basic number core component, whereas calculation involves more complex mathematical operations (Cross, Woods, Schweingruber, & National Research Council, 2009). Number core and counting skills develop earlier than skills in more complex mathematical operations. Similarly, children's inhibitory control skills may develop earlier than more complex self-regulatory abilities such as working memory and complex inhibition measures such as the HTKS (Diamond, 2002). These results suggest that whereas earlier developing components of self-regulation (e.g., inhibitory control) are associated with basic number core components such as counting, measures of more complex self-regulation components (e.g., working memory, attentional or cognitive flexibility) may be more aligned with complex mathematical operations such as calculation. At the same time, there are some intriguing cultural differences that warrant further investigation.

Together, this body of research suggests that self-regulation and the underlying executive function components form a foundation for learning early in life. The next sections build on this general finding by discussing specific processess through which self-regulation skills may relate to learning and achievement. In particular, the demands on children's self-regulation capacity are explored from a new vantage point: motor development, the demands that motor tasks place on the developing person, and implications for self-regulation.

Self-Regulation of Motor Processes and Relevance for Cognitive Development

Throughout development, children encounter increasingly complex tasks that require increasingly sophisticated cognitive processes to solve. Consider a child, Duncan, in a second grade classroom. Duncan's teacher has asked the students, one row at a time, to each fetch a small box of LEGOs from the coat room, bring it back to their desk, empty it out, and sort the LEGOs by color, 10 at a time. The final step involves writing down how many sets of 10 they find for each color. In order to do this, Duncan must:

> *Remember the teacher's directions*, push his chair back from the desk, ignore his friend in the next row who has just playfully punched him, walk to the coat room, find a LEGO box that no one else is using, ignore the loudspeaker announcement for the fourth-grade field trip, return to his desk, *remember the teacher's directions*, pull the chair up to be able to sit at the desk comfortably, *remember the teacher's directions,* use his hands and fingers to pick up only the LEGOs that are the correct color, count to ten while picking up the LEGOs, write down the number of sets in each color, and finally, wait for his teacher to come and check his work.

This vignette reveals just how complex and cognitively demanding an early learning environment can be. Duncan must use his behavioral and emotional regulation skills to ignore his friend and shut out the distractions of the loudspeaker announcement and the adult. He must also sort and count a set of interesting blocks that he might rather use to build a bridge than count, so in addition to using his counting skills, he must inhibit the urge to play with LEGOs and instead use conflict inhibition to activate different behaviors so he can complete the assignment. Finally, he must use fine, gross motor, and visuospatial skills to move about the classroom, pick up the LEGOs and place them with their set, arrange his paper on the desk, and write down his name and the number for each color.

Surprisingly little research in normative samples has examined self-regulation in relation to motor development. This is an interesting gap in the literature, given the strong neuroscience and clinical evidence that links the early development of motor processes to the development of EF and other abstract cognitive processes (Diamond, 2000; Paus, 2001). The work of scholars such as Adolph, Diamond, Keen, and their colleagues (Adolph, 2008; Diamond, 2002; Keen, Carrico, Sylvia, & Berthier, 2003) suggests that the neural networks that are built during infancy for crucial developmental milestones such as reaching and walking are later co-opted and used for complex cognitive processing.

Results from research using the dual task paradigm, an experimental paradigm that poses two types of demands, suggests that simultaneously exercising self-regulation and performing a motor task is quite difficult for infants. In one study, the increased motor demands of a task were negatively related to infants' ability to self-regulate by not reaching to a known incorrect choice (Boudreau & Bushnell, 2000). Additional research suggests that self-regulation and motor skills remain related through adulthood. For example, neurological studies where adults must learn a novel motor sequence until they master it show that activation patterns change in both quantitative and qualitative ways (Floyer-Lea & Matthews, 2004). Early in the learning trajectory, there is more activation overall, especially in the prefrontal cortex. After many practice trials, as automaticity and task performance increase, overall activation lessens in EF neural areas and shifts to subcortical areas traditionally associated with motor activity including the cerebellum and basal ganglia. This work suggests that responding to motor and EF demands in a novel learning context draws from an overlapping set of finite cognitive resources. Much of the evidence that links self-regulation with motor development and achievement in early childhood has been established in populations with disabilities. But growing evidence links fine motor skills in particular with school performance in normative samples as well. This makes sense given the substantial motor requirements in school. In an observational study of early childhood classrooms, children spent from 30% to 60% of their time in fine motor activities (Marr, Cermak, Cohn, & Henderson, 2003).

Self-regulation in school settings may be especially difficult for young children because such environments often place simultaneous demands on their developing cognitive, attention, emotional, motor, and behavioral capacities. To complete many school-related and self-care tasks, children must coordinate complex visual and/or auditory input while ignoring distractions, represent and transform stimuli in working memory, and then plan and realize a series of precise motor movements (Korkman, Kirk, & Kemp, 2007a; Sortor & Kulp, 2003). These include visuomotor tasks that adults may take for granted, such as tying shoes, packing a backpack, arranging or sorting materials, cutting with scissors, and writing on a piece of paper (Cameron, Chen, et al., 2012). When children are faced with a task that requires processing in both self-regulation and visuomotor modalities, those who have difficulty in both domains may be more likely to struggle. But, evidence also suggests that self-regulation and visuomotor skills may relate with academic achievement in a complementary, compensatory, way, illuminating each as potential sources for intervention.

Strong motor skills may support children's ability to navigate complex classroom environments. In one study, early elementary students from two sites—one middle-SES and one low-income—whose teachers rated them higher on the "classroom fine motor" subscale of the Motor Skills Rating Scale (Cameron, Brock, et al., 2012) performed better on a range of tasks including attention and design copy visuomotor integration tasks, earned better ratings in achievement from teachers, and scored at higher levels on a direct measure of achievement (Cameron, Brock, et al., 2012). Large longitudinal studies also show that children who do well on a fine motor composite measured at the beginning of kindergarten (i.e., at approximately 5 years old) achieve at higher levels at the end of the school year (Son & Meisels, 2006). Moreover, Grissmer, Grimm, Aiyer, Murrah, Steele (2010) reported that kindergarteners with strong fine motor skills had higher third- and fifth-grade achievement (i.e., at 8 and 10 years old, respectively) in reading and mathematics, after controlling for teacher-rated attention and children's previous achievement.

Like self-regulation, fine motor measures draw on multiple component processes including visuospatial skills and sensorimotor processing. EF is also an essential contributor to fine motor competence (Korkman, Kirk, & Kemp, 2007b), so studies are needed that clarify how and whether they relate to other cognitive outcomes. Current work shows some intriguing trends as well as inconsistencies that may depend on sample or age differences. For example, one study examined middle-SES children who completed both a fine motor task and the HTKS before kindergarten (Cameron, Brock, et al., 2012). The fine motor skill composite and the HTKS self-regulation measure were correlated below .20 and made separate contributions to achievement in multiple domains. Self-regulation was more strongly related to mathematics than were fine motor skills, and fine motor skills were most related to skills that involved combining visual symbols (word-reading and comprehension) or manipulating the sounds in language.

In another study (Becker, Miao, Duncan, & McClelland, 2014), variation in both fine motor skills and self-regulation predicted variation in early literacy, but only performance on self-regulation tasks (the HTKS, the Auditory Working Memory task and the Day/Night Stroop task) predicted math and vocabulary skills. In a related longitudinal study (Becker, Duncan, Miao, & McClelland, 2012), both fine motor skills and self-regulation were associated with change in each measure between fall and spring of prekindergarten. Specifically, although strong levels of fine motor skills and self-regulation in the fall predicted greater improvement in math between fall and spring, self-regulation was a stronger predictor of math gains than was fine motor skills.

Other work has suggested that fine motor skills may confer an advantage when there are other challenges present (Liew, Chen, & Hughes, 2010). Thus, in addition to an additive model where fine motor and self-regulation contribute separately to outcomes, a compensatory model may also describe how these two predictors relate to other aspects of children's development (Barron & Harackiewicz, 2001). Compensatory associations were found in a study of low-income children ages 2 to 5 years (mean age 4.1 years) across the United States who were given the pencil-tap inhibitory control task as a self-regulation measure and a common visuomotor design copy measure, the test of Visuomotor Integration (VMI; Beery, Buktenica, & Beery, 2010). Compared to children with high levels of both skills, children who had initial strengths in either inhibitory control or in visuomotor integration achieved at similar levels in early teacher reports of their classroom behavior, expressive and receptive language, and a measure of phonological processing (Cameron et al., 2014). Only children who were weak in both inhibitory control and visuomotor skills performed more poorly on the outcome measures. This compensatory pattern also applied for gains over the school year in print knowledge and to a weaker extent, phonological awareness. Finally, in a separate study of 5- to 6-year-old children from a high-poverty community, Byers (2013) found that the compensatory pattern between visuomotor integration and a composite measure of EF emerged for predicting gains in early math skills.

Together, this research suggests domain-specific relations between fine motor skills including visuomotor integration, self-regulation, and early academic outcomes for children. Fine motor skills seem important especially for early literacy development, whereas self-regulation has demonstrated stronger relations to early math and vocabulary skills. This must be considered in the context of longitudinal work, which demonstrates that early fine motor skill predicts math achievement in middle school (Grissmer et al., 2010; Murrah, 2010). In addition, fine motor and self-regulatory skills may interact, for some children in relation to some behavioral or academic outcomes.

Self-Regulation, General Intelligence, and the Importance of Automation

As Gestsdóttir and Lerner (2008) note, self-regulation is not necessarily fully conscious, such as when a young child notices that snack is ready but seemingly instinctively goes to wash his hands first. But automated actions are acquired through practice and deliberate modification of prepotent, already-established, or desired responses, such as reaching instinctively for the snack. In other words, self-regulation may be involved—or even required—to turn nonautomatic processes, such as tying a shoe or writing one's name, into automatic processes. This rationale has been supported by neurological activation studies of adults (Floyer-Lea & Matthews, 2004), but similar data are more difficult to collect with children. This represents a ripe area for further work to validate (or refute) a working theory among scholars who study children during the school years.

Applied to early development, the *cognitive load theory* holds that when a child automates a skill, this automation frees up cognitive resources for the next task (Diamond, 2002). As noted above, self-regulation has enormous implications for learning and development during childhood. A child who can tie his shoes without thinking about it can be more independent than a child who must fetch an adult to tie his shoes for him. Similarly, a child who has an organizational system for her homework, where she keeps a notebook with all her assignments and checks completed items off a list, is better equipped for school and its myriad organizational demands when compared to a child without such a system.

The role of self-regulation in automating nonautomatic responses, including the learning of new motor sequences, also overlaps with notions of general intelligence (Blair, 2006). As noted earlier, scholars distinguish between domain-general cognitive skills related to cognitive processing across tasks—which would include constructs like EF—and domain-specific skills such as spatial, linguistic, and quantitative abilities (Demetriou, Spanoudis, Mouyi, Ferrari, & Vuletic, 2010). In one study using this framework, the domain-general working memory and attention control components of self-regulation predicted growth in domain-specific emergent literacy and mathematics (Welsh, Nix, Blair, Bierman, & Nelson, 2010).

From an information-processing perspective, Demetriou, Mouyi, and Spanoudis (2010) described the nature of neurological architecture with three hierarchical, interrelated levels. One level includes specialized domain-specific areas dedicated to processing types of information such as verbal, quantitative, and spatial reasoning. Another includes core general capacities such as speed of processing and memory span that are implicated within and across domains. The third level is self-regulatory and monitors, evaluates, and integrates information from the other two levels. The authors found support for the notion that progress emerges within a level and is constrained by the resources and capacity at that level. When information at one level becomes sufficiently complex, the need for automaticity arises, such as in the shift from processing single letters and their sounds to reading whole words. Children have slower reaction times than adults, which may partially reflect that they have automated fewer cognitive processes (Demetriou et al., 2002; Kail, 2003).

Although research has established that self-regulation is related to cognitive processes that become more automatic over time (e,g., reading, counting), scholars have generally distinguished intelligence from self-regulation and other measures of EF. In American 16- to 18-year-olds, the working memory component of EF was more strongly related to both fluid and crystallized intelligence (*r*s above .60) as compared with inhibition or shifting, with correlations around .30 (Friedman et al., 2006). Other research has found that although self-regulation and intelligence are related, they are not the same and demonstrate differing patterns of predictability especially to academic outcomes (Blair, 2006; McClelland et al., 2006; McClelland, Morrison, & Holmes, 2000). In another series of studies using a measure of grit, defined as intensely focusing on a single goal over the long-term, no correlation was found between grit and traditional measures of intelligence (Duckworth, Peterson, Matthews, & Kelly, 2007), though both uniquely contributed to outcomes such as educational attainment. Thus, research supports the notion that although aspects of self-regulation may overlap with indices of intelligence depending on how self-regulation is measured, they also contribute unique variance to outcomes.

Risk and Self-Regulation

Children's sociodemographic characteristics are a major predictor of variation of self-regulation skills and, accordingly, of related developmental outcomes. This section considers the possibility of differences regarding the relevance of self-regulation for other outcomes, issues that arise in measurement, and the way early experiences may support the development of self-regulation. Research suggests that adaptive self-regulation is associated with academic achievement across many cultures (von Suchodoletz et al., 2013; Wanless, McClelland, Acock, et al., 2011), across varying levels of socioeconomic risk (McClelland & Wanless, 2012), and for both genders (Wanless, McClelland, et al., 2013). Although self-regulation positively relates to child academic outcomes for both girls and boys, a mixed picture of gender differences in self-regulation during early childhood is beginning to emerge. In the United States, girls consistently show higher self-regulation than boys based on direct assessments (Cameron Ponitz et al., 2008; Kochanska, Coy, & Murray, 2001; Matthews, Ponitz, & Morrison, 2009; Wanless, McClelland, et al., 2013) and teacher reports (McClelland et al., 2000; Ready, LoGerfo, Burkam, & Lee, 2005; Wanless, McClelland, et al., 2013). In Asian countries such as Taiwan, South Korea, and China, however, research has found no gender differences in directly assessed self-regulation, but teacher-reported self-regulation showed an advantage for girls in Taiwan and South Korea (Wanless, McClelland, et al., 2013). Finally, research in Europe has not documented gender differences in directly assessed or teacher-reported self-regulation in France or Germany. European girls have shown higher self-regulation, however, when directly assessed in Iceland and Norway, and when rated by teachers in Iceland (Gestsdóttir et al., 2014; Størkson, Ellingsen, Wanless, & McClelland, 2014). These mixed findings across cultures and across assessment tools suggest that gender may be considered a risk factor in some contexts, but not others. Understanding these differences may help support boys' development in those parts of the world where gender gaps in self-regulation are documented.

Differences in children's self-regulation can also be seen based on the degree and number of risk factors present (Evans & Rosenbaum, 2008; Galindo & Fuller, 2010; Raver, Blair, & Willoughby, 2012; Sektnan et al., 2010; Wanless, McClelland, Tominey, et al., 2011). For example, research has examined cumulative risk and the effects of being low-income and an English-language learner on children's self-regulation growth between the ages of 4 and 6 years (Wanless, McClelland, Tominey, et al., 2011). Children from low-income families began the study with lower self-regulation than their peers from middle-income families. Within the low-income group, English-speaking children exhibited a faster rate of self-regulation growth than English language learners. However, although low-income English-speaking children caught up to their more economically advantaged peers by the end of the study on self-regulation, low-income English-language learners did not. Taken together, these findings suggest culture plays a unique role in determining how being from a low-income environment relates to the emergence of self-regulation.

Toxic Stress

Low socioeconomic status is related to low self-regulation on a variety of measures (e.g. caregiver report, direct assessments) and may be indicative of children's responses to chronic stress and to being exposed to fewer optimal learning experiences (Blair & Diamond, 2008; Blair & Raver, 2012a). In one study, although poverty between birth and 13 years old was related to adult working memory, this relation was partially mediated by the degree of chronic stress the child had experienced (Evans & Schamberg, 2009). Specifically, children who lived in poverty tended to experience more stress over longer periods of time, and amount of stress (beyond poverty status) predicted lower levels of working memory in adulthood.

Conceptualizations of children's development provide a model through which early childhood adversity is related to weaker self-regulation in children through stress hormones and neural connectivity (Blair & Raver, 2012a). In this model, cumulative risk is related to increased levels of stress hormones in ways that may benefit the person by increasing a child's vigilance and ability to quickly react to threatening situations, which would be helpful for children living in unsafe or unpredictable environments. However, this increased level of reactivity also comes with short- and long-term costs to children's health and adjustment, including EF and self-regulation deficits. Such associations also emerge in the context of the caregiving environment. For example, research from the Family Life Project has also indicated that positive parenting was modestly related to lower stress hormones in children through Age 4 (Blair, Raver, Granger, Mills-Koonce, & Hibel, 2011). Moreover, poverty was related to lower self-regulation in children through its association with lower parenting sensitivity and higher levels of cortisol in children (Blair, Granger, et al., 2011).

Another study utilized data from the NICHD Study of Early Child Care and Youth Development and investigated how self-regulation mediated relations between early risk (growing up in chronic poverty, being of minority status, having mothers who were depressed or parents with low parent education) and later academic success (Sektnan et al., 2010). As might be expected, results indicated that many of these risk factors had negative effects on children's reading, math, and vocabulary achievement in first grade. Moreover, children's self-regulation in preschool and kindergarten were significant mediators between family risk factors and first grade achievement. Low maternal education and chronic levels of high maternal depressive symptoms were associated with lower first-grade achievement through lower self-regulation skills at 54 and 66 months. This is particularly concerning because research suggests that growing up in the context of risk can set the stage for a negative cycle. Specifically, children experiencing multiple risk factors (poverty, minority status, maternal depression) may enter school around 5 years old with poorer self-regulation, have more difficulty in the classroom and on academic tasks, have teachers and other children who find them challenging, and as a result, may disengage from school and learning (Blair & Diamond, 2008; Ladd et al., 1999).

Self-Regulation as a Protective Factor

Research also suggests that self-regulation is an important compensatory factor for children growing up in the context of risk. For example, the results from one study (Sektnan et al., 2010), indicate that regardless of the presence of a risk factor, children with stronger self-regulation, defined as one standard deviation above the sample average self-regulation score, had stronger achievement than children with self-regulation that was one standard deviation below the average score. Moreover, for children with the same number of risk factors, those with strong self-regulation did better academically than children with low self-regulation. Another study found similar results with a sample of homeless children (Obradović, 2010). Self-regulation, indexed by measures of effortful control, was the most significant predictor of teacher ratings of academic competence, peer competence, and internalizing and externalizing symptoms and of resilient status of homeless children, relative to IQ, parenting quality, and the presence of cumulative risks. Together, this research suggests that even when children are exposed to considerable risks, those with stronger self-regulation have better school outcomes than those with weaker self-regulation.

Clarifying how poverty, attention, and negative emotional tendencies interrelate to produce regulatory outcomes in early childhood is critical. At least in the United States, school in the modern era presents numerous attentional, behavioral, and emotional demands for children, many of whom arrive at school ill-equipped to cope with such demands. This can be seen in the national average of 5% of preschoolers expelled from their classrooms each year, the highest rate for any age group between 4 and 18 years old (Gilliam, 2005), and the estimated 30% to 50% of children whom their teachers rate as having difficulties regulating their behavior in the classroom (Rimm-Kaufman, Pianta, & Cox, 2000). Rather than blaming children for regulatory failure, another interpretation of this "crisis" of poor adaptation to school is that many children come from home environments that have a particular set of expectations that vary across families (e.g., to be quiet, or to be inquisitive) and may or may not align with expectations in classrooms (Wachs, Gurkas, & Kontos, 2004).

Cross-Cultural Variation in Self-Regulation

Self-regulation research increasingly includes international perspectives that describe average differences between cultures as well as variability within cultures. This advancement is critical to understanding the richness of the concept of self-regulation because self-regulation may be defined, fostered, and related to later outcomes in culturally specific ways. Although there is often considerable cultural variation within a country, research on self-regulation is included that uses country of origin as a proxy for culture.

Average differences in self-regulation between cultures are informative because they may direct attention toward culturally driven practices that may support or hinder self-regulatory development. Comparisons between Asian and European/North American cultures have been particularly popular in past research. For example, in comparing infants in the United States, Spain, and China, Chinese infants were rated by their mothers as having significantly longer attention spans than either American or Spanish infants (Gartstein et al., 2006). Similarly, a Chinese advantage was also present at the entry to formal schooling, based on a directly assessed working memory task (Geary, Bow-Thomas, Fan, & Siegler, 1993). Cultural differences in the amount of self-regulatory support for children, however, may lead to culturally specific judgments about children's levels of self-regulation. Research in classrooms in the United States and China, for example, has shown that although there were more behavioral problems in U.S. classrooms, there was also more unstructured time than in Chinese classrooms. This contextual factor was culturally situated and may have elicited certain behaviors (Tobin, Wu, & Davidson, 1989). In other words, U.S. children's observed skill level may have been undermined by a lack of structure in their classrooms.

Moreover, seminal research by Stigler, Stevenson, and colleagues (Stevenson et al., 1990; Stevenson, Lee, & Stigler, 1986) described children's approaches to a difficult task. Whereas U.S. children gave up after seconds, Japanese children persisted as long as the researchers allowed, up to one hour. In contrast, Chinese children showed more adaptive self-regulation skills compared to children from the United States and New Zealand, but this same advantage was not evident for Japanese children (Jose & Bellamy, 2012). This work begins to tease apart Asian cultural practices, and suggests that although Asian cultural practices may prioritize self-regulation in broad terms, Chinese parenting and teaching practices, specifically, may uniquely support self-regulation development.

Cross-cultural research also demonstrates that although the components of self-regulation may be similar across cultures, cultural variations among these components may emerge. In a study using direct assessments of components of self-regulation, for example, correlations between working memory and attention were virtually equal in the United States and China, but correlations between inhibitory control and attention were much stronger in China than in the United States (Lan et al., 2011). These cultural nuances regarding subcomponents of self-regulation were also present in Carlson and Meltzoff's (2008) study of bilingual children. Bilingual children showed a self-regulation advantage over monolingual children in terms of attentional shifting, but not inhibitory control (Carlson & Meltzoff, 2008). Although the bilingual and monolingual children were both from the same country (United States), the differentiation in self-regulation components underscores the importance of cultural practices, such as the extent to which children are expected to become bilingual, for promoting self-regulatory development. Learning two words for the same thing may exercise children's ability to notice and select between a seeming contradiction. For example, research finds a bilingual advantage in children's ability to process complex information in self-regulation and EF tasks, especially those requiring conflict resolution, switching, and updating (Bialystok, 2010; Bialystok, Craik, Green, & Gollan, 2009). Thus, although attentional flexibility, working memory, and inhibitory control are important elements of self-regulation across cultures, cross-cultural differences are also present.

By comparison, parent and teacher ratings of self-regulation are more consistent across cultures than are direct assessments. For example, cross-cultural studies have found the same factor structure for self-regulation when using parent reports of effortful control in the United States and China (Ahadi, Rothbart, & Ye, 1993). Additionally, teacher ratings of self-regulation have shown fairly similar overall internal consistencies across cultures (Gestsdóttir et al., 2014). Adults appear to show some agreement about what constitutes self-regulation. This same consistency is not evident, however, with adult ratings of children's levels of self-regulation. One study suggested that cultural factors such as adults' expectations for children's self-regulation may influence their ratings of children's skill levels. For example, when teachers in the United States and Taiwan rated their own students' skills, the Taiwanese children had lower scores than the U.S. children on politeness and extraversion (Jose, Huntsinger, Huntsinger, & Liaw, 2000). When the U.S. teachers watched videotapes on these Taiwanese children, however, they rated the Taiwanese children similarly to the U.S. children. These findings may suggest that the Taiwanese teachers had higher expectations for the children's abilities than the U.S. teachers had. Thus, despite similarities in the components of self-regulation across cultures, cultural differences in the expectations that adults have for children's skills may lead to culturally specific nuances in ratings of self-regulation.

Despite differences in self-regulation within and between cultures, one finding remains consistent. Self-regulation significantly relates to academic achievement concurrently, and in some cases, over time in multiple cultures including the United States, China, Taiwan, South Korea, Japan, Australia, Germany, Iceland, and France (Blair & Razza, 2007; Gestsdóttir et al., 2014; Lan et al., 2011; Purdie & Hattie, 1996; von Suchodoletz et al., 2013; Wanless, McClelland, Acock, et al., 2011; Zhou, Main, & Wang, 2010). Moreover, in many of these cultures, self-regulation positively predicts mathematics skills more strongly than other academic skills. These relations have also been found across multiple cultures when using a teacher-reported measure (Wanless, McClelland, Acock, et al., 2011). Other examples of research examining cross-contextual variation includes work by Ahadi and colleagues, who found that effortful control related differently to other aspects of temperament in Chinese and American samples (Ahadi et al., 1993). Similarly, Feldman, Masalha, and Alony (2006) examined differences in self-regulation among Israeli and Palestinian children. In this study, children from both cultures displayed equivalent scores on an overall self-regulation composite variable, but Israeli children scored higher on compliance while Palestinian children scored higher on inhibition. Further investigation into such differences can accordingly inform the many ways that people actively engage their contexts and direct the course of their own development.

Measures of Self-Regulation Across Cultures

Most self-regulation measures are parent-reported, teacher-reported, or direct assessments. Researchers are beginning to examine the cross-cultural utility of these types of measures in order to draw conclusions about universal versus culturally specific aspects of self-regulation. Similarities in the functioning of the measure across cultures seem more evident for direct measures than for adult-reported measures. For example, in one study of young children in the United States, Taiwan, South Korea, and China, the predictive validity of a direct self-regulation measure was more stable across cultures than was a teacher-rated measure (Wanless, McClelland, Acock, et al., 2011).

Although direct assessments may show promise for cross-cultural research, many of these assessments assume that children have a certain degree of independence. For example, researchers often ask children to remember and follow a rule that guides them to do the opposite of what the research assistant asks, which was earlier defined as conflict inhibition. The child's willingness to act independently and do the opposite of what an adult is asking, however, may vary depending on the value that the child's culture places on independence. In Hispanic cultures, for example, children are expected to show independence at a later age than their peers in the United States (Markus & Kitayama, 1991). It is possible that these children will not be comfortable with self-regulatory tasks that ask them to behave independently before they are old enough for it to be culturally appropriate for them to do so.

Conducting research across cultures requires the researcher to determine whether one measure can be used for all participants or whether culturally specific measures are needed to most accurately capture the construct. Studies that have used the same measure across cultures lead to conclusions about the differences between self-regulatory ability in each culture, and need to present evidence that the measure worked sufficiently well in each culture. This evidence usually consists of high internal reliability, predictive validity with expected outcomes such as math skills, testimony of face validity by experts in the culture, and significant relations with other measures of self-regulation such as a teacher report. Although evidence is compelling, the question remains whether, and to what extent, nuances in the validity of the measure and the amount of measurement error in each culture play a role in the substantive findings.

Van de Vijver and Leung (1997) suggest three types of equivalence to establish before making comparisons across cultures (see also Van de Vijver, Hofer, & Chasiotis, 2010). First, construct equivalence is when both cultures define the construct measured in the same way. One culture may view self-regulation as the ability to regulate oneself to achieve one's own goals for behavior (i.e., stopping from speaking before the teacher calls on you to achieve the goal of being a better student). Another culture, however, may view self-regulation as the ability to regulate oneself to be more aligned with the collective behaviors of a group (i.e., waiting to sit down at a table until there are enough chairs available for all of the people in the group). These differences in construct equivalence have implications for the validity of measures of self-regulation across cultures and may limit the utility of cross-cultural comparisons.

Second, measurement unit equivalence refers to the introduction of bias due to differences in administration protocols, in the characteristics of the children in each sample, or in the children's familiarity with the self-regulation tasks. For example, children may be more comfortable being tested in the hallway or on a computer in one culture than another and this difference may influence their self-regulation scores. Third, full score equivalence refers to item bias, usually resulting from linguistically accurate, yet not substantively accurate translation of measures. For the most part, self-regulation direct assessments are comprised of simple commands (i.e., "Touch your toes, touch your head"; Cameron Ponitz et al., 2008) and are less at risk for item bias than more complex parent or teacher questionnaire items that ask the caregiver to make a judgment of many behaviors over time (i.e. "When drawing or coloring in a book, shows strong concentration," Putnam & Rothbart, 2006).

Consulting experts from the culture being studied may help to achieve comparability across self-regulation measures (Van de Vijver et al., 2010). Ideally, researchers would then pilot the measures in the culture, using a mixed methods approach. This may include (a) observing children during the assessment and comparing their comfort level with the procedures, (b) conducting focus groups with caregivers in the culture about their understanding of the construct and how they view the measure's likelihood of accurately capturing it, and (c) comparing children's observed self-regulation in their natural context with their scores on the self-regulation task to examine rank order. These steps would occur before full-scale data collection occurs, but examining cross-cultural comparability after data collection starts using statistical analyses such as factor analysis and item response theory is also useful (Van de Vijver et al., 2010).

Influences on Self-Regulation Across Cultures

Trommsdorff and Cole (2011) write that culture may influence self-regulation through parents' and teachers' goals and expectations for young people, the practices that result from these goals, and ultimately the neural and behavior changes children experience (Kitayama & Uskul, 2011). Caregiver expectations and social norms transmit to children through relationships and experiences, and in turn, children internalize expectations that they should have associated levels of self-regulation (Tomasello, 1999). Specific experiences in early childhood that are rooted in these different cultural beliefs are potential processes through which culture influences children's early self-regulatory development. Moreover, as children develop self-regulation they look for culturally specific clues to guide and scaffold their actions. For example, as toddlers and young children spend more time in social environments, they gather information about how and when it is acceptable or beneficial to behave in particular ways. These behaviors are dictated by the cultural milieu in which children are raised. For instance, cultural emphases on independence and interdependence help shape children's goals and their use of self-regulatory behaviors (Trommsdorff, 2009).

Depending on the context, children may be expected to use self-regulatory skills to help align their behaviors with those of their peers, or, alternatively, to establish independence from their peers. For example, a child in Asia may learn that when her grandparents are visiting they expect her not to speak at the dinner table unless someone else initiates a conversation with her. In this case, the child will learn that when grandparents are visiting, dinner is a time for more inhibition in order to meet grandparents' expectations (Hsieh, 2004). This cultural difference was seen in a study comparing parents of young children in the United States and Japan. Parents in Japan encouraged children to show empathy and to meet others' expectation, but U.S. parents were more comfortable with children's willfulness and attention to their own personal needs (Kazui, 1997; Rothbaum & Weisz, 1989). Being raised in each of these cultures would require children to self-regulate at different times and to different degrees to match the cultural expectations.

As another example, when children move into formal schooling, expectations may change and the demand for children to regulate their behaviors may be greater than in preschool or childcare. Although a move to formal schooling around 5 years old is somewhat common across cultures, it is not universal. In Finland, for example, children's early learning environments do not become more formal until they are around 7 years old. This delay does not appear to hinder the development of children's self-regulation, possibly because Finnish cultural values and associated caregiver practices emphasize the importance of children's self-sufficiency before formal schooling begins (Ojala, 2000). In other words, cultural expectations, such as Finnish parents' strong belief in the importance of children's self-sufficiency, may be reflected in parenting practices that promote self-regulation before formal schooling. In contrast, parents from Hispanic cultures focus on compliance and are more likely to expect school environments to instill self-regulatory skills (Brooks-Gunn & Markman, 2005; Wasserman, Rauh, Brunelli, Garcia-Castro, & Necos, 1990). Compliance may look similar to self-regulation because children are controlling their behavior, but they are doing it to meet an adult's requirement rather than to meet their own understanding of what behaviors to enact or inhibit. A child with high compliance but low self-regulation, for example, may struggle to develop and follow rules during sociodramatic play, but would be able to follow a teacher's command to stay in line when walking with classmates in the hallway. These children, however, may experience greater increases in self-regulation after they enter formal school and are expected to develop these skills. In sum, cultural differences in children's self-regulation may reflect, in part, different cultural expectations and practices. These influences on children may occur at home and at school and have long-lasting impacts on children's outcomes.

There is broad variation in children's self-regulation within as well as between cultures (Eid & Diener, 2009; OECD, 2010a, 2010b; Rescorla et al., 2011; Winterhoff, 1997). One study examined means and standard deviations on the HTKS collected with 3- to 6-year-olds in the United States, Taiwan, South Korea, China, Germany, and Iceland (von Suchodoletz et al., 2013; Wanless, McClelland, Acock, et al., 2011). In general, the variation observed within cultures was substantively larger than between cultures. The variation in self-regulation scores in samples of children in South Korea and Germany, for example, was much larger than the variation between the two cultures. These samples both had a mean age of 5 years, and showed substantial variability in self-regulation despite assumed differences in each sample's cultural beliefs and practices. Although greater variation within cultures than between cultures is not evident in all cross-cultural research (Keller et al., 2004; Lan et al., 2011), this comparison draws attention to the fact that average cultural differences provide only one perspective, and should be interpreted in combination with additional information about variability.

Increasing the Focus on Person ←→ Context Relations

Cross-cultural research makes it clear that differing contexts have an impact on different levels of self-regulation and different rates of growth in self-regulation. Research in this area, however, is still developing. Three areas of research have emerged to inform the thinking about the dynamic relations between contextual factors and children's self-regulation. First, cross-cultural research has aptly taken advantage of natural variations in contexts across cultures to examine cultural-specific influences on self-regulation. This work currently centers on establishing the psychometric properties of self-regulation measures in different cultures, but future work may consider how differences in cultural beliefs and practices may support or hinder self-regulatory development. For example, socialization practices that encourage Chinese children to focus on the collective needs of the group may offer many opportunities for these children to practice regulating their own needs to align with the state of their peers. Evidence from studies that only measure the child's country of residence, however, and not the extent to which their context reflects collectivist practices, for example, are limited for informing practice. Ideally, cross-cultural research may uncover specific processess supporting self-regulation that may be adapted and incorporated into self-regulation interventions.

Second, research on children experiencing varying levels of sociodemographic risk, including toxic stress, also examines natural variation in contextual factors. Not only does this work highlight the ways that challenging circumstances can affect on self-regulation, it also uncovers the role of self-regulation as a protective factor. Specifically, self-regulation can universally support children's social and academic development regardless of the risk factors children are experiencing (McClelland & Wanless, 2012; Obradović, 2010; Sektnan et al., 2010). Together, studies of self-regulation and risk factors advance the understanding of person ←→ context relations and suggest that children in certain contexts should be the first in line to access self-regulation interventions. Finally, limited research has examined the variability of children's observed self-regulation as they encounter varying contexts throughout the day. Preliminary work in this area suggests that although children may have a core level of self-regulation skills, the ways that those skills manifest across situations is highly dependent on contextual factors such as the presence of certain activity-types, routines, materials, adults, and peers (Booren, Downer, & Vitiello, 2012; Pellegrini, 1984; Vitiello, Booren, Downer, & Williford, 2012). All three research foci provide different angles by which to examine person ←→ context relations and learn how to apply these findings to intervention efforts to support self-regulation development. Most studies in these areas, however, offer crude measures of the environment such as using country as a proxy for culture, or attendance at Head Start as a proxy for low-income status. Future research would benefit from a more fine-tuned assessment of contextual factors.

STUDYING SELF-REGULATION FROM THE PERSPECTIVE OF RDS

Yogi Berra said, "In theory, there is no difference between theory and practice. But in practice, there is." Thus, arming self-regulation researchers with RDS-informed hypotheses is only half the battle when conducting research framed by the RDS perspective. Although this perspective is an important way forward for self-regulation research, it can also be challenging to translate theory into practice.

Implications of RDS for Analyzing Self-Regulation

Understanding development, especially the development of self-regulation, as it occurs in a transactional, multilevel, dynamic, and relationally integrated person ←→ context system requires equally complex analytic tools that are capable of detecting phenomena at both the macroscopic and microscopic levels. To date, "the relational developmental systems approach has lacked [such] a toolbox of nonlinear analytic methods and, as a consequence, has often been in the unfortunate position of attempting to express nonadditivity effects in an additive context," (Overton, 2011, p. 260). In the following sections, a few key implications of the RDS perspective for measuring self-regulation as it develops across the life span are highlighted (see also Geldhof et al., 2014, for a parallel discussion of measurement issues related to RDS in general).

Incorporating an Idiographic Perspective

Since Allport (1955) popularized Windelband's terms *idiographic* and *nomothetic* in psychology (see Holt, 1962; Marceil, 1977, for reviews), researchers and theorists have debated whether the province of psychology is to study common (i.e., nomothetic) characteristics shared by all people or the idiosyncratic (i.e., idiographic) characteristics that make each person unique. As Holt (1962) commented more than 50 years ago, the idiographic versus nomothetic debate is, "[o]ne of the hardiest perennial weeds in psychology's conceptual garden," (p. 376) and indeed it remains a source of considerable discussion (e.g., Lamiell, 2009).

Although a majority of existing self-regulation research has emphasized cross-person (i.e., cross sectional, between group, interindividual variation), nomothetic relations and developmental trajectories, contemporary "developmental science [and RDS as a part of this science] seeks to describe, explain, and optimize intraindividual changes and interindividual differences in intraindividual changes across the life span" (Lerner & Benson, 2013, p. 2). As a consequence, intentional self-regulation can be defined as an idiographic (intraindividual) process. Self-regulation involves specific persons coacting with their contexts in ways that bring about their personally desired states (i.e., goals). This suggests that as the child develops, his or her self-regulated actions become increasingly deliberate and fashioned in ways that align unique personal strengths with resources in their equally unique contexts. Self-regulation may, therefore, be optimally studied in highly nuanced ways. In addition, there is no guarantee that phenomena observed at the population (or sample) level necessarily hold for any specific person.

As Molenaar (e.g., 2004) notes, the asymptotic equivalence of inter- and intraindividual observations, known as the assumption of ergodicity, does not hold for most psychological processes (see Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume). Put more simply, ergodicity as a theoretical assumption posits that individuals are assumed to look like the group. In reality, however, the individual may not mirror the group. Statistical conclusions based on the average findings from a sample of individuals may not be directly relevant for any given person in the sample; similarly, the trajectory of development for a single person may be wholly distinct from the patterns observed using group-level data. Because self-regulated actions are highly idiographic, the implications of nonergodicity may be especially important to interpreting research on self-regulation.

The presence of nonergodicity does not mean nomothetic research on self-regulation is without merit. Every field needs a starting place. Group-level observations likely reflect person-level phenomena to some degree, and a fusion of idiographic and nomothetic observations (e.g., Molenaar & Nesselroade, 2012, Chapter 17, this *Handbook,* this volume; Nesselroade & Molenaar, 2010) will help researchers tease apart inter- and intraindividual processes. A fuller understanding of person- and group-level development can then be applied cohesively to maximize the effectiveness of developmental interventions and youth development programs.

Mixed-Methods Triangulation

The precise nature of self-regulation as defined by the RDS perspective will never fully be appreciated if it relies only on quantitative methods. Instead, the complexity implied by an RDS framework demands that researchers more thoroughly integrate their quantitative findings with qualitative research that describes development from the perspectives of the developing individuals and important figures in their lives like teachers, parents, and peers. Researchers must "attempt to map out, or explain more fully, the richness and complexity of human behavior by studying it from more than one standpoint" (Cohen & Manion, 2000, p. 254).

Fusing the understanding of inter- and intraindividual phenomena will require that researchers supplement their nomothetically derived research. Idiographic and semi-idiographic methods describe the experiences of individuals with single-subject designs or designs that deliberately emphasize classes of relatively homogenous participants. In other words, researchers must merge existing methods, which have arisen within disciplines and are often based on convenience samples, with methods similar to what Magnusson (1999) has called the *person-oriented perspective* (see von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume, for an extensive discussion of person-oriented techniques). Adopting a more person-oriented perspective will also help align empirical examinations of self-regulation with RDS, by both explicitly acknowledging the specificity and nuance of self-regulated actions and by treating the active agent or person as a holistic gestalt (see Lerner, 1982).

In some ways this is similar to the age-old debate that pits quantitative against qualitative approaches and at the same time transcends the debate. A mixed methods movement has gained momentum and is characterized by research teams with diverse backgrounds (Huston et al., 2005; Lowe, Weisner, Geis, & Huston, 2005, see also Tolan & Deutsch, Chapter 19, this *Handbook*, this volume). The goal of mixed methods work is to incorporate diverse perspectives to better understand general trends as well as the specific stories of development (Weisner, 2005). Mixed methods are needed to address why interventions that target self-regulation do not benefit all children in all contexts. For example, treatment effects for the New Hope project—which offered randomly assigned working families living in poverty a range of benefits such as earnings supplements, health insurance, and health care—quantitatively showed a stronger relation of boys' scholastic and behavioral outcomes than girls' outcomes (Huston et al., 2005). Using inductive analyses (here, ethnographic interviews) to understand the lack of statistical effects for girls, Gibson and Weisner (2002) learned that families may have allocated more resources to boys to prevent delinquent behavior. As this example demonstrates, qualitative research can be particularly useful for bring unexpected processess to light. This set of complex findings, where puzzling quantitative results are illuminated by focused qualitative work, warrants further person-oriented investigations of the development of self-regulatory strengths and deficits.

Truly idiographic designs require in-depth analysis of individual subjects, especially to determine which self-regulatory strengths each person displays and how people intentionally align these strengths with characteristics of their contexts. Any interindividual differences in these intraindividual processes will necessarily indicate nonergodicity and suggest areas where nomothetic theories require greater nuance and refinement. Idiographic findings can also be aggregated in ways that filter out idiographic specificity (e.g., Molenaar & Nesselroade, 2012; Nesselroade, Gerstorf, Hardy, & Ram, 2007), allowing for some nomothetic generalizations despite intraindividual variability.

Semi-idiographic (also known as person-oriented) methods will also allow self-regulation researchers to explore the differences and similarities of self-regulated action across different "types" of people. These methods may make use of cluster analysis (e.g., Bergman, Magnusson, & El-Khouri, 2003) and latent class analyses (e.g., Collins, 2001), for example, and are especially likely to be informed by exploratory methods such as qualitative interviews and focus groups. From the perspective of RDS, clusters uncovered by semi-idiographic methods represent heuristically defined groups of people who display similar strengths and weaknesses and exist in relatively similar contexts. The relative homogeneity of such groups increases the probability that violations of the ergodicity assumption will be trivial. Understanding processes at the level of such groups will facilitate the generalizability of group-level findings to individual group members, while potentially informing universal principles of how people intentionally regulate their own development.

The probability that these idiographic and semi-idiographic methods will reveal important interindividual differences suggests that researchers might increasingly begin to define self-regulation as a multidimensional, contextually dependent concept rather than as a unidimensional construct. The existence of different types of people with heterogeneous self-regulatory styles, strengths, and weaknesses makes it inappropriate to compare individuals on a unidimensional continuum of "better" versus "worse" self-regulation. Self-regulation instead emerges as an adaptive coaction between an individual and his or her specific context. It is, however, possible to argue that a group or individual displays deficits in specific components of regulation compared to other individuals, and that such deficits impair adaptive coactions with their contexts. Through idiographic and semi-idiographic analyses, discussion focuses on how people with various constellations of self-regulatory strengths and deficits experience different developmental regulations when set in different contexts.

Coupling nomothetic and idiographic information about self-regulation thus allows a closer coupling between RDS-derived theory and practice. For example, group-level data can provide information about the conditions that affect average performance on a self-regulation task. These group-level analyses can then be supplemented with single-subject interviews, which may help researchers understand which subsets of self-regulatory strategies individual participants implemented, and which factors promote the development of these strategies under which conditions. As one example, Kidd, Palmeri, and Aslin (in press), found that when children trusted the adult giving the instructions, they could wait on average 12 minutes in the marshmallow task, compared with children in a condition where the examiner first promised them a gift (crayons) that was not given. The children who had been disappointed by the examiner could wait only 3 minutes on average, which researchers attributed to a lack of trust in the adult responsible for giving them their marshmallow.

Analyzing Discrete Constructs Holistically

Regardless of whether researchers take nomothetic or idiographic methodological approaches to their work on self-regulation, many available statistical tools are overly simplistic. The most common models of developmental phenomena can be considered models of additively concatenated intervariable relations. Such models treat the developmental phenomena that were reviewed earlier in the chapter, (e.g., attention shifting and working memory) as separable components whose contributions to an outcome, such as classroom behavior, can be added together as one would add discrete quantities. One reflection of this assumption is the prevalence of hierarchical regression, which pits one or more predictors against each other in explaining variance in a measured outcome. Investigators may allow these components to interact by calculating an interaction term, but even such models tend to follow a linear function. Nonlinear terms, such as quadratic terms, are rarely considered, and nonlinear equations (e.g., the Gompertz function) are considered even less frequently, despite the fact that such relations likely exist (Grimm, Ram, & Hamagami, 2011; Ram & Grimm, Chapter 20, this *Handbook,* this volume). For example, poor self-regulation skills may lead a person to experience anxiety, but one might argue that overly high levels of self-regulation can lead to anxiety as well (Eisenberg & Fabes, 1992). Disrupting an overly internalized behavioral routine can cause dissonance, for example. As such, the relation between aspects of self-regulation and reports of anxiety may take the common inverse U-shape of a quadratic relationship.

Additive methods do not align with the holistic approach put forth by RDS, and developmental researchers must consider both benefits and drawbacks when implementing these techniques. Factor analysis, for example, can serve as a versatile tool, which allows researchers to aggregate directly assessed components or observer-reported indices of self-regulation into distinct latent factors. These factors may accurately and parsimoniously reflect the constructs that underlie the analyzed indicators and allow for more accurate tests of interconstruct relations. The underlying assumption that data can be linearly decomposed into discrete factors is atomistic, however, and can only serve as a first step in understanding self-regulation from the RDS perspective. By aggregating empirical data into distinct bins (i.e., factors), factor analysis necessarily attempts to “carve nature at its joints.” This kind of heuristic atomism is necessary as a first step in understanding self-regulation, but it can only take researchers so far. As Overton (2010) notes, relational scientists must treat such categories as “groundings, not bedrocks of certainty,” (p. 13; see also Overton, Chapter 2, this *Handbook*, this volume).

Mediation and moderation models also allow researchers to model their data as representing a relationally interconnected person-context system. Investigators who implement such models can even move beyond simple mediation and moderation effects to include complex combinations of each. For example, moderated mediation models allow researchers to investigate conditional indirect effects (Preacher, Rucker, & Hayes, 2007). Mediated moderation models likewise allow researchers to examine the processes through which interaction effects may occur (Baron & Kenny, 1986; Little, Card, Bovaird, Preacher, & Crandall, 2007).

Especially when framed in a multilevel framework, such models allow investigators to explicitly consider how the components of self-regulation dynamically coact in leading to specific behavioral outcomes (e.g., Preacher, Zhang, & Zyphur, 2011; Raudenbush & Bryk, 2002). Understanding these outcomes help us understand the implications of various self-regulatory strengths and weaknesses for person-context fit, and accordingly for positive development.

Nonlinear Development

Relative plasticity in the relational person-context system implies that developmental trajectories are mutable and can be changed by multiple moderating influences. As such, acknowledging plasticity implies the need for investigators to implement longitudinal designs and analyses that explicitly account for nonlinearity to uncover meaningful information about the developmental implications of any complex phenomenon. Although methods for analyzing such nonlinearity have not fully penetrated the social sciences (and indeed many are still in their infancy), researchers who study self-regulation are not without options (see Molenaar & Newell, 2010; Ram & Grimm, Chapter 20, this *Handbook*, this volume; Witherington, Chapter 3, this *Handbook*, this volume, for extended discussions of nonlinear models). For example, the now-common growth curve model allows researchers to efficiently model development. While traditional growth curves specify linear change over time, quadratic, cubic, and even higher-order time effects can also be easily modeled. Furthermore, translating the standard multilevel growth curve into a structural equation modeling framework (i.e., latent growth curve models, see Bollen & Curran, 2006) allows researchers to test empirical hypotheses about the shape of a construct's developmental trajectory, as well as to examine relations among developmental trajectories and other variables. Such models specify growth parameters as latent constructs, which allows researchers to simultaneously model multiple growth trajectories, examine the correlations among these trajectories, and determine which person-level variables predict interindividual differences in these trajectories.

The common growth curve model is widely generalizable, but one distinct limitation is that it assumes development can be modeled as a linear function. That is, all parameters in the standard growth curve model (e.g., $b1$, $b2$) must be combined additively. Aspects of self-regulation do not likely develop in such a linear way, and alternative growth models may be more appropriate for examining the development and developmental implications of different aspects of self-regulated action. Complex coactive relations among the parts of larger relational person ←→ context systems can also be analyzed using methods borrowed from systems science and dynamic systems theorists (see Witherington, Chapter 3, this *Handbook*, this volume). For example, the simulation-based methods of systems science allow users to simultaneously model a high number of multidirectional processes in ways that promote theory development, exploration, and synthesis (Urban, Osgood, & Mabry, 2011). These tools can be used to forecast the effects of various public policies, allowing researchers to more directly translate their theories into practice.

Self-regulation researchers can also draw on concepts and methods derived from dynamic systems theories. As discussed above, self-regulation is not a blanket trait that individuals bring equally to every situation. Self-regulation instead emerges as the real-time interaction between attributes of unique individuals and their dynamically changing contexts. Methods designed from the perspective of dynamic systems theories explicitly account for the real-time nature of such phenomena and allow for a more nuanced approach to action within the relational developmental system. Granic (2005; see also Witherington, Chapter 3, this *Handbook*, this volume) discusses various methods that allow researchers to derive and test hypotheses directly related to dynamic systems concepts, including attractor states, behavioral resilience to perturbations, and phase transitions. Plotting real-time data using state-space grids (Hollenstein, 2007) and analyzing the variability of actions are among some of these methods that may be especially relevant to self-regulation research.

With regard to the study of self-regulation, there are also practical implications to consider. First, longitudinal models require multiple time points, with more being ideal, though they can accommodate some degree of missing data. So far, complex nonlinear models have been used with success on vertically equated achievement tests, but more dynamic and complex skills such as self-regulation may pose a steeper measurement challenge (Grimm et al., 2011). Namely, there are few self-regulation measures that can be vertically equated (Zelazo et al., 2013). A computerized measure that can be administered from 2 years to adulthood would be an ideal measure with which to apply nonlinear models. Progress is being made in this arena, however, and advances with the NIH Toolbox initiative have resulted in a series of cognitive measures (including measures of EF) that can be administered between Ages 3 and 85. Research demonstrates that the cognitive measures have strong psychometric properties, with evidence of increasing differentiation in cognitive abilities between Ages 3 and 15 (Zelazo et al., 2013). Future researchers may be able to utilize these measures in nonlinear models.

Second, multiple time points are more costly to collect. Third, these models require an advanced degree of expertise. Like most sophisticated analytic techniques, there is likely to be a lag between when they are developed and refined and when the average psychology or education department has resources to either train or hire someone with this knowledge. Fourth, the momentum of a field led by seasoned scholars who often rely on two time points and multivariate regressions (including the authors of this chapter!) must shift to incorporate new analytic techniques, when appropriate.

Time as a Proxy for Development

Developmental researchers widely understand that change occurs over time, and that modeling complex, plastic developmental trajectories requires longitudinal data and analyses. Longitudinal data are only as good as the forethought put into longitudinal study design, however. On top of collecting data longitudinally, researchers must explicitly account for the many ways that "time" can manifest in a relational developmental system. As noted by several authors (e.g., Lerner, Schwartz, & Phelps, 2009; Little, Card, Preacher, & McConnell, 2009; Wohlwill, 1973), "time" can mean many different things in relation to many different phenomena. Further, each of these phenomena can evolve on a different time scale. Developmental change in some phenomena can be measured in terms of years, whereas other developmental phenomena can only be adequately captured at the scale of weeks or days. The effects of time also manifests in historical factors (e.g., the Great Depression) and episodic factors (e.g., September 11, 2001), and the same amount of chronological time can mean different things to different children (e.g., the onset of puberty varies across individuals). The RDS perspective acknowledges all of the above conceptualizations of time as co-occurring, and developmental researchers must pay close attention to how they conceptualize, measure, and analyze development as a function of time.

Acknowledging multiple metrics of time may be especially important for self-regulation researchers, given that self-regulated actions themselves occur over the span of seconds, whereas the long-term consequences of control by the active agent might be best analyzed over the course of several years. Young children's behavior on a real-time measure of self-regulation can predict developmental outcomes in adolescence and adulthood, for example (e.g., Ayduk et al., 2000; Mischel, Shoda, & Peake, 1988). Researchers must accordingly measure and analyze time in a metric that is meaningful to the phenomenon of interest and at a rate that allows for the accurate representation of that phenomenon's development. The importance of this consideration stands in stark contrast to the all-too-often annual data collection schedule followed by large longitudinal investigations, which reflects financial and personnel constraints. The next section discusses how integrative methodological approaches, which connect large-scale longitudinal and cross-sectional work to literature reviews to experimental designs, can be combined systematically to accomplish more than a single study can on its own.

Some research on the development of self-regulation is beginning to tackle these methodological challenges, illuminating the importance of assessing not only self-regulation levels, but also the pathway of self-regulation development (Kochanska et al., 2001; Kochanska, Murray, & Harlan, 2000; Li-Grining, 2007; McClelland et al., 2007). For example, a study by Wanless, Kim, Zhang, and Degol (2013), found two distinct self-regulation trajectories in a sample of almost 200 young Taiwanese children between 43 and 72 months of age. Although the two trajectories reflected similar behavioral regulation scores at the beginning and end, their pathways were strikingly different. These trajectories were related to children's vocabulary skills in kindergarten, with children who developed strong self-regulation skills early having the greatest vocabulary benefits (Wanless, Kim, et al., 2013). This research reflects efforts to study development over time, and moves the field toward understanding the complex emergence of these skills.

FUTURE DIRECTIONS FOR RESEARCH IN SELF-REGULATION

Future efforts to support children's adaptive self-regulation development must consider strategies that capture adequate variability in measured phenomena and account for child-environment interdependencies. The following section discusses how researchers can increase the focus on person ←→ context relations, and intervention efforts that have been shown to be effective in improving self-regulation in children. Finally, several strategies for integrating methods in the study of self-regulation are presented, including those that represent within-study techniques and between-study (or between-discipline) approaches. These all have costs and must be weighed against overall study aims. But up-front investment in planning activities, such as a systematic review of possible measures and pilot tests in the sample to be studied, can also save time and frustration later.

Studying Self-Regulation in Context

As noted earlier, context permeates the study of self-regulation and it is evident that a child's self-regulation depends on the context in which it is measured. In line with RDS and closely related perspectives such as dialectical theory (Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume; Sameroff, 2010), a person's self-regulation depends on dynamic coactions between his or her own characteristics and the nature of the environment. Myriad statistical interaction results provide examples of the codetermination of children's regulatory outcomes. For example, infants with depressed mothers tend to show poorly regulated attention and perform worse on cognitive measures (Murray, 1992). In contrast, young children whose families encourage them to ask questions and challenge authority tend to be more inquisitive and less controlled (Wachs et al., 2004). Further, the level of engagement and attention that observers report in young children's behavior depends on whether the children are interacting with teachers, peers, or tasks (Booren et al., 2012).

Another set of interaction findings highlights how similar environments can co-act with child characteristics. For example, one study found that urban first graders (i.e., 6- and 7-year-olds) with low self-regulation benefited more than children with strong self-regulation when their teachers spent more time planning small-group instruction and when their classrooms spent less time in transition (Connor et al., 2010). In another study, first grade boys in a rural setting made greater gains in mathematics when their classrooms were better organized, which is thought to support self-regulation (Cameron Ponitz, Rimm-Kaufman, Brock, & Nathanson, 2009). Together, these studies demonstrate that the regulatory behaviors and learning that children achieve depend in part on what is happening around them, and on characteristics of children themselves.

Improving Intervention Efforts

As demonstrated throughout this chapter, mounting evidence suggests that children's self-regulation is malleable and undergoes significant development during infancy, childhood, and adolescence (Diamond & Lee, 2011). Thus, efforts have focused on interventions to strengthen self-regulation in children, and on identifying the key processess underlying these interventions' effectiveness.

For example, a number of studies have supported the efficacy of the Preschool Promoting Alternative Thinking Strategies (PATHS) social-emotional intervention for strengthening emotional regulation and social competence in young children, where intervention participation was related to significant improvements in socio-emotional competence and self-regulation skills (Bierman et al., 2008; Domitrovich, Cortes, & Greenberg, 2007). Moderated effects were also found where intervention-group children with low self-regulation scores at the start of the year demonstrated greater improvement in social competence, lower aggression ratings, and stronger print knowledge than children in the control group who also had low self-regulation scores at the beginning of the year. In contrast, no significant intervention effects were found for social competence, aggression, or print knowledge for children with higher self-regulation at the start of the year. Bierman et al. (2008) identified pathways of influence where improvements in teacher-rated task orientation partially mediated intervention effects on emergent literacy and social-emotional skills.

Other research on a classroom-based self-regulation and social competence intervention called the Kids in Transition to School Program (KITS), suggests that the intervention was related to improvements in observer-reported social competence and emotion regulation (Pears, Fisher, Heywood, & Bronz, 2007). Interventions focusing on improving specific aspects of self-regulation through classroom games have also demonstrated some impacts. For example, one intervention with young children focused on the behavioral aspects of self-regulation, utilizing games designed to help children practice paying attention, remember instructions, and demonstrate self-control (Tominey & McClelland, 2011). Participation in the intervention was related to stronger self-regulation for children who started the year low in these skills. In addition, the intervention led to gains in emergent literacy skills over the school year for children in the intervention group compared to children in the control group. In a related study utilizing a larger sample of low-income children 3 to 5 years old, Schmitt, McClelland, Tominey, and Acock (in press) found that children in the intervention group demonstrated gains in two direct measures of self-regulation. Indirect effects were also found for children's spring achievement through their self-regulation scores. Finally, English-language learners who participated in the intervention showed greater gains in math compared to children in the control group, and to English speakers in the intervention.

Other research has focused on professional development for teachers in classroom interventions. The Chicago School Readiness Project (CSRP) is a comprehensive intervention aimed at improving self-regulation and socio-emotional skills in the prekindergarten year by helping teachers improve classroom management, deal with children's difficult behavior, and reduce their own stress (Raver et al., 2011). Children who participated in the intervention showed improvements in self-regulation and academic achievement relative to the control group. Ursache et al. (2012) posit that such interventions minimize stressful and negative events within the classroom, which diminish the demands on children's emerging self-regulation and enable them to show more long-term adaptive behaviors.

There is also some evidence that participating in computer-based interventions may improve aspects of self-regulation. For example, one study found that children who received computer-based attention training demonstrated greater gains in executive attention and intelligence scores as compared to control children (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005). Another study targeted either working memory or inhibitory control in young children (Thorell, Lindqvist, Bergman Nutley, Bohlin, & Klingberg, 2009). Children in the working memory intervention group demonstrated improvements in working memory and attention compared to those in a control group. Children who were trained on inhibitory control also showed improvement in inhibitory control, but no transfer effects to working memory or attention tasks (Thorell et al., 2009). Although these results are somewhat encouraging, there has been less evidence of transfer or generalization of intervention effects to behavior or indicators such as academic achievement (Diamond & Lee, 2011; Melby-Lervåg & Hulme, 2013).

Partly because of these issues, work has focused on identifying the key components of effective interventions for improving children's self-regulation. In general, research has demonstrated that activities that help children practice skills like stopping, thinking, and *then* acting, help children develop self-regulation (Bodrova & Leong, 2006; Diamond & Lee, 2011; Tominey & McClelland, 2011). A review by Diamond and Lee (2011) found that effective interventions included activities and tasks that constantly challenged self-regulatory skills and increased in complexity. There is also some evidence that computer-based interventions and physically active interventions (such as martial arts) may be more effective for older children compared to younger children (Diamond & Lee, 2011). Another key component may be increasing children's ability to reflect on their thoughts, which has also been called mindfulness. Research has suggested that mindfulness training, which helps children reflect on experiences in the moment, may help facilitate self-regulation (Zelazo & Lyons, 2012). Specifically, mindfulness training may strengthen the cognitive (top-down) aspects of self-regulation while also decreasing negative emotional (bottom-up) aspects of self-regulation such as anxiety or stress (Zelazo & Lyons, 2012). Finally, an intervention that emphasized copying designs with creative materials in an after-school setting had positive effects on kindergarteners and first graders' executive function, visuospatial skills, classroom behavior, and first grade mathematics achievement (Grissmer et al., 2014).

Taken together, intervention research supports the malleability of self-regulation in childhood and provides accumulating evidence to suggest that these interventions are effective at improving self-regulation, especially in young children. More work is needed, however, on the long-term effects of such interventions. It is also unclear if interventions have varying effects for different groups of children and under which conditions these interventions are most effective. Future research needs to continue to probe these questions and examine complex mediated and moderated relations, consistent with the RDS view of development.

Improving Methodology

Moving the field of self-regulation forward requires that researchers integrate innovative within-study techniques with between-study (or between-discipline) approaches. Within-study approaches include broadening the ways that self-regulation is measured over time and across levels of analysis. Between-study (or between-discipline) approaches include identifying commonalities in findings across studies and disciplines that can pave the way for new questions to be raised and answered.

Within-Study Approaches

Within a single research study, strategies for improving methodology include (a) increasing measurement occasions or measuring the same skill more than once (Adolph & Berger, 2006); (b) diversifying measurement types or using multiple measures of a construct (Duckworth & Kern, 2011; Willoughby et al., 2012); (c) systematically measuring the component processes of interest in an effort to link theory and practice (Korkman, 1999); and (d) covering multiple units of analysis such as children, families, and classrooms to capture all the important elements that likely contribute to children's self-regulation (Blair & Raver, 2012a; McClelland et al., 2010).

First, increasing measurement occasions can help address the finding that the number of times a phenomenon is measured seems to affect its course of development (Adolph & Berger, 2006). This is especially relevant for EF, which, by definition, involves assessing a person's reaction to a novel set of demands.

Second, diversifying measurement types addresses the question of whether the same findings would have emerged if a different measure had been used (Duckworth & Kern, 2011; Willoughby et al., 2012). This is especially relevant for the study of self-regulation and EF given the huge variation in response modalities (e.g., fine motor movements such as pointing and mouse-clicking, gross motor movements such as touching one's head, oral responses, or observed classroom behavior).

A third strategy to improve methodology is to systematically measure the component processes of interest (Korkman, 1999). This strategy is sometimes referred as the component process approach and has been used most commonly in neurological work to link behavioral measures with underlying neural networks (Machamer, Darden, & Craver, 2000). The advantage of this approach is that it systematically identifies the individual components of behavioral measures along with their higher-order phenomena. It helps to address the "third variable problem" of processess and can be used to link specific measures to specific outcomes or to eliminate other measures that may appear to be contributing to an outcome but are actually linked because of some other process.

Finally, covering multiple units of analysis within studies is also critical (Blair & Raver, 2012a; McClelland et al., 2010). This is because acknowledging environmental contributions to self-regulation must be accompanied by methodological investments that include measurement across contexts such as talking to teachers and parents, observing classrooms, and examining out-of-school contexts. In addition, a literature that establishes the emotional and regulatory impacts on caregivers from dealing with many children who struggle with self-regulation has yet to be fully incorporated (Jennings & Greenberg, 2009).

Between-Study Approaches

A second set of strategies involves looking beyond individual research programs to identify key areas of convergence in findings and identify new research questions. Between-study approaches attempt to draw connections across disparate disciplines. They focus less on improving measurement at a microlevel and more on identifying big-picture points of convergence and divergence. These strategies may not be as intuitive to the current and historical scholarly paradigms that tend to assume a single lead researcher or small research team with training in the same area. Yet such between-study or between-discipline approaches may reveal commonalities that were previously unnoticed, provide ground for developing new theory or increasing precision of current theory, and point to new, untested hypotheses.

One such strategy is a systematic literature review across disciplines. For instance, the research reviewed in this chapter draws from studies of self-regulation across diverse disciplines, including psychology and its codisciplines, sociology, economics, public policy, and medicine (including psychiatry and occupational therapy). Keeping up with these diverse literatures can be time-consuming, and integrating findings from all these perspectives may be overwhelming for any single scholar. But a systematic literature review by a team can reveal connections, areas of overlap, and gaps.

Meta-analysis of a measure or construct is likely the most common between-study approach to convergence and involves analyzing the effect sizes from studies using the same set of constructs as a dependent variable. Meta-analyses of self-regulation or related skills have confirmed its importance for adaptive development (Duckworth & Kern, 2011). Meta-analysis of self-regulation may be somewhat impeded by the diversity of measures that differ in quantitative as well as qualitative ways across development. But after 20 years of research examining self-regulation and executive function, the field is ripe for more studies that tell us which measures of self-regulation predict which outcomes at which points in infancy, childhood, and adolescence.

Another strategy is to examine multiple data sets that contain similar measures. Such examination can lead to convergence, point to new research questions, and inform a program of research. It can be illuminating to start with a large longitudinal data set and then move to smaller-scale correlational and intervention studies to test hypotheses. For example, Duncan and colleagues (2007) found that early math achievement and attention, a teacher-report proxy for classroom self-regulation, was more important for later achievement than early reading achievement and social skills. Follow-up studies including Grissmer et al. (2010) and Murrah (2010) added two new constructs, fine motor skills and general knowledge, which were surprisingly strong predictors of later achievement as well. A subsequent study used a smaller convenience sample to confirm that both fine motor skills, particularly design copying items, were the most important contributors to achievement in addition to self-regulation (Cameron, Brock, et al., 2012).

The approaches described above can be realized more easily when scholars from different fields are involved on the same research team or who participate in an advisory capacity, such as on a board that meets annually to review the progress of a project. Regular conversation with scholars and practitioners who have different training, viewpoints, and experiences can open up new research questions and shed light on issues that may otherwise go unnoticed. Scholars who are steeped in data may also want to talk regularly with teachers and clinicians who work with children. A psychologist with clinical training, for example, may be able to easily describe why a child has difficulty with an aspect of an assessment.

CONCLUSIONS

Self-regulation has an impact on numerous developmental outcomes throughout the life span. Relational-Developmental-Systems (RDS) provides an important and useful lens through which to view the development of self-regulation, (Lerner, 2006; Overton, 2006), and this chapter discussed key implications that taking such a relational metatheory has for the study of self-regulation.

From the perspective of RDS and, as well, theories that fall within a relational framework (e.g., dialectical theory, Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume; Sameroff, 2010; dynamic systems theory, Witherington, Chapter 3, this *Handbook*, this volume), the term "self-regulation" may be an oversimplification. Individuals constantly regulate their behavior in reaction to, and with support from, the opportunities and constraints afforded by their environments (Sameroff, 2010). Optimal self-regulation therefore requires orchestrating a diverse set of self-regulatory skills and abilities. Thus, similar to the conceptual shift away from deficit models, which describe where children are lacking in comparison to other children, is an acknowledgment that people develop the most adaptive regulatory strategies for a given context. In other words, it is not as accurate to say a child "has" or "lacks" self-regulation, but to instead to describe the nature of his or her self-regulatory behaviors and the conditions under which he or she self-regulates in ways that optimize development.

Inherent in a relational understanding of self-regulation are decisions about the measures and methodology that are used to study these skills. As such, this chapter also highlighted methodological considerations and advances that are vital to considering the complex processess at play in the development of self-regulation during childhood and adolescence. Of these considerations, the relational interdependence of children's regulatory behaviors and environmental factors is especially important to consider. The chapter also emphasized several ways researchers can continue to explore the context-dependent nature of self-regulation during childhood and adolescence.

Contextual supports are particularly important early in development, when children's survival and states of arousal are determined by whether their caregivers provide food, warmth, and attuned emotional coactions. Moreover, as children enter daycare, preschool, and formal school settings, nonfamilial adults, peers, and learning materials all become part of the regulatory context. For researchers to study self-regulation adequately in all its contexts, it may be helpful to begin by considering the forest for the trees and then decide what to study and when. Studying children across cultures, sociodemographic backgrounds, and instructional settings, for example, may provide researchers with particularly rich examples of person ←→ context relations. Such a nuanced understanding of the development of self-regulation is useful for developing scientifically valid interventions and, as described, may inform youth interventions. A number of interventions have shown promise, especially in the short-term, but more work remains. The field of self-regulation is ripe for creative and interdisciplinary research that incorporates multiple measures, methods, and perspectives to understand how self-regulation unfolds throughout the life span.

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CHAPTER 15

Developmental Psychopathology

E. MARK CUMMINGS and KRISTIN VALENTINO

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Developmental psychopathology (DP) has as a primary goal integrating concepts of developmental science and psychopathology into a coherent approach to explanatory models for both normal and psychopathological development, with strong implications for approaches to prevention and intervention as well as nosology and treatment (Cicchetti, 2006; Cicchetti & Cohen, 1995). However, any simple definition of DP as an approach is inevitably elusive, largely because of the ambitiousness and scope of this direction. For heuristic reasons toward increasing its value for scientific explanation and clinical treatment, DP aspires to be broadly integrative across multiple areas of psychology and related disciplines relevant to child psychopathology and developmental science, acknowledging overlapping themes with other important traditions concerned with child development and child psychopathology (Cummings, Davies, & Campbell, 2000). For example, DP models for normal development and the development of psychopathology are consistent with a relational developmental systems perspective (Overton, 2010a, 2013), which emphasizes plasticity, and the moderating influence of time and space, toward explaining pathways of development. Thus, Cicchetti (2006) has stated: "Risk factors and protective factors have been established at multiple levels of analysis and in multiple domains. . . . Contributions to the field of developmental psychopathology have come from many areas of the social and biological sciences" (p. 7). The resulting models for developmental science and clinical research and practice are (appropriately) sophisticated and complex, and (appropriately) are becoming more so as progress is made.

WHAT IS DEVELOPMENTAL PSYCHOPATHOLOGY?

In terms of the organization of this chapter, the remainder of this section is concerned with further defining DP, including the attention called to the vital importance of infusing development into the study of psychopathology and its diagnosis and treatment, the major theoretical assumptions of the approach to research and mental health diagnosis and treatment, and DP in comparison to other emerging disciplines also concerned with developmental process. Next, an updated review and extensive analysis of the key conceptual elements of DP is advanced, including directions that are still emerging topics of debate, controversy, and conceptual development. Third, the radical, at least in terms of current approaches to these matters (e.g., *DSM-5*), implications of DP for treatment and diagnosis of mental health problems are considered in depth. Fourth, the impact of selected contexts of development is analyzed from a DP perspective, illustrating how substantial advances in the sophistication of process-oriented research that may be furthered by this approach. Finally, new directions and emerging themes arising from this rapidly advancing model for study of normal development and the development of psychopathology are briefly considered.

Gaps Addressed in the Study of Child Psychopathology by DP

The gaps addressed by DP in integrating development into the study of psychopathology merit consideration. These gaps are articulated to highlight at the outset the significance of the problems addressed, and to underscore the distinctiveness of the DP perspective.

Clinical and Social Psychology as a Psychology of the Adult

One gap addressed by DP is that many areas of the study of clinical and social psychology remain focused on these matters from the perspective of adults, with scant consideration of children or how child development factors into models of adult functioning. A first question that arises about DP concerns its distinctive contribution in this regard. One may wonder whether DP does no more than provide a faint image of the endeavors of adult clinical and social psychology as applied to college samples or adult clinical populations. For example, is DP simply the windward extension of theories and findings based on the adult abnormal psychology or social psychology perspective applied to children? In fact, with all due respect to adult-focused traditions, DP provides strong arguments, in theory and in a rich and rapidly growing research literature, against the adequacy of simply a downward application of adult models of psychopathology or social psychology to children. Notably, the DP perspective is vigorously advancing highly sophisticated theory and research at an increasing rate to support the dynamic role of developmental processes. Thus, DP makes a case for focused study on the clinical and social psychology of children and the inclusion of child development concerns as fundamental to the multiple areas of the subject matter of clinical and social psychology. Given the assumption of a life-span perspective on normal development and the development of psychopathology, DP also makes a strong case for the inclusion of elderly and aging populations as the subject matter of clinical and social psychology (Achenbach & Rescorla, 2006; Greve & Staudinger, 2006).

Nosology and Treatment as a Clinical Psychology and Psychiatry of the Adult

Similarly, progress has been made in the advancement of nosology (e.g., *DSM-5*) and treatment approaches (e.g., cognitive behavioral treatments) from the perspective of adults. Against this backdrop of scholarship, one might wonder whether DP proposes ultimately to simply relabel adult approaches to understanding, diagnoses, and treatment of child adjustment problems. Again, by integrating dynamic developmental process into these issues, DP proposes directions that are substantively different from adult approaches to understanding, classification, and treatment of psychopathology in childhood (Jensen, Hoagwood, & Zitner, 2006).

For example, the distinctiveness of DP is evident when one considers its contributions toward understanding diagnoses of psychopathology and treatment from a developmental perspective in relation to a traditional medical model for diagnosis and treatment (Sroufe, 1997). As a case in point, consider you are aware that an adolescent has met clinical criteria for *DSM-5* depression. Does this mean the adolescent has a "disease" that the adolescent always had and always will have (i.e., a genetic disorder)? Alternatively, is it something the person somehow "gets" (e.g., a "contagious illness," "transmitted" from family members or peers)? Is the best way to treat the "disease" almost always to find the right medication (e.g., an appropriate pill or other primarily medical intervention)? In fact, the emerging work strongly argues for the role of developmental and contextual processes in the onset and course of childhood depression (Garber, 2006; Goodman & Gotlib, 1999; Hammen, Burge, & Stansbury, 1990). Although *DSM-5* provides progress in the reliability of classification, NIMH Directors have questioned the validity of the approach, including whether *DSM-5* is primarily a political document that does not mirror reality, calling for alternative, scientifically-based approaches, consistent with the DP perspective (Insel, 2013).

Another example of a clinical problem that is the subject of much societal concern is childhood aggression. Is this a "disease"? Is treatment a question of finding the right medication? In fact, the DP perspective holds these explanations in terms of disease models as reflected in a traditional medical model are oversimplified, and the problem of understanding diagnosis is much more complex than identifying a disease entity or understanding a disorder an individual has or always has had and will have (i.e., a genetic problem; a temperament-based disorder). That is, understanding the development of problems is more complex than something a person "gets" and effective treatment is more complex than simply identifying a medication for a problem. For example, with regard to childhood aggression, there is impressive evidence that developmental process and the ecology of antisocial behavior merit consideration (Dishion & Patterson, 2006).

In addition, DP scholars are interested in explaining both disorders that meet criteria for clinical disorders and dimensions of adjustment, for example, rates of symptoms of psychopathology (Cicchetti & Cohen, 1995). Categorical approaches place greater emphasis on more severe disorders. Moreover, classifications of an individual as meeting clinical criteria for a specific form of psychopathology may well change over time: An adolescent may meet criteria for depression at one point in time but not at a later period. Individuals may weave back and forth over between normal and abnormal classifications of functioning. Dimensions of adjustment provide a perspective on degrees of adjustment that has continuity over time and is amenable to the study of changing patterns of symptomatology over time. Given that these approaches are fundamentally empirically-based (e.g., Achenbach & Rescorla, 2006), they are less susceptible to concerns about validity.

Furthermore, an assumption of DP is that ultimately maladjustment is reflected in dynamic processes of functioning. Explaining bases for symptoms over time holds particular promise for increasing understanding of pathways of development, developing empirically based diagnostic symptoms, and increasing the acuity of prediction and prevention of later problems (Sroufe, 1997). Thus, understanding of the dynamic processes underlying development is relevant to advancing theoretical models for psychopathology, prevention, and treatment for either categorical or continuous assessments of child outcomes.

NOTIONS OF DEVELOPMENTAL PSYCHOPATHOLOGY INADEQUATELY INCORPORATED IN ADULT CLINICAL PSYCHOLOGY

Developmental processes are not being adequately considered or incorporated into adult clinical psychology. Consequently, this is inherently an area of incompleteness of these models, in that all psychological processes develop over time, and must therefore ultimately be understood, at least in part, in a developmental context. For example, there is limited evidence that core notions of the DP perspective are being incorporated in nosology and practice. The argument made by leading DP scholars (e.g., Sroufe, 1990, 1997, 2009) that the abnormal and normal must be considered together to understand the development of psychopathology and that psychopathology should be understood as "developmental deviation" is not often considered in diagnoses and treatment derived from adult psychopathology models and approaches.

Also, to understand the origins and course of psychopathology an important direction entails charting developmental pathways over time (Cummings et al., 2000; Kobak, Cassidy, Lyons-Ruth, & Ziv, 2006; Mayes & Suchman, 2006; Moffitt, 2006; Pickles & Hill, 2006) and charting the persisting effects of childhood processes over time (Moffitt, 2006; O'Connor, 2006). However, these notions are not being effectively incorporated into adult models of psychopathology or social psychology.

Infusing Development Into the Study of Psychopathology and Its Diagnosis and Treatment

DP has, as a primary objective, a scientific understanding of how and why, and for whom and when, processes related to psychopathology and adaptive functioning develop. With regard to the matter of definition, Sroufe and Rutter (1984) offered an early statement: "the study of the origins and course of individual patterns of behavioral maladaptation, whatever the age of onset, whatever the causes, whatever the transformations in behavioral manifestation, and however complex the course of the developmental pattern may be" (p. 38).

The fundamental assumptions of DP are (a) psychopathology is not a disease, an entity or pathogen within the child, but reflects processes of functioning that are maladaptive, (b) an effective basis for understanding maladaptive response processes is in relation to adaptive or normative responses, and (c) adaptive and maladaptive response processes develop over time, are subject to change, and their optimal interpretation requires consideration in relation to developmental and other contextual factors (Cicchetti, 2006; Cicchetti & Cohen, 1995). Relatedly, DP argues for the expansion of models for explanation to move beyond consideration of risk processes to also incorporate and evaluate protective factors, positive outcomes and influences and resilience into developmental models for psychopathology (Luthar, 2006; Masten, Burt, & Coatsworth, 2006; Thompson, Flood, & Goodvin, 2006).

Moreover, an important principle is that DP is concerned with more than simply identifying predictors of risk for later disorder in childhood. DP is centrally concerned with the articulation of the dynamic developmental processes that underlie risk. In this regard, Cicchetti (2006) has articulated:

> Developmental psychopathology refers not simply to the search for the indicators or predictors of later disturbance, although these are of interest, but also to the description of the interactive processes that lead to the emergence and guide the course of disturbed behavior. (p. 8)

From this perspective, differential diagnoses are of secondary interest because diagnoses are essentially, at least at the level of scientific understanding, a shorthand for the dynamic processes underlying what may be categorized as a clinical problem. Relatedly the role of developmental and ecological context is strongly advocated in conceptualizing, diagnosing, and treating disorders, with disorder conceptualized as an ongoing interplay between an active, changing person in a dynamic changing context (Jensen & Hoagwood, 1997).

Accordingly, the primary goal of DP is achieving a science that can articulate the dynamic process-relations underlying multiple pathways of development associated over time with what may be considered at any point in time normal development or psychopathology. Moreover, the articulation of psychopathology in terms of dynamic developmental process and pathways of development advocates and supports prevention models for ameliorating mental health problems (Cicchetti, 2006; Cummings et al. 2000; Ialongo et al., 2006).

Theoretical Assumptions About the Nature of Human Development

Understanding the underlying assumptions is important to appreciating the model for the development posited by DP, because these assumptions inevitably affect components of a scientific approach and clinical application, including the nature of theories and hypotheses, the use of research designs, interpretation of research findings, and models for prevention and treatment. These ways of viewing psychology, including assumptions about human development, have been described as worldviews (Overton, 2013, Chapter 2, this *Handbook,* this volume; Overton & Horowitz, 1991; Overton & Reese, 1973).

Worldviews organize study and understanding of phenomena in terms of underlying guidelines or rules for seeking truth (Cummings et al., 2000). The notions about worldview associated with DP merit consideration, given the contrasts between DP and adult-oriented approaches toward investigating, conceptualizing, and advancing interventions for psychopathology. In this regard, we next turn to several closely related assumptions about the nature of human development, which have implications for models of the development of psychopathology.

Contextual Embeddedness

Development is an ongoing interplay between an active, changing individual and a dynamic, changing context. Developmental process is thus conceptualized as an ongoing phenomenon progressing in development contexts of varying scope and depth, inevitably intertwined with past influences and embedded in multiple ongoing and interconnected level of functioning, including intraindividual, interindividual, and ecological systems. As a result, development regulates and is regulated by multiple events and processes at multiple levels of analysis that occur concurrently and unfolding over time (see the special issue of *Development and Psychopathology,* 1998, *10*[2]).

Active Organism

People play a major role in their own development: The environment does not create experience. Experience is constituted by the person's actions in an environment (Lerner, 2006; Overton, 2006, Chapter 2, this *Handbook*, this volume; Zigler & Glick, 1986). Therefore, the person's cognitions or representations of events are not mirror images reflecting a mind-independent objective world. People *construct* their world as known based on their actions, active perceptions, and meanings and representations constructed in the past. Relatedly, people actively seek out and make choices about the contexts in which they live, and the person's own characteristics have alternative meanings for others in their environments. DP encourages measures of children's appraisals of events, rather than simply event records, and the effects of the individuals' dispositions on contexts of development, rather than assuming universal effects of contexts on development.

Multiple, Diverse Causes of Development

Development reflects the mutual interplay and reciprocity between a multifaceted changing child and a multidimensional, dynamic context. This notion underscores the importance as a goal for any program of research on a phenomena of articulating complex models of causation—including *reciprocal determination* (Overton & Reese, 1973), *fusion* (Greenberg, 2011; Partridge, 2011), *relational bidirectional* (←→) *causality* (Lerner, 2006), *relational* (←→) *causality* (Gottlieb & Halpern, 2002; Overton, 2006, Chapter 2, this *Handbook,* this volume), and *circular causality* (Witherington, 2011, Chapter 3, this *Handbook*, this volume)—and constitutes an argument in principle against the adequacy of simple risk models that seek only predictors of psychopathology, without regard to mediating or moderating influences or pathways of development, or treatment models that seek "silver bullet" explanations, which identify single factors that account for any given form of psychopathology (e.g., a specific psychophysiological process).

Holism

There is interdependency among the parts of any developmental system; development cannot be fully understood by dissecting the parts. The parts are informed by each other and give meaning to the whole (see Overton, Chapter 2, this *Handbook*, this volume). From this perspective, synthesis is the ideal, with the goal that the parts be examined in the context of the whole. For example, emotion researchers (or cognitive scholars) may focus on identifying specific emotions (or cognitions) associated with a stressors or risk factor, which is a valuable direction. However, from the perspective of holism, broader objectives for understanding must be considered, that is, emotions cannot be understood apart from the goals of the individual, for example, the aging adult, and the context within which the aging adult is acting.

An important related construct, because no one research investigation can possibly hope to examine all these levels of analysis simultneously, is *floating holism*. According to this construct, choosing the "whole" to be studied is to some extent arbitrary. Components of any whole that are studied can be themselves viewed as relative wholes. Thus, the hierarchical, nested structure of part-whole relations can be made relatively specific or more general, bearing in mind that each element is a "floating hole" of a smaller or larger area of inquiry. Hence, the development of psychopathology can be understood at multiple and diverse levels of process, which across multiple investigations may be extended, for example, to include communities and schools, cultures and subcultures, families and dyads, and the child, adult or aging adult and their psychological processes of functioning (e.g., cognitions, psychophysiology, emotions).

Invoking the principle of floating holism, the aim of research necessarily must be to construct over time a cogent process model across a body of literature, rather than attempting (or even hoping) to resolve all matters in a single report. Thus, ideally, an overarching aim, over time and across studies, is to construct a "big-picture" explanatory model for development of adjustment or maladjustment or specific psychopathologies. This picture would include patterns of maladjustment reflecting specific dynamic processes emerging as a function of specific contexts, stage-salient tasks, and multiple perspectives on developmental processes. These efforts are likely to incorporate the findings across multiple laboratories, disciplines, and levels of analysis. Ideally, these research-based findings and theories are then systematically and cogently translated into prevention and intervention designs, including further tests of the explanatory models in the context of prevention and intervention designs, with basic research and intervention having bidirectional relations over time in further validating (or falsifying or qualifying) research-based theoretical models for the development of adjustment or maladjustment, or specific psychopathologies, across the life span and in individual (e.g., genetic, epigenetic, temperamental), environmental (e.g., family, community, peers) and developmental (e.g., developmental histories and stage-salient tasks) contexts.

Orderly Change and Directionality

Development follows orderly pathways of continuity and change, which encourages the study of developmental processes underlying the development of psychopathology across the life span. The study of orderly change and directionality from this perspective, in the ideal, does not involve the search for one-to-one correspondences between simple efficient causes and effects during development, or simply the cumulative addition of new elements to individuals' biopsychosocial repertoires as they get older (see Overton, Chapter 2, this *Handbook*, this volume). Instead, the proposition is better reflected in Werner's argument that development proceeds directionally "from a state of relative globality and lack of differentiation to a state of increasing differentiation, articulation and hierarchical integration" (Werner, 1957, p. 126), which Werner (1948) termed the *orthogenetic principle*.

Developmental Psychopathology in Relation With Other Disciplines

Developmental psychopathology is not a narrowly defined specialty area, but a broadly conceptualized approach defined in terms of its primary goal, that is, a science that advances understanding of human development and treatment of psychopathology. The work of DP thus is reflected in multidisciplinary directions toward the aim of unraveling the dynamic process-relations underlying normal development and the development of psychopathology (Cicchetti & Cohen, 1995, 2006).

Moreover, DP by design is articulated as a "work in progress," still being shaped and developed. Toward achieving the best theory and treatment in the long run, DP is intentionally open, flexible, and responsive to new research, concepts, and methods, with self-consciously "permeable" boundaries with regard to multiple other areas that may potentially contribute to understanding of the development of psychopathology (Cummings et al., 2000). That is, "developmental psychopathology is an evolving scientific discipline whose predominant focus is elucidating the interplay among the biological, psychological, and social-contextual aspect of normal development across the lifespan" (Cicchetti, 2006, p. 1).

This definition reflects the assumption that the optimal study of the processes underlying human development requires that multiple domains, factors, and variables be studied and evaluated, and that the best conceptual and treatment models will ultimately emerge from cross-fertilization and integration across multiple and diverse disciplines. A guiding assumption of DP is that the adequate study of the full range of processes contributing to human development requires a collaborative endeavor that spans disciplinary boundaries. Toward increasing the articulation of developmental processes underlying psychopathology across multiple domains, DP encourages research and theory that crosses traditional boundaries of psychological, medical, and biological sciences (Cummings et al., 2000).

The historical origins of the field are derived from the contributions of multiple disciplines, including embryology, philosophy, psychiatry, biology, experimental, clinical and developmental psychology; matters which have been treated in detail elsewhere (e.g., Cicchetti, 1990, 2006). Thus, the area has been defined in the context of a mix of interrelations with other perspectives on the development of psychopathology and continues to advance in the context of this multiplicity of diverse influences.

Toward further defining the field, the differences and overlapping themes with several closely related areas merit consideration. An important caveat is that these are broad distinctions and over the years some of the most closely related areas have become overlapping to an increasing degree.

Developmental Psychology, Developmental Science, Applied Developmental Psychology, and Life-Span Developmental Psychology

Given the concern with developmental process and tracking development over time, the methods, theories, and approaches of developmental psychology are of inherently great pertinence to DP as a field. The developmental component is fundamental in DP, evident in the concern with childhood and life-span functioning, with explanations for continuity and discontinuity, and directions toward charting developmental trajectories and pathways. Thus, pathways of development and the dynamic processes investigated for their contribution to explanations for the development of psychopathology are substantively drawn from the universe of emotional, social, cognitive, biological, and contextual processes that characterize human development, examined in relation to what is maladaptive or dysfunctional as well in relation to what might be regarded as adaptive or normal as developmental process (Cicchetti & Cohen, 1995; Cummings et al., 2000).

Relatedly, intersections with notions of developmental science, applied developmental psychology, and life-span developmental psychology merit consideration. Developmental science is concerned with the relational causes and processes of developmental change and also encourages multidisciplinary perspectives (Lerner, 2012). Although initially focused on human mental development, the approach has expanded to include social development and related aspects of development, including work with atypical populations, neuroscience, and developmental biology. The flagship journal is *Developmental Science*, which was founded a decade and a half ago by George Butterworth and has emerged as one of the most cited journals in developmental psychology. Applied developmental psychology reflects directions toward integrating developmental theory, research, and practical applications, and the application of behavioral science research. It is increasingly concerned with articulating developmental processes and preventing the development of psychopathology across the life span, including multiple processes and contexts of development. The flagship journal is the *Journal of Applied Developmental Psychology*. Finally, life-span developmental psychology has been highly influential in articulating notions of developmental process and pathways, including the emphasis on aging and relational developmental systems across the life span (Overton, 2010a). The increasing conceptual, methodological and statistical sophistication of process-oriented approaches to life-span development is reflected in the two-volume *Handbook of Life-Span Development* (Lamb & Freund, 2010; Overton, 2010b). Thus, there is increasing emphasis on advancing synergistic and complementary models of development within areas concerned with developmental process, adding to the vibrancy and excitement of the move forward in injecting sophisticated notions of human development in the study of normal development and the development of psychopathology.

Finally, at the outset DP was distinguished from clinical child and abnormal child psychology by its focus studying the processes that underlie child psychopathology rather than nosology, emphasizing the mutual interplay between normal and atypical development in order to articulate the complex interplay of factors affecting the dynamic, ontogenic processes of human development (Sroufe & Rutter, 1984). DP advocates that normal development can inform trajectories of risk and disordered development can elevate understanding of normal development. However, although these differences were evident at the outset, these differences in areas of clinical science concerned with children are less evident at this time. In fact, many of the leading researchers on topics closely tied to DP are child clinical psychologists and child psychiatrists. In addition, leading journals associated with child clinical psychology and related areas have contributed and are contributing to major advances in understanding the dynamic processes underlying the development of psychopathology in children, including *Journal of Abnormal Child Psychology*, *Journal of Child Psychology and Psychiatry*, and the *Journal of the American Academy of Child & Adolescent Psychiatry*, which are also now among the most cited journals in both developmental and clinical psychology. Thus, these exciting and overlapping synergies between multiple areas of study concerned with developmental process in the development of psychopathology remain defining themes of this approach.

KEY CONCEPTUAL COMPONENTS OF DEVELOPMENTAL PSYCHOPATHOLOGY

DP is thus not a narrow area of specialty but an approach that is broadly conceptualized with regard to the aim of understanding the dynamic-process relations that underlie pathways of normal development and the development of maladjustment. Although in its broad scope DP overlaps with other disciplines, as investigators have seen, it is distinct in its breadth and scope from other approaches to understanding mental health science and practice. DP is not made up of a limited restrictive set of perspectives, procedures, or theories but can be considered a “macroparadigm” that acts as a type of framework for understanding developmental processes from multiple perspectives and levels of analysis (Cummings et al., 2000). Next, we consider some of the core principles at the heart of this approach. Notably, these principles are inherently interrelated. Thus, although we highlight certain principles in specific sections, it should be understood that these concepts are interrelated.

A PROCESS-ORIENTED PERSPECTIVE ON THE DEVELOPMENT OF PSYCHOPATHOLOGY

Research on psychopathology has long been concerned with identifying risk factors, that is, factors correlated with maladjustment and abnormal outcomes. Identifying risk factors at the level of prediction of outcomes remains an important direction for psychopathology research. However, this aim reflects an early stage of the programmatic study of a clinical research question regarding the development of psychopathology from a DP perspective and is not the final goal of research. From the onset, the heavy emphasis has been placed on identifying the coactive processes that initiate, maintain, or foster the course of disturbed behavior over time. The aim is to describe the specific responses and patterns that underlie child development in the context of specific experiences, toward defining the factors that underlie children's development at a dynamic level of analysis. Dynamic process is defined in terms of well-defined and articulated transactional relations among the multiple and diverse factors relating to development over time; that is, the particular, often complex, organizations of social, emotional, cognitive, physiological, and other processes that relate to children's functioning over time in particular contexts. In turn, transactions reflect a series of dynamic, mutually influential coactions potentially involving multiple of functioning between the child and the social ecological contexts, for example, including multiple family members (e.g., mother, father, siblings), family-wide processes (e.g., family-wide emotional security; Forman & Davies, 2005), multiple dimensions of community (e.g., sectarian and nonsectarian community violence; Cummings, Goeke-Morey, Schermerhorn, Merrilees, & Cairns, 2009), ethnic or cultural identity (e.g., social identity as a Catholic or Protestant in Belfast, Northern Ireland; Merrilees et al., 2013) and even larger contexts (e.g., political violence or war; Cummings et al., 2011).

Relatedly, with regard to the search for explanatory processes, DP is not limited to specific behaviors (e.g., pigeon bar pressing) or domains of study (e.g., simply cognitive outcomes) but is concerned with expanding the causal net for explaining development, toward best characterizing how and why psychological, physiological, and other factors operate over time as influences on child development. Notably, even when predictors of risk are identified as statistically sound, individual predictors are likely to account for only a limited degree of the variance to be explained in child outcomes, and are unlikely in isolation to provide adequate explanation. Moreover, increasingly the requirement for links between predictors and outcomes before studying mediation is being relaxed in statistical tests of mediation. This direction is another reflection of the increasing emphasis being placed on understanding the role of mediating and moderating processes to understanding child outcomes as a function of predictor variables, which are likely to be only linked probabilistically and as a function of dynamic process relations with child outcomes.

Accordingly, as a goal for the field, increasingly more sophisticated models are being sought concerning the onset and course of adaptive and maladaptive patterns of development over time. The regular appearance of special issues pertaining to new and key themes in developmental psychopathology in the journal *Development and Psychopathology* is indicative of the commitment of this area to aggressively and continually advancing ways of understanding and conceptualizing models for patterns of development of psychopathology.

For example, there is concern with accounting for the transaction of person and process in normal development and the development of psychopathology in terms of effects of histories of experience and development over time. Thus, Davies, Sturge-Apple, Bascoe, and Cummings (in press) examined whether a mediational pathway involving interparental conflict, emotional insecurity, and adolescent psychological problems was altered by adolescent's childhood histories of insecurity. Consistent with previous research (e.g., Cummings, George, McCoy & Davies, 2012; Cummings, Schermerhorn, Davies, Goeke-Morey, & Cummings, 2006), marital conflict was linked prospectively in this study with increases in adolescent emotional insecurity which, in turn, predicted subsequent increases in their psychological problems. However, this study also examined the impact of histories of family experiences in childhood on adjustment in adolescence. In this regard, childhood insecurity about marital conflict predicted adolescent maladjustment even after considering contemporaneous family experiences in adolescence. Moreover, reflecting a moderating role of developmental histories, adolescents with relatively higher levels of insecurity in childhood evidenced disproportionately greater levels of insecurity in the context of high levels of interparental conflict in adolescence. Thus, illustrating a role of dynamic processes underlying vulnerability over time in relating to development of maladaptive patterns, histories of insecurity in childhood were associated with pathways of adolescent adaptation to interparental conflict as a predictor of symptoms of adolescent mental problems and a moderator of links between exposure to marital conflict and adolescent emotional insecurity.

CONSIDERING THE NORMAL AND ABNORMAL TOGETHER

Sroufe (1990) referred to considering normal and abnormal together as the "essence" of developmental psychopathology. The underlying assumption is that disorder is not a category but rather, disorder reflects patterns of maladaptive processes that emerge over time in transactions with contexts of human development; that is, developmental deviation. Development is expected to typically show coherent patterns for normal and abnormal development; therefore, it is relevant to search among the same classes of dynamic processes in order to understand normal development and psychopathology.

A foundational notion of developmental psychopathology is that one needs to take the concept of development seriously in the study of psychopathology in children, which has implications for the conceptualization and description of abnormal child psychology, including the origins and developmental course of problematic behavior and how research on these questions about psychopathology are most appropriately approached and interpreted (Sroufe, 2009). Maladaptation is a function of development and the course of developmental process that occurs over time and in transaction with multiple contexts of childhood (Sroufe & Rutter, 1984). From this perspective childhood psychopathology is not a simple matter of classification or diagnosis but requires the consideration of multiple processes of normal and abnormal development and their interrelations. Accordingly, at any given time, a person's development is ultimately seen as occurring along a continuum including relatively adaptive and maladaptive processes, with individuals viewed as "normal" typically expected to have some problems during development. Psychological problems thus are "diagnosed" when there is evidence of deviation from healthy course from a developmental perspective.

Given one accepts the assumption of developmental psychopathology that disorder reflects maladaptive processes that emerge in transaction with the contexts of development, it follows that one can only understand what is normal in relation to abnormal, and what is abnormal in relation to what is normal, in the context of complex, always-changing patterns of development. Given that disorder may not necessarily be an entirely well-defined entity, it makes sense that disorder is understood relative to other processes, not in an absolute sense. Relatedly, evaluation of what is normal compared to abnormal must take into account children's developmental period, stage of development, or critical developmental issues (Achenbach, 1997; Sroufe, 1990).

Multiple Perspectives on Dynamic Processes

Another fundamental principle of DP is to emphasize the importance of interdisciplinary research and a diversity of developmental processes. To this point, knowledge about factors related to the onset, course, and explanatory processes underlying psychopathology is based on a relatively limited involvement of other perspectives on the development of psychopathology although involvement of other disciplines and disciplinary perspectives is increasing, reflecting, in part, impetus from scholars from the DP and developmental science perspectives. For example, special issues of *Development and Psychopathology* have been devoted to fostering and stimulating research on specific and timely issues and topics from a developmental psychopathology perspective. There has been an increasing involvement of biological, neurobiological, and genetic factors in studies as explanatory variables or contexts as moderators of developmental outcomes, including the development of psychopathology, evidenced by increasing publication of such findings in a widening literature, including *Developmental and Psychopathology*, *Developmental Psychology*, *Child Development*, *Journal of Child Psychology and Psychiatry*, and *Developmental Science*.

As noted by Cicchetti (2006), one of the challenges is establishing communication and links across disciplines engaged with very different approaches and means of evaluating and understanding developmental process. Another challenge is to develop theories and conceptualizations that effectively include and integrate multiple dimensions of emotional, social, cognitive and physiological or biological processes. One goal is to include response processes from multiple disciplinary perspectives or at least reflecting multiple domains of functioning. However, equally important is the development of conceptual models or theories that effectively accommodate these different perspectives and make use of them toward developing models for understanding the development of psychopathology. Simply collecting complex data sets or using them as single predictors in analyses, or in ways that do not reflect cogent theory or at least compelling conceptual frameworks is unlikely to maximize contributions to understanding of the development of psychopathology.

Sroufe (2009) has called attention to a possible countertrend that may erode progress; treating biological correlates as independent predictors with inherently greater value than other levels of analysis, or even holding status sufficient to account for outcomes without regard to other factors or even developmental process. Although biological factors merit greater emphasis in research on developmental psychopathology, it is imperative that this emphasis does not impede progress by resulting in devaluing or even ignoring many other developmental or behavioral contributions to childhood disorder and its development.

Finally, the entire domain of normal or normative human development merits consideration in the construction of models for the development of psychopathology from a DP perspective. A case can be made that a sufficiently broad consideration of normative developmental processes has not been undertaken by DP scholars in the search for identifying process models regarding maladaptive development (Cicchetti, 2006). For example, biological, individual, family, social, and cultural contexts and related processes require study in order to optimize models from a DP perspective. With regard to the biological context, genetics, epigenetics, embryology, neuropsychology, and temperament are relevant to evaluations of deviations from normality contributing to elevate symptoms of maladjustment. With regard to individual contexts of development normative trends in cognitive, emotional, and moral development merit consideration for comparisons between adaptive and maladaptive development, given the empirical foundation for possible links with dynamic processes in response to these contexts and the development of childhood adjustment problems. Developmental processes and relevant family contexts may include maltreatment, destructive marital conflict, insecure parent-child attachment, and dysfunctional sibling relationships. For each of these domains key issues may concern how these processes of development may go awry, and if and why deviations from normal patterns of development may manifest themselves over time in psychopathology.

Compared to studies of factors in isolation, a search for combinations of factors that relate to maladaptation in development in relation to normal development is likely to be most fruitful. However, it is also important to be accepting of the possibility that there are no links between some normative processes and deviations of these developmental processes that are implicated in the development of psychopathology. For example, many features of human development are subject to study in developmental psychology with an emphasis in many areas on normative developmental trends, and it is an empirical question for future research as to whether deviations in some domains of functioning are related to maladaptive functioning. For example, Wakefield (1997) advances *harmful dysfunction* as a criterion for evaluating maladaptation, suggesting that if harm does not result, developmental deviations may not reflect psychopathology. In terms of what is meant by harm, Wakefield states “While there are often objective indicators of harm . . . in the end harm is a value term . . . determined by complex social judgments and social circumstances” (p. 280). Also, deviations can be healthy adaptations to deviant environments or usual but effective solutions to adaptive challenges that are not properly viewed as disorders. In addition, it merits recognition that a developmental process is associated with psychopathology does not mean that it is a form of psychopathology. For example, insecure attachment or factors relating to the development of insecure attachment have sometimes been erroneously classified as predictors of psychopathology because of links with insecure attachment (DeKlyen & Greenberg, 2008). In fact, a necessary next step for demonstration of pertinence to a DP perspective is to show these variables or insecure attachment as related to these factors are associated with deviations from adaptive development, for example, elevated levels of externalizing or internalizing symptoms.

Adherence to Diverse and Inclusive Methodological Directions

The developmental psychopathology approach makes strong demands concerning the types of information that are required to describe the development of psychopathology. That is, the process-oriented focus of developmental psychopathology reflects a concern with identifying the emotional, social, behavioral, and biological factors that mediate, moderate, or otherwise account for patterns of development of psychopathology. Thus, in addition to measuring predictor (i.e., risk factors) and outcome (i.e., indices of maladjustment) variables at a sufficient level of detail to reflect meaningful variations, one must also find ways to measure explanatory constructs (e.g., mediators, moderators) in sufficient detail to reflect variations and at a level of responding that can indicate dynamic processes of functioning (e.g., processes of emotional insecurity, Cummings & Davies, 2010). Consistent with the study of developmental process as a fundamental goal of the DP perspective, measurement needs to be sensitive to stage-salient aspects of development, which means that measures should reflect considerations of developmental period and the key tasks for developmental period. The search for developmental process requires the examination of multiple levels of analysis, including interdisciplinary approaches and methodologies (Cicchetti, 2006). Finally, the study of the development of psychopathology calls for the use of longitudinal research designs, including designs that include age periods thought (based on research as well as theory) to reflect the origins, maintenance, and course of developmental processes related to the development of psychopathology.

Accordingly, emphasis on the need for methodological rigor, diversity, and innovation are key tenets of the DP model (Cicchetti & Cohen, 1995). DP is not just a focus on psychopathology in an abstract sense but a template for directions in scientific research. Toward the goal of unraveling the complex processes underlying development, emphasis is placed on the importance of using multiple methods, exploring multiple domains, and integrating approaches from multiple disciplines. For example, there is a tendency for discipline-specific methods to evolve within areas of study. The process-oriented model of DP requires diverse methodological approaches. The assumption is that any one method has gaps and weaknesses as well as limits in elucidating process. Advanced measurement as well as, increasingly, advanced approaches to analyses, are needed to clarify various causal processes.

Thus, no one response or even domain of responding holds the “truth” about the developmental processes related to adaptive and maladaptive patterns of development. For example, assessments of physiological functioning are not a “silver bullet” for understanding developmental process. Components of developmental process are not distinct; they are related to broader or higher-order organizations. Using a time-worn analogy, each of many blind men (i.e., responses or methods) may only feel a specific parts of the elephant, and reports of all are needed to construct an adequate view of the elephant (i.e., higher-order organizations of functioning). At the same time, consistent with the principle of “floating holism,” each component of the whole can itself be a complete and appropriate area of inquiry for a researcher, for example, the individual dyadic, triadic, and family as a unit for analysis for understanding family influences on normal development and the development of psychopathology. From a practical perspective, focus on specific organizations of functioning may be necessary for heuristic reasons, but it remains important to seek examination of the effects of influences across multiple systems and processes in the context of programmatic directions in research.

With regard to research strategies for DP, teasing out and elucidating the role of multiple variables, multiple patterns of influence, and multiple qualifying factors of group or context over time requires sophisticated research designs. Mediatiors explain “how and why” factors lead to pathways of normal development or the development of psychopathology, that is, the generative processes influencing the development of psychopathology. Moderators specify “who” is at risk and “when” risk is operative, referring to the strength and/or direction of relations between independent variable(s) and symptoms of psychopathology (Holmbeck, 1997).

More complex models may also be identified in the context of attempting to explain the development of psychopathology. For example, synergistic moderation models may identify when two or more factors (e.g., age, gender, ethnic group, or socioeconomic status) increase the risk over the sum of factors considered in isolation (Cohen, Cohen, West, & Aiken, 2003; Rothman, 1976). Multiple moderator models may be obtained when more than one factor affects the size of outcomes (Cohen et al., 2003; Monroe & Simons, 1991). Notions of mediation and moderation may also be integrated into process models. For example, in mediated moderation, there is a moderator (e.g., gender) and this effect is mediated (e.g., emotional insecurity) in relation with risk for psychopathology (e.g., symptoms of maladjustment). In moderated mediation, the effect of the predictor (e.g., marital conflict and violence) on the mediator (e.g., emotional insecurity) is moderated (e.g., Cummings et al., 2006) or the effect of the mediator (e.g., emotional insecurity) on risk for psychopathology (e.g., symptoms of maladjustment) is moderated (e.g., elevated cortisol reactivity; Bergman, Cummings, & Davies, in press).

However, because no one study can include all possible methodologies, informed decisions about methodology are crucial. Among the various research designs relevant to the DP perspective, longitudinal, also termed *time series*, research designs hold many advantages, and are ultimately necessary for cogent examination of process models for the development of psychopathology. As Lerner and Benson (2012) point out, contemporary "developmental science [including DP] seeks to describe, explain, and optimize intraindividual changes and interindividual differences in intraindividual changes across the life span" (p. 2). Time series designs are essential to this task. That is, these designs are essential to demonstrating the nature of processes over time and to charting pathways of individual development (see, e.g., Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2010; Ram & Grimm, Chapter 20, this *Handbook*, this volume). Given the serious sources of error in reconstructing events and overinflating relations between psychopathology outcomes and predictors of those outcomes associated with retrospective research designs (Cowan, Cowan, & Schulz, 1996; Cummings et al., 2000), and the well-known problems with cross-sectional designs in inferring causality, prospective research is the "gold standard" for cogently advancing the role of "development" in developmental psychopathology models. Further, as discussed by Molenaar (e.g., 2004), the use of what are termed the *ergodicity* theorems of classical mechanics, demonstrate that conclusions drawn from from averages of a group are often inconsistent with conclusions about any particular individual in the group. Thus, time series designs combined with ideographic observations (see von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume) are often central to a complete understanding of the development of psychopathology.

Although longitudinal research designs are centrally important in developmental psychopathology research programs, their use should be judicious and selective, ideally based on a strong foundation of experimental, cross-sectional, and other means of *first* exploring the viability and promise of hypotheses that motivate longitudinal research. Longitudinal research is inherently costly and time-consuming, with many potential pitfalls, including that a hasty design may not measure key factors or measure them adequately, and weak measurement unless based on adequate pilot work or other rigorous measurement preparation may undermine the interpretability of results. In addition, measures may soon become outdated or shown to be invalid if not carefully evaluated at the outset by all possible means. Resources and preparation must be adequate to ensure adequate sample size, minimal attrition, and collection of an adequate number of data points (Nesselroade & Molenaar, 2010), appropriately timed, to cogently test hypotheses about developmental process that are adequately grounded in theory and research (Cole & Maxwell, 2003). Longitudinal research may have excellent external validity but does not support causality in the same way as a randomized experiment; ideally these two methods are used together in programmatic research testing causal models about the development of psychopathology.

Relatedly, an important emerging direction for process-oriented research is person-oriented research, which emphasizes the study of intradividual variability in the context of change over time (Nesselroade & Molenaar, 2010; von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume). Change during human development occurs at the level of the person, so that the ultimate goal of research must be to understand interindividual differences and similarties in patterns of intraindividual change over time. Over time a person functions as an integrated whole (i.e., an integrated biological, social, and psychological person) so that the person is in the final analysis the most informative organizing principle for understanding developmental process (Bergman, von Eye, & Magnusson, 2006). Longitudinal process-oriented research has typically reflected variable-oriented methods, which can be, and have been, highly informative about change in individual trajectories or heterogeneity of change across people. No doubt such approaches will continue to dominate much psychological research, and will remain highly valuable. Nonetheless, it is important to recognize the inherent limitations for understanding developmental process at the level of holistic individual functioning. By comparison, within-person analyses aims to describe each individual's shape of change or growth trajectory in the context of interindividual change. For example, Cummings and colleagues (Cummings, Merrilees, et al., 2013, Cummings, Taylor, et al., 2013) have shown how person-oriented methods can enhance understanding of developmental processes and contexts in relations between political violence and adolescent adjustment. However, it remains that these approaches are highly challenging from the perspective of research design, requirements of the data to test person-oriented theory, and the adequacy of various person-oriented methods to test person-oriented theory (Sterba & Bauer, 2010). Moreover, person-oriented theory may reflect a relatively wide variety of propositions about processes concerning holistic, transactional, and individualized processes of change over time. Specific person-oriented methods may only be amenable to testing specific features of person-oriented theory, but these limitations may not be ackowledged. Sterba and Bauer (2010) have called attention to the problem of distinguishing between person-oriented theory and methods, and, in particular, the importance of clarifying which aspects of person-oriented theory are being tested or can be tested with specific person-oriented methods (see also Bergman et al., 2006; Nesselroade & Molenaar, 2010; von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume).

Treatment programs provide another methodology for testing relational causal hypotheses. Demonstrating relational causal processes in the context of treatment or intervention research provides cogent evidence for process models for the development of psychopathology. The DP approach provides a conceptual foundation to support the promise of prevention programs, with the aim of reaching groups early enough in development trajectories to prevent or minimize the likelihood of later problems. Thus, Cicchetti (2006) has noted:

> If the developmental course is altered as a result of a randomized preventive trial and the risk for negative outcomes is reduced, then prevention research has contributed to specifying the processes that are involved in the emergence of maladaptive developmental outcomes and psychopathology.... Accordingly, preventive intervention science can be conceptualized as true experiments in modifying the course of development, thereby providing insights into the etiology and pathogenesis of disordered outcomes. (p. 16)

Elsewhere in this chapter we consider at length the critical matter of basing the content of intervention and prevention programs on developmental theory and research; that is, translating findings of developmental theory and research into program contents (i.e., *translational research*), thereby increasing the scientific bases for intervention studies as well as adequately informing programs of developmental factors. Ideally, development science informs prevention and intervention efforts, which, in turn, informs developmental theory and research, in a back and forth or bidirectional way over time. Unfortunately, to this point, the scholarly traditions concerned with developmental process and clinical intervention, respectively, continue to remain somewhat distinct (Cicchetti, 2006).

Risk and Protective Factors

Approaches to the study of psychopathology guided by the traditional medical model have focused on the identification of risk factors, that is, variables that are correlated with classifications of psychopathology. Causal models have often been assumed to be linear, that is, moving in a unidirectional fashion from predictor to outcome, with an emphasis on the specification of single factors expected to predict discrete diagnostic categories. These assumptions about risk processes may lead to misleading conclusions about causal processes, especially when examined in cross-sectional research designs that leave wide open the reality of highly complex process explanations.

Risk From a DP Perspective

In contrast with the dictates of the medical model, the DP approach advocates for the search for dynamic and multiple explanatory processes, including processes of mediation, moderation, and complex interrelations and coactions between them (e.g., mediated moderation), that relate to the individual's unfolding patterns of adaptation and maladaptation over time (Cummings et al., 2000). The aim is not to find linear associations between predictors and outcomes as endpoints but models that are relational and transactional involving multiple processes accounting for children's development over time. Emphasis is placed on the necessity of longitudinal research designs for identifying and differentiating various causal processes.

A fundamental assumption of DP is that a myriad of risk factors are influential in normal development and the development of psychopathology. Moreover, the impact of risk on development must be considered in terms of a larger biopsychosocial context. For example, the effects of family violence in contexts of political violence or war may be affected by the strength of an individual's social identity (Merrilees et al., 2013) or by perceptions of exposure to sectarian community violence (Cummings, Merrilees, et al., 2012).

A conceptual ordering of risk in testing relational causal hypotheses, based on an analysis of past research findings, relevant theory, or, ideally, both, is sought in any DP research agenda on the impact of risk on development. That is, DP researchers seek to impose some conceptual or ecological framework on the domain of multiple risk factors that might be expected to be influential in the study of relations between particular phenomenon and child development. Efforts are made to operationalize variables as process and not fall into traps defining constructs at the level of "social address," which confuse categories of group membership with causal process, in conceptualizing risk process. An example of such an error would be to draw conclusions from simply comparing children on molar dimensions of ethnicity, parental characteristics, or social background (e.g., socioeconomic status). That is, risk is conceptualized as a process, affecting the probability of negative outcomes, not a trait.

Protective Factors From a DP Perspective

Equal weight is also given to the search for and identification of protective factors in conceptualizing process models for understanding the relational (←→) causes, developmental course, and interventions for psychopathology. That is, disorder, or adaptive functioning, is seen as a function of the complex coacting operation of protective and risk factors over time. For example, across the teen years an adolescent's social identity as a Catholic or Protestant, respectively, in Belfast serves as a protective factor against symptoms of emotional problems. At the same time, exposure to sectarian community violence acts as a risk factor to increase the likelihood of symptoms of emotion problems, with older adolescents (16 years old and older) more vulnerable to the impact of sectarian community violence than younger adolescents (12 to 15 years old) (Merrilees et al., 2013). The concern with the positive role of positive and protective factors, as well as the negative impact of risk processes, in normal development and the development of psychopathology, is another hallmark of the DP perspective. Moreover, multiple protective factors may also be relevant to developmental models of normal development and the development of psychopathology. As with risk factors, a conceptual ordering of protective factors, based on theory and research, is highly desirable for effective exploration of a phenomenon.

Contextual Influences

A fundamental assumption of DP is that the evaluation of what is disordered or adaptive must take into account the context in which the pattern occurs. For example, some behaviors may appear disordered but may actually reflect healthy adaptations from the perspective of the individual in the contexts in which they are living or in which they have grown up. Relatedly, reflecting the construct of contextual relativism, the behaviors that may appear adaptive in one setting may be maladaptive in another environment.

From the perspective of a science of DP, relational transactions between individuals and the environments in which they develop hold keys to understanding causal processes. All development entails temporal individual ←→ context relations. Dynamic relational transactions occur between the individual and social contexts, with social contexts of family, school, community, and culture factoring importantly in children's risk for maladaptation and disorders. With regard to conceptualizations of multiple levels of disorder, Bronfenbrenner's (1979) model for multiple and nested levels of contexts of human development, including micro-, meso-, exo-, and macrosystems, has proven valuable. For example, building upon this framework, Cummings et al. (2009) proposed a social ecological model for conceptualizing the effects of political violence on children. In the context of the political conflict in post-conflict Belfast, Northern Ireland, findings have lent support to this model, indicating the distinct impacts of political violence (i.e., historical death rates), sectarian community violence, marital and family conflict, children's psychological processes of emotional insecurity and symptoms of externalizing and internalizing problems (Cummings et al., 2011; Cummings, Merrilees, et al., 2012).

Pathways of Development

The notion that maladjustment and disorder can be described and conceptualized in terms of developmental pathways is central to the DP perspective. Pathways are essential for study because disorder is viewed as a deviation from adaptive development over time. According to the DP perspective, diversity characterizes developmental processes and pathways (i.e., complex *multideterminism*), and there are multiple pathways during development, (i.e., *developmental pluralism*). Expanding on these points, multiple pathways may lead to the same outcome at a given point in time (i.e., *equifinality*) and different outcomes at any point in time may result from a common earlier point of origin (i.e., *multifinality*) (Cicchetti & Rogosch, 1996; McClelland, Geldhof, Cameron, & Wanless, Chapter 14, this *Handbook*, this volume). At any given time, an individual's development occurs along a continuum spanning adaptive and maladaptive, with variations across areas of developmental process and functioning. Thus, the fact that comorbidity is found in individuals evidencing maladaptive functioning does not pose challenges to the DP perspective on psychopathology as it does to a medical model perspective that views psychopathology in terms of discrete diagnoses (Sroufe, 1997). Relatedly, although change is seen as always possible because of the dynamic nature of processes of development, change is also assumed to be constrained to some degree by prior levels of functioning, because past organizations and structures within the individual factor in developmental pathways (Cicchetti, 2006; Sroufe, 1997).

The view of developmental pathways reflects a systems perspective that is quite compatible with a relational-developmental systems perspective on developmental processes. According to the DP perspective, psychological processes are most informatively viewed as holistic, reflecting a hierarchical organization, with higher-order aspects of functioning tending to continue over time. Thus, stability reflecting highly similar overt behaviors at different points in time is unlikely (i.e., *homotypic continuity*). However, coherence in the underlying meaning and organization of behavior over time is much more likely (i.e., *heterotypic continuity*). Thus, even in the context of progressive change, older psychological organizations may contribute to the development of emerging psychological systems (i.e., *hierarchical motility*) (Davies et al., in press; Witherington, Chapter 3, this *Handbook*, this volume). In this context, discontinuity in the dramatic sense of the term reflecting complete change at a qualitative level of analysis is unlikely to occur. Rather apparent discontinuity is likely to be systematic and "lawful," reflecting complex processes of development that involve *relatively* greater changes in pathways of development due to *relatively* elevated levels of processes of change. According to the DP perspective, developmental pathways reflect a series of dynamic, mutually influencing relational (←→) transactions between past developmental functioning, the individual's current functioning, and contexts of development (e.g., family, community, school, cultural context). Thus, the etiology of psychopathology reflects a complex causal pattern of coacting systems, with maladaptative functioning not a disease entity but an outcome of development.

Against this background of the fundamental assumptions for the study of pathways of development, theory and research merit consideration regarding this vital direction in the DP approach. With regard to theory concerning what they term as the "pathway metaphor," Pickles and Hill (2006) have called attention to the need for further conceptualization of the specifics and definitions of what is meant by the *pathways* concept. Pickles and Hill (2006) stress the need, at least in theory, to be aware of possible complexities in the forms taken by developmental pathways, including:

- Relative continuity may be punctuated by relative change.
- The most influential processes influencing functioning may vary along a developmental pathway.
- The direction of change of pathways may change over time.
- Children's responses to risk may sometimes result in "steeling effects," that is, longer-term benefits, in reactions to the challenges presented (although they note that actual empirical evidence for such effects is limited).
- The specific dynamic processes affecting development may change in their relative explanatory power along a pathway.

These and other notions advanced by Pickles and Hill (2006) thus offer interesting speculations toward conceptualizing developmental pathways, providing more nuance for future empirical testing of pathways hypotheses. That is, these concepts are interesting as starting points for raising awareness of ways to move beyond underdeveloped notions of the pathways metaphor, such as assuming pathways are deterministic or simultaneously provide both prediction and explanation.

Dynamical systems approaches (see Witherington, Chapter 3, this *Handbook*, this volume) offer other possibilities for studying pathways of development over time. Granic and Hollenstein (2006) have articulated the principles and methods for using dynamic systems (DS) theory to examine complex developmental pathways. DS is based on open systems concepts (Overton & Horowitz, 1991; Richters, 1997) that are consistent with the holistic, systems, and transactional assumptions about pathways made by DP. DS approaches underscore the mutual and reciprocal coactions among developmental influences, which are also hierarchically organized, with consideration given to the context in which dynamic systems are embedded. In particular, Granic and Hollenstein (2006) argue that dynamic systems approaches offer valuable possibilities for addressing the "Developmentalist's Dilemma," that is, bridging the gap between the rich process-oriented conceptualizations for studying developmental pathways of the DP perspective and the methods and analytic tools available for testing these notions. In the spirit of methodological pluralism, Granic and Hollenstein (2006) describe DS as a complement rather than alternative to other approaches for studying developmental pathways. A particular advantage of the DS approach is the capacity for describing pathways with a focus on the individual. Dynamic systems are self-organizing (i.e., "a process of creating structure and order without explicit instructions from outside" [van Geert, 2003, p. 654]). These systems have the potential for enormous diversity. Through their activity they ultimately stabilize into a limited number of patterns, which increases the heuristic value of the approach. For example, Schermerhorn, Chow, and Cummings (2010) demonstrated how a dynamical systems approach based on parents' diary reports of interparental conflict over 15 days demonstrated parents' influence from one conflict to the next, with the total number of conflicts also related to the influence of the wives' behavior on the husband's behavior during conflict. Finally, Granic and Hollenstein (2006) call attention to the potential for DS approaches to elucidate the change processes that underlie treatment (see also Laurenceau, Hayes, & Feldman, 2007).

The *probabilistic epigenetic* approach (Gottlieb, Wahlsten, & Lickliter, 2006; see also Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume)—a metatheoretical model consistent with Relational-Developmental-Systems—reflects another approach to further exploring pathways of development, through its focus on relational causality (Gottlieb & Halpern, 2003; Overton, 2006) among multiple levels of analysis related to gene-environment coactions (e.g., genetic, epigenetic, neural, behavioral, and the social and cultural elements of the external context) (Gottlieb & Willoughby, 2006). A central tenet of probabilistic epigenesist is the recognition that genes do not produce developmental outcomes but gene-environment coactions can be enormously important in understanding both adaptive and maladaptive pathways. The orientation of probabilistic-epigenetic studies entails the exploration of relational causal factors between and within various levels characterizing organism-environment coactions. Given that the study of the role of genes in development often relies on single nucleotide polymorphisms (SNPs), which are vast in number and markers for genes rather than genes themselves, and these elements are influenced by multiple other levels of analysis (e.g., the epigenetic level; Meaney, 2010), the challenges for articulating, and even more so replicating, developmental pathways are enormous. Nonetheless, some evidence is emerging to support relations between specific life events (e.g., conditions of maltreatment) and specific SNPs (short forms of the MAOA polymorphism) in the likelihood of disorder (e.g., Caspi et al., 2002; see, however, Charney, 2012; Joseph, 2010; Slavich & Cole, 2013). Given the value of exploring multiple levels of analysis, consistent with the DP perspective, the significance of multidisciplinary collaborations for future progress is emphasized.

O'Connor (2006) has called attention to the emerging interest in whether early experience has lasting effects on developmental pathways, and the importance from a DP perspective of exploring through what processes these effects may occur. Three developmental models for the lasting effects of early experience are identified: sensitive period, experience-adaptive, and life course. Although there is scant evidence for sensitive periods for psychological development in humans, there is evidence for biologically mediated sensitive periods for psychological phenotypes (e.g., exposure to rubella infection during the first trimester and autism). The programming or experience-adaptive model has received more attention than the sensitive period model in humans, but the focus has been the effects of early environmental experiences on biological rather than psychological processes (e.g., HPA axis). The metaphor of developmental pathways from a DP perspective is most directly applicable to the life-span developmental model, which proposes risk and protective experiences accumulating in development relate to individual differences in development. A key assumption, which contrasts with the other two models, is that the impact of early experiences on long-term outcomes may be mediated by subsequent risk and protective factors, rather than having necessarily having a direct effect on later experience. Also, contrasting with the other two models, life-span models place emphasis on psychological processes as accounting for relations between early experience and long-term outcomes.

In closing, the articulation of developmental pathways is at the heart of the DP perspective. That is, psychopathology is seen to result over time from a continual process of successive and changing patterns of adaptation and maladaptation of the individual in relation to their environment. The processes that result from these relational transactions are reflected in the emotional, behavioral, cognitive, and/or physiological patterns that may be labeled as normal behavior or a clinically significant syndrome. DP is ultimately concerned with accounting for how complex patterns of transaction over time are reflected in diverse pathways, some reflected in normal and desirable outcomes and others in maladjustment and disorder, which lays the foundation for both advanced DP science and optimal prevention and intervention directions. Inspired, at least in part, by DP, research on multiple forms of disorder has begun to make substantial progress in integrating a developmental perspective regarding pathways into the study of psychopathology, with evidence of future progress to come.

Resilience: A Deficit Problem-Based Perspective and Other Perspectives

The notion of resilience has great intuitive appeal and has been the subject of widespread interest within and beyond psychology. However, the notion of resilience is sometimes used at the level of weak metaphor and quite loosely defined; minimally, considerable definitional diversity is evident in the literature (Luthar, Cicchetti, & Becker, 2000a). A contribution of the DP perspective has been to grapple with the challenge of providing a more precise definition of resilience, including defining resilience from a developmental perspective (Garmezy, Masten, & Tellegen, 1984). The origins of the construct from a DP perspective can be traced to Garmezy's (1974) pioneering work with children of parents who had schizophrenia. In this work Garmezy identified a subset of children who evidenced positive outcomes despite high risk for psychopathology (see also Rutter, 1979). There is consensus from a DP perspective that the construct of resilience is concerned with children functioning well in the face of adversity. For example, Masten, Best, and Garmezy (1990) stated that "resilience refers to the process of, capacity for, or outcome of successful adaptation despite challenging or threatening circumstances" (p. 425). Luthar et al. (2000a) similarly note that "resilience refers to a dynamic process encompassing positive adaptation within the context of significant adversity" (p. 543). Resilience refers to dynamic developmental processes by which individuals are able to evidence competence despite adversity.

Relatedly, in early formulations, resiliency was thought of as a trait-like construct such as "invulnerability" (Anthony, 1974) and to operate in an "all or none" fashion. With regard to a DP perspective, there is now a consensus that resilience is not a unidimensional aspect of functioning or a static trait of some individuals and not of others (Luthar, Doernberger, & Zigler, 1993). Resilience is viewed as being best understood as a dynamic process reflecting the relational transactions of the individual with their environments (individual ←→ context) over time rather than a trait of the individual, a conclusion now supported from interdisciplinary perspectives (Hanson & Gottesman, 2012). Resilience is the process of achieving positive psychological outcomes in the face of adversity, which may also include physiological reactivity as part of the adaptive process (Obradović, 2012), or gene × environment coactions (Cicchetti & Rogosch, 2012). Approaching resilience as a dynamic process moves the construct beyond being a vague hypothetical toward articulating it in terms of substantive, testable DP models such as, for example, moderating, mediating or more complex models (e.g., moderated mediation) of underlying processes (Cummings et al., 2000; Roisman et al., 2012). Accordingly, from a DP perspective attention is focused on how resilience processes—involving potential relational transactions among child, family, and other environmental factors—function to promote positive outcomes. Thus, attention is focused on the underlying processes that operate in the context of a broader developmental and social ecological context (Luthar et al., 2000a).

There is less agreement about whether the construct of resilience should be limited only to individuals facing high risk, or whether resilience is a process that is widely observed. Either way, resilience is to some extent defined in relation to risk, reflecting interrelations between protective and risk factors in adaptive functioning. One perspective is that only those faced with high risk can truly qualify as resilient (e.g., Luthar et al., 2000a). According to this view, two conditions must clearly be met to demonstrate resilience: (1) a child must experience a relatively high level of risk processes, such as threat or adversity, associated with negative outcomes (i.e., vulnerability processes); and (2) the child is able to achieve positive adaptation in the sense of functioning well or at least avoid negative outcomes, despite high risk or threat to optimal developmental process (i.e., protective processes) (Luthar et al., 2000a; Luthar, 2006). This can be viewed as a deficit-problem based approach to resilience.

Despite the intuitive appeal of this deficit formulation, questions arise concerning how to define risk and how to establish "enough" risk for an individual to qualify as resilient. Can a cogent definition be achieved for the "significant" or "high" risk threshold to qualify responses as demonstrating resilience? For example, Egeland, Carlson, and Sroufe (1993) stated, "Resilience is often conceptualized as the positive end of the distribution of development outcomes in a sample of high-risk individuals. While these definitions are accepted by researchers of risk and resilience, factors defining risk samples and definitions of adaptation and competence vary widely across studies" (p. 517).

In contrast to the deficit model, a second approach conceptualizes resilience as a relatively commonly occurring process that is not confined to any one group of individuals, such as those experiencing high levels of adversity. For example, resilience may also be a relevant process in affluent as well as nonaffluent youth (Luthar & Barkin, 2012). From this point of view, resilience is a protective process that widely operates in opposition to processes of vulnerability to adversity, and thus it is a topic that merits study across many samples and contexts. For example, one can argue that all marital relationships, not just a specific subgroup, are at risk for problems with conflict resolution, which ultimately hold potential threats to the mental health of parents and children, as well as the stability and well-being of families (Cowan et al., 1996). Thus, efforts toward promoting prevention of conflict escalation—the effective coping with conflict between the parents—are relevant to promoting resilience in most families. From this perspective, it is not necessary to attempt to establish that risk level is sufficient (i.e., "high") to establish the occurrence of resilience, but it is still necessary to identify that individuals do face risk factors. Without this demonstration, it may be difficult to distinguish resilience processes from notions of factors more generally contributing to positive adjustment patterns (Luthar et al., 2000a). Moreover, resilience may reflect relatively more adaptive functioning than shown by others facing the same risk, rather than necessarily a high degree of positive functioning. Also, even if one assumes a high degree of risk is not needed for a definition of resilience, it is important for research designs to be sensitive to the fact that causal processes may operate differently for higher- versus lower-risk groups (Rutter, 2012).

Regardless of which of these two perspectives is adopted, each requires a fine-grained delineation of resilience processes. Whether individuals can be viewed as demonstrating resilient processes may depend on what domain of functioning is being studied, (i.e., children may be resilient in face of adversity in some contexts or domains but not others). In other words, although children may succeed in some domains of functioning, they may nonetheless have problems in other areas. For example, a child may be able to show resilient processes in sports at school but may not be resilient in academics. Thus, whether, or the extent to which, the child is resilient may change across contexts and people. As another example, a child's processes of resilience may vary widely in peer relations across different peer groups. Thus, care should be taken with regard to the developmental processes and contexts in which resilience is identified. Moreover, research designs should be sensitive to the possible operation of "steeling" effects as resilience processes (i.e., exposure to adversities resulting in decreased vulnerability to risk). Although evidence for the operation of steeling effects is limited in humans—due partially to the lack of sensitive research designs for detecting such processes—the strong evidence for steeling effects in animal research supports the promise for future investigation of this category of resilience process (Rutter, 2012).

Factoring in the critical role of development, from a DP perspective, resilience can be seen as the product of multiple developmental processes occurring over time in relational transactions between the child and environment (e.g., home, school, community, family, peers) by which children experiencing contexts of risk are able to function adaptively. Culture and immigrant status are also relevant contexts for relevant understanding the operation of processes of resilience (Motti-Stefanidi, Asendorpf, & Masten, 2012), and thus merit investigation as elements of the social ecological context relevant to understanding risk, protection, and resilience. From an empirical standpoint these coaction effects of the individual and context are central to the study of resilience (Roosa, 2000; Rutter, 1987). Thus, factors external to the child (e.g., family) may be important sources of resilience and resilience as a process may fluctuate over time. Criteria for adaptive functioning include demonstrating resilience in the face of risk, including the child's ability to function adaptively in stage-salient tasks, avoid negative mental health outcomes, or experience positive outcomes. Moreover, delineation of multiple aspects of resiliency processes in relation to multiple social ecological contexts and specific theoretical models about process are further goals for programmatic research on resilience (Luthar, Cicchetti, & Becker, 2000b). For example, in areas of political violence, sectarian community violence elevates risk for adjustment problems in children. Emotional security about family and community, family conflict and cohesion, and social identity with one's own ethnic groups, are dynamic processes in these contexts that are relevant over time to children's resilience in these contexts. Although resilience can only be inferred from the coaction of risk and protective factors and cannot be directly observed, emotional security (as opposed to insecurity) about community and family, low family conflict, greater family cohesion, and higher ethnic identity are evident as apparent resilience processes (Cummings et al. 2011; Cummings, Merrilees, et al., 2010, 2012, 2013; Cummings, Schermerhorn, Merrilees, Goeke-Morey, & Cairns, 2010; Merrilees et al., 2013).

Conclusion

Beginning with considering the defining elements of the DP perspective, including a call to increasingly include a developmental perspective in the consideration of adult clinical and psychiatric traditions, and closing with the treatment of the conceptual features of the DP perspective, including the important albeit conceptually and empirically complex construct of resilience, the authors have now reviewed many of the fundamental principles of developmental psychopathology. With regard to further articulating a theoretical frame for DP research, Figure 15.1 presents a model for visualizing the interrelations among factors relating to normal development and the development of

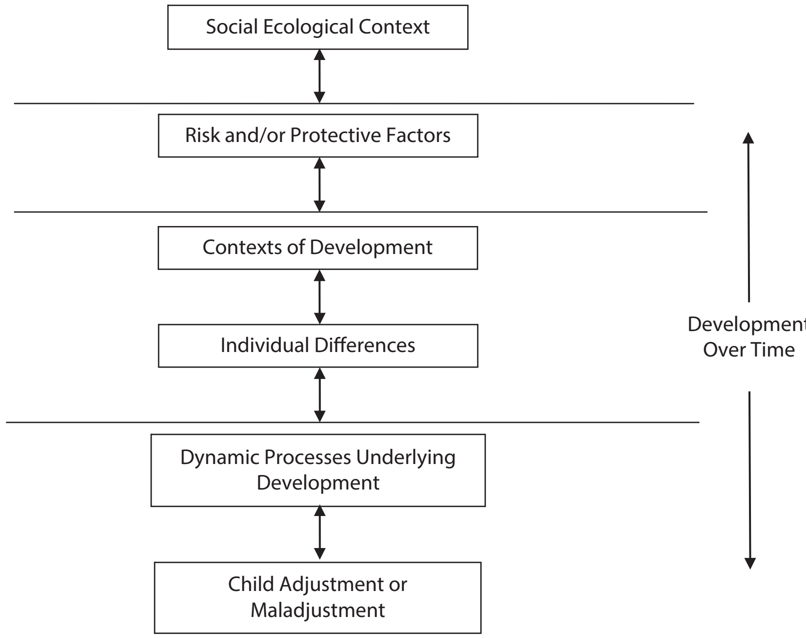

Figure 15.1 A framework for interrelations among factors relating to normal development and the development of psychopathology from a DP perspective.

psychopathology from a DP perspective. This frame can serve as a broad guidepost for the "big picture" what to consider in DP research, which may help identify what is adequately included and what may be missing in a program of research. With regard to explicating further the nature of these components, the social ecological context in this model provides a representation of more distal influences on development (e.g., political or community violence). Risk and protective factors reflect variables conceptualized as more immediate predictors of risk and/or protection (e.g., parental depression or alcohol problems). Contexts of development reflect relatively proximal influences on development (e.g., parenting; sibling relations; marital conflict, peer relations) which may closely coact with individual difference variables (e.g., biological or temperamental factors). All of these variables are potentially interrelated in affecting dynamic processes underlying development (e.g., emotional, social, physiological functioning; higher-order constructs of emotional security about parent-child relationships, family or community; allostatic load), which are likely to be the most proximal causal processes in predicting the individual's adjustment or maladjustment, including spectrums of symptoms of specific psychopathologies (e.g., autism spectrum disorder, depressive symptoms, conduct problems, or ADHD). Critically overarching all of these interrelations is development over time, by which these variables may have transactional influences over time, and evidence pathways of relative adjustment, maladjustment, or, more specifically, symptoms of specific psychopathologies.

APPLIED IMPLICATIONS AND DIRECTIONS

In the next section the investigators review applied implications and directions and the extension of the DP perspective to the study of specific contexts of development. Finally, we consider new directions in this always-developing area of inquiry.

Translational Research

The term *translational research* has received attention as an area of inquiry. Though use of the term has been widespread, agreement regarding the definition of *translational* has been difficult to establish (Cicchetti & Toth, 2006; Guerra, Graham, & Tolan, 2011; Toth & Cicchetti, 2011). Most broadly, the goal of translational research is to facilitate connections between basic research and its application to health outcomes including, but not limited to, treatment in the field of medicine, physical and/or mental health improvement, and positive child development. The principles that are reflected in translational approaches to research are consistent with and are an application of several key tenants of DP.

The emphasis on translational research was triggered by the National Institutes of Mental Health when they issued a roadmap (National Advisory Mental Health Council, 2000) to prioritize research emphasizing the usefulness and utilization of basic research discoveries toward the treatment or prevention of human disease (Zerhouni, 2003). Focusing research on its utility for improving public health has commonly been conceptualized in the medical field as how to transition research from “bench to bedside” (Insel, 2005) and includes a focus on how to apply knowledge gained from research on basic processes to inform, develop, or test new treatments (Insel, 2009; Pine, Helfinstein, Bar-Haim, Nelson, & Fox, 2009). As such, translational research includes all research along the chain from basic molecular research, to efficacy trials of interventions under controlled conditions (Type 1 translational research), to research on program implementation and effectiveness in bringing translational findings to scale in real world settings (Type 2 translational research) (Guerra et al., 2011).

Traditionally, bench to bedside research has been unidirectional with molecular or cellular studies preceding research in clinical settings. However, there has been a shift toward awareness that translational research is better conceptualized as a relational bidirectional (←→) process. As noted by Cicchetti & Toth (2006), just as basic scientists can develop new medications or tools for use with patients, clinical researchers may too learn new, valuable information about the nature and course of pathology that can inform new approaches to basic research. Such a relational bidirectional process is consistent with the developmental psychopathology perspective whereby knowledge on typical and atypical development is mutually informative (Cicchetti & Toth, 1998; Rutter & Sroufe, 2000). Just as unidirectional, main effects-type research has given way to more complex relational transactional models of developmental psychopathology (Cicchetti & Lynch, 1995; Cicchetti & Valentino, 2006), the original vision of translational research as solely proceeding from bench to bed has been conceptualized as overly simplistic and limiting (i.e., Aber, Brown, Jones, Berg, & Torrente, 2011). Current trends in translational research call for a two-way iterative processes between science and practice. An ongoing, mutual dialogue between basic scientific researchers and practitioner scientists is viewed as essential for progress in utilizing research to improve public health in real-world settings (Aber et al., 2011; Dodge, 2011).

Toward the goal of reducing the gap between research and practice, another inherent principle of translational research is to encourage new interdisciplinary partnerships and collaborations. The value placed on multidiscipline, multilevel research is a core pillar of DP that has been repeatedly emphasized (Cicchetti, 1990; Cicchetti & Valentino, 2007; Nelson et al., 2002; Sroufe & Rutter, 1984). Single discipline research is undoubtedly important for scientific progress. Nonetheless, as we have accumulated knowledge regarding the complexity of the onset and developmental course or progression of mental illness (or any disease processes), collaboration among multiple domains of expertise is central for the most timely advancements in the prevention and treatment of public health issues such as mental illness (Toth & Cicchetti, 2011).

Further, translational research focuses on processes, and recognizes that research on both risk and protective processes are informative. Underscoring the value of basic research, there must be a clear understanding of the processes that initiate and perpetuate the developmental pathways to disease (Cicchetti & Toth, 2006). Similarly, research on resilience that focuses on identifying processes allowing at-risk populations to overcome adversity and avert the development of psychopathology are informative to the development of preventive and intervention efforts (Luthar et al., 2000; Luthar, 2006). Some of the most informative exemplars of translational research are those studies that have identified modifiable risk or protective factors, which can be targeted in subsequent preventive or intervention efforts. For example, Berlin, Appleyard, and Dodge (2011) conducted a prospective, longitudinal study of child maltreatment across two generations. This research revealed that mothers’ childhood physical abuse directly predicted offspring victimization, but that this association was mediated by mothers’ social isolation and aggressive response biases (Berlin et al., 2011). Such research is informative with respect to the prevention of the intergenerational transmission of maltreatment through its highlighting the potential value of both increasing maternal social support and decreasing aggressive response biases in preventive programming, especially for mothers with their own physical abuse history.

Analysis of mediators and moderators within program evaluation research is another important component of translational research, which provides data to further refine program content and the appropriate targeting of services. For example, the Conduct Problems Prevention Research Group (Bierman et al., 2000) has demonstrated that the fast-track preventive intervention is successful in reducing multiple conduct and behavior problems, but only for those who are at the highest initial risk. Thus, tests of explanatory processes, including mediating and moderating processes are central to informing for whom interventions work best and, more importantly, why.

Finally, as research has attempted to move from Type 1 to Type 2 translational efforts, translational science has begun to recognize the necessity of studying the context in which individuals are embedded. Type 1 research is concerned with determining the efficacy of interventions whereas Type 2 research focuses on effectiveness of bringing interventions to scale in the real world. Rigorous scientific research with randomized clinical trials, typically in tightly controlled settings, is necessary for establishing whether intervention or prevention programs are efficacious. However, in order to move from efficacy to effectiveness to scalability, researchers must address the issue of real-world, typical conditions (Aber et al., 2011; Dodge, 2011). An emphasis on individual ←→ context relations is, of course, a central tenant of developmental psychopathology, which building upon Bronfenbrenner's social-ecological model (1977; Bronfenbrenner & Morris, 2006), has long since underscored the necessity of evaluating risk and proactive processes at multiple levels of ecology including the family, community, and broader culture (Bronfenbrenner, 1979). The process, then, of adapting interventions that demonstrate positive effects under favorable and controlled conditions to be successful in typical and less favorable conditions must begin to identify what factors at multiple levels (family, organizational, community, and policy) influence the effectiveness of interventions at scale (Aber et al., 2011).

Prevention and Intervention Research

Intervention and prevention science aims to intervene in the course of development in order to either eliminate or prevent the emergence of maladaptation and/or mental illness or to facilitate resilient functioning among individuals at high risk for psychopathology (Ialongo et al., 2002; Luthar & Cicchetti, 2000). Cicchetti and Gunnar (2008) have noted that "the discipline of developmental psychopathology, with its major focus on the dialectic between normal and abnormal development, is uniquely poised to provide the theoretical foundation for prevention science" (p. 737). In advancing toward this end a sophisticated, multilevel understanding of typical developmental processes and how deviations from these processes may lead to psychopathology is necessary to achieve the goal of identifying when, where, and how in the course of development to intervene. In addition to being one specific type of translational research, as noted above, prevention and intervention research is an especially critical domain of research because, from a DP perspective, randomized controlled trials (RCTs) provide vital opportunities for testing causal processes of development. Notably, these approaches may be further strengthened by propensity score matching, instrumental variable analyses, and regression discontinuity and other innovations in research designs (e.g., Heckman & Todd, 2009). Due to the nature of research on psychopathology and/or risk processes, researchers are almost always limited to correlational research designs one cannot, for example, randomize children into homes with and without interparental conflict. One can, however, manipulate key aspects of children's experiences through randomized controlled intervention studies, which then allows for examination of causal links between children's experiences (i.e., exposure to interparental conflict) and children's development. Thus, although prospective, longitudinal designs to identify salient explanatory risk and protective processes are highly valuable, prevention and intervention RCTs are true experiments and may further scientific advancements regarding the etiology of maladaptation and psychopathology (Cicchetti & Hinshaw, 2002; Ialongo et al., 2002).

A DP perspective on intervention and prevention science emphasizes the value of utilizing theoretically informed and empirically derived research findings to inform program content. Optimal prevention and intervention programs are informed and guided by a testable theoretical framework (Borkowski, Farris, & Weed, 2007; Nation et al., 2003). Moreover, the development of an intervention, including what developmental processes it aims to alter, should be based upon a foundation of rigorous empirical research. Several excellent examples of theoretically grounded and empirically informed intervention and prevention translational research have emerged (see the 2011 Special Issue of *Development & Psychopathology*, *23*, and 2011 Special Issue of *Child Development, 82*(1), for examples).

Grounded in emotional security theory (EST), Cummings and Schatz (2012) present data from a series of studies that has translated research on family conflict, emotional security, and child adjustment into a brief, psycho-educational prevention program. EST provides a family-wide model for the effects of conflict and related family influences on children's functioning (see Cummings & Davies, 2010, for review), and serves as the theoretical model for this prevention program. The basic premise of EST is that children's emotional security, that is their sense of protection, safety, and security about their parents' relationship and about the family as a whole, is related to children's well-being over time. Thus, children's emotional insecurity is a primary process explaining the effects of parental and family conflict on children's later maladjustment. Following extensive longitudinal research that has supported EST as an explanatory framework and has identified specific behaviors, which (a) undermine or (b) facilitate children's emotional security, the prevention program was designed to reduce risk behaviors and enhance protective behaviors toward the goal of improving child emotional security. For example, although destructive forms of family conflict increase risk for maladjustment, constructive forms of family conflict have been shown to support family security and promote positive child functioning in multiple domains (McCoy, Cummings, & Davies, 2009). As such, the program goals include advancing the constructiveness and decreasing the destructiveness of family conflict (Cummings & Schatz, 2012).

Consistent with a DP approach to intervention evaluation, this prevention program included multidomain assessments with multiple reporters and contexts to assess family-wide outcomes. Postintervention analysis of families randomized into: (a) a parent-adolescent program, (b) a parent-only program, (c) a self-study control, or (d) a no-treatment control revealed that adolescents who received the full intervention condition reported more secure attachment to their fathers. Moreover, fathers in the treatment groups reported that their adolescents were more emotionally secure about both interparental and parent-adolescent relationships (Cummings & Schatz, 2012). As such, results were consistent with the underlying theoretically based goal of improving children's attachment security about family relationships as a means to prevent later adjustment problems. Subsequent information from longer-term follow-up assessments will provide essential data about whether the program prevented and/or reduced child maladjustment, and has the potential to further establish children's emotional security as causally linked to emotional adjustment and well-being (Cummings & Schatz, 2012).

The Attachment and Biobehavioral Catch-up (ABC) Intervention for infants in foster care (Dozier et al., 2006) serves as another key example of intervention research informed by a DP perspective. Building on extensive research that has demonstrated the vital role of sensitive and responsive caregiving in modulating infants' developing HPA (hypothalamic-pituitary-adrenocorticol) stress and arousal (Gunnar & Donzella, 2002), Dozier's intervention focuses on improving foster parents' ability to detect signals of distress from infants and toddlers in foster care, and to respond to them in a consistent and sensitive manner. Young children in foster care have likely experienced abuse and/or neglect, which are likely to interfere with their development and functioning in multiple domains (Cicchetti & Valentino, 2006). Beyond traumatic experiences in the family of origin, children in foster care often face several additional circumstances where they may experience the absence of a supportive, responsive caregiver to externally scaffold their stress regulatory system, such as being placed with a nonsupportive foster parent or experiencing multiple disrupted foster placements and transitions. Preclinical research, however, indicates that reparation of the effects of early adversity on stress regulatory systems is possible during early childhood (Francis, Diorio, Plotsky, & Meaney, 2002). Thus, by supporting the foster caregiver-child relationship, the ABC intervention's conceptual model hypothesizes that the negative effects of early stress on the child's physiological system will be remediated, which will increase subsequent psychosocial functioning (Fisher, Gunnar, Dozier, Bruce, & Pears, 2006). Findings from the RCT, which included a foster care sample that was randomized into the ABC intervention or a regular foster care condition and a community comparison sample, indicated that children in the foster care intervention showed diurnal cortisol patterns that were similar to the community comparison group post-intervention, whereas the children in the regular foster care group showed abnormal patterns of diurnal cortisol. Additionally, fewer behavior problems were observed for toddlers in the foster care intervention group (Dozier et al., 2006).

Dozier's ABC intervention, as well as the similar intervention work of Fisher and colleagues (i.e., Fisher, Burraston, & Pears, 2005), coheres to provide evidence that interventions, which target improvement in caregiver behavior, can help normalize children's physiological functioning, and these changes are associated with improved behavioral functioning. These findings are particularly significant because they validate models of early stress that were based primarily on rodent research, and translated these models into efficacious intervention programs for some of our nation's most vulnerable children. Additionally, the intervention research of Dozier and Fisher demonstrates that by facilitating more competent, sensitive, and supportive caregiving among caregivers in the foster care system, that some of the effects of early adversity on children's neurobiology may be reversible. Finally, this research serves as an excellent example of how psychosocial interventions may influence biological as well as behavioral processes, and highlights the importance of measuring processes of action and potential change at multiple levels of analysis.

As preventive and intervention science moves forward and researchers increasingly adopt a DP, multilevel perspective, the next generation of research on the effects of psychosocial interventions should embed assessments of multiple psychological and biological systems into RCT designs (Cicchetti, Rogosch, Toth, & Sturge-Apple, 2011). Such multilevel designs will provide vital information on associations among multiple developing systems and complex pathways toward adaptive and maladaptive functioning.

Diagnosis and Classification of Mental Health Disorders

The standard for diagnosis and classification of mental health disorders in the United States is the *Diagnostic and Statistical Manual of Mental Disorders*, Fifth Edition (*DSM-5*), which is published by the American Psychiatric Association (APA; 2013). The *DSM* has made substantial progress in the standardization and reliability of psychiatric diagnosis. As we have noted, however, there are ongoing concerns from a DP perspective regarding (a) the use of a medical model for characterizing psychopathology, (b) the arbitrary boundaries between diagnostic categories and between typical and pathological functioning, (c) the minimal consideration of how psychopathology processes develop over time or differ as a function of development and (d) the insufficient attention paid to contextual factors and transactions between the individual and multiple levels of ecology (Achenbach & Rescorla, 2006; Cicchetti, 2006; Cicchetti & Cohen, 1995).

Following the tradition of classification based on observable symptoms, the *DSM* has intentionally strived to be atheoretical in its development and it utilizes a medical model to provide descriptive information about mental disorders akin to medical diseases. Although the current definition of psychopathology (or mental disorder) provided by the *DSM-5* improves over definitions offered in earlier versions by recognizing a mental disorder as “a syndrome characterized by clinically significant disturbance in an individual’s cognition, emotion regulation, or behavior that reflects a dysfunction in the psychological, biological, or developmental processes underlying mental functioning,” it continues to delineate that it “results from a dysfunction in the individual” (APA, 2013, p. 20).

Thus, the conceptualization of mental disorders as something that “occurs in an individual” is entirely inconsistent with the DP perspective that psychopathology represents processes of functioning that are maladaptive and that exist between the individual and multiple environmental influences (Cicchetti, 2006; Cummings et al., 2000). Moreover, as a categorical classification system, where clusters of symptoms are grouped together to form distinct “syndromes” that have criteria for determining whether they are clinically significant, the *DSM-5* forces those making diagnoses to determine whether the disorder is present or absent, rather than conceptualizing symptoms on a continuum. Such an approach to classification of mental health disorders has resulted in arbitrary boundaries between normal and pathological functioning, and among discrete disorders. In contrast, dimensional approaches to classification include three or more ordinal values to place symptomatology along a continuum of functioning.

Importantly, categorical and dimensional classification systems are not mutually exclusive, as every dimensional diagnosis could be made categorical by setting a clinical threshold value, and every categorical diagnosis could be made dimensional by considering issues such as severity of symptoms and impairment in functioning. Integrating continuous approaches into the current categorical system has several potential advantages from a DP perspective including the availability of more rich data, with greater statistical power and the opportunity to better integrate psychopathology with normative developmental research (Pine, 2006). Recognizing these issues, recommendations from a research planning conference for *DSM-5* included integrating dimensional components into the *DSM-5* (Helzer, Wittchen, Krueger, & Kraemer, 2008). Nonetheless, the *DSM-5* opted to not integrate more dimensional approaches into its official classification criteria. Instead, an alternate dimensional model for personality disorders, for example, is included in a separate section (Section III) described as “not sufficiently well established to be part of the official classification of mental disorders” (p. xliii), leaving the categorical criteria for personality disorders unchanged from the previous edition.

As argued earlier, from a DP perspective both development and context must feature prominently in diagnosing and treating mental disorders (Achenbach & Rescorla, 2006; Cicchetti, 2006; Cummings et al., 2000; Jensen & Hoagwood, 1997). If one exclusively focuses one’s attention on present symptomatology and the diagnostic category, one is ignoring why or how this maladaptation developed. The *DSM* definition of mental disorders implies that they are static or stable, rather than recognizing that adaptive and maladaptive response processes develop over time. Most disorders defined by the *DSM* have one set of diagnostic criteria and make no mention of how symptomatology may differ as a function of development, whereas accumulating evidence suggests the opposite (Levendosky, Huth-Bocks, Semel, & Shapiro, 2002; Scheeringa, Peebles, Cook, & Zeanah, 2001; Silk, Nath, Siegel, & Kendall, 2000).

Importantly, as children develop over time, so do age-appropriate expectations for behavior. Thus, it is virtually impossible to delineate the boundary between typical and atypical behavioral patterns without consideration of the individuals' developmental stage. Developmental science has clearly demonstrated that children change over time and the central tasks of development include continuously adapting in age-appropriate ways to the changing environment. As such, diagnostic criteria should reflect this ongoing transactional process and should be developmentally specific and contextually informed. Some changes in the *DSM-5* are promising in including more developmentally sensitive information. For example, some subheadings on development and course now provide descriptions of how symptom presentation may change across the life span; a different pattern of symptoms is now required for a diagnosis of PTSD among preschool-aged children than among adults.

By focusing merely on descriptions of behavior, the *DSM* largely ignores the complex contextual transactions and adaptations that affect individuals' developmental trajectories (Achenbach & Rescorla, 2006; Cicchetti & Cohen, 1995; Cicchetti, 2006; Jensen & Hoagwood, 1997). Individual development cannot be studied in isolation of the context in which the individual is embedded. Indeed, a vast body of literature coheres to demonstrate the critical role of contextual factors (i.e., family, peer, neighborhood, and culture) in psychopathology research among youth (e.g., Boyce et al., 1998; Cummings et al., 2000; Deater-Deckard, 2001). In contrast, there is a dearth of attention paid to these contextual influences in research involving *DSM* diagnoses (Drabick & Kendall, 2010).

The salience of the interpersonal context, for example, is especially relevant for children, as positive parenting is vital in supporting young children's cognitive development and in providing external emotional and physiological regulation for the child (e.g., Bowlby, 1969; Spangler, Schieche, Ilg, Maier, & Ackermann, 1994; Sroufe, Carlson, Levy, & Egeland, 1999). As such, parenting is a central factor for understanding both normative development as well as the development of psychopathology. Problems arising from "troubled relationships" however, are not considered to be clinical disorders in the *DSM* (Volkmar & Schwab-Stone, 1996). Thus despite including some of the most serious concerns that bring children to the attention of mental health professionals, such as child abuse, exposure to domestic violence, and bereavement, these serious relationship disruptions are classified in the *DSM* as special "v-codes." As noted by Achenbach and Rescorla (2006), the current system ignores everything the authors have learned from a transactional perspective, where psychopathology arises in the context of relationships, and is the product of reciprocal influences of individuals on one another. In this context, DP offers directions for advancing the diagnosis and classification of mental disorders including the consideration of normative development, dimensional models of psychopathology, and the roles of development and contextual factors in influencing the emergence and maintenance of psychopathology.

CONTEXTS OF DEVELOPMENT

The evaluation of what is adaptive or maladaptive must take into account the context in which the pattern occurs. Below, consider selected contexts as influences on development, including theory and evidence regarding processes associated with the impact of these contexts on development.

New Directions in the Study of Parenting

Current directions in the study of parenting (see Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume, for an extended discussion of parenting and socialization in general) are in line with many of the principles of a DP perspective, including the social ecological perspective (see Figure 15.1). The goal of the following section is to highlight salient examples of advances in parenting that embody the DP perspective and inform future directions in this field. In particular, the authors present exemplars of parenting research that have emphasized the importance of context, and the incorporation of multiple levels of analysis into research designs including neurobiology and behavior genetics.

The Context of Parenting Style

The benefits of an authoritative parenting style as well as the risks associated with an authoritarian style in relation to child development are well-documented (Gershoff, 2002). Whereas authoritative parenting is characterized by a warm, but firm style, authoritarian parenting is characterized by low warmth, demandingness, and high expectations for conformity and compliance with parental authority. Children raised in authoritative homes are better emotionally adjusted, have better school achievement, and fewer internalizing and externalizing disorders than do peers who have been raised in authoritarian, indulgent, or neglectful homes (i.e., Steinberg, 2001; Steinberg, Lamborn, Darling, Mounts, & Dornbusch, 1994). However, this research has focused on Caucasian and middle-class families. Consistent with an ecological-transactional perspective, variables operating at all ecological levels may influence each other in relation to child developmental outcomes (Cicchetti & Valentino, 2006). For example, cultural, racial, or ethnic group membership has been conceptualized as macrosystem-level factor that influences parenting practices (Cicchetti & Valentino, 2006; Spencer, 2006). An emerging literature suggests that authoritarian parenting, and its association with child outcomes, varies by racial context. For example, African American parents adopt authoritarian and restrictive parenting styles more frequently than do European American parents (Furstenberg, Brooks-Gunn, & Chase-Lansdale, 1989). Moreover, the adoption of authoritarian parenting styles in African American families are not associated with the adverse behavioral outcomes commonly linked with authoritarian parenting in European American families, such as hostility and resistance (Baumrind, 1972; Taylor & Roberts, 1995) or externalizing behavior problems (Deater-Deckard, Dodge, Bates, & Pettit, 1996). In contrast, authoritarian parenting may act *protectively* among African American families (Gunnoe & Mariner, 1997; Lansford, Deater-Deckard, Dodge, Bates, & Pettit, 2004), leading to less aggressive behavior and more positive developmental outcomes among African American children. Research on the intergenerational continuity of child abuse among a sample of adolescent mothers found that authoritarian parenting attitudes was associated with disrupting the continuity of child abuse into the next generation, but only among African American families (Valentino, Nuttall, Comas, & Borkowski, 2012). Such research underscores the need to include diverse samples of parents and children in parenting research, and to consider broader contextual influences on parenting styles, in particular. An implication is that parent training programs and their effects on child outcomes may vary based on racial or cultural context.

Incorporation of Biological Levels of Analysis Into Parenting Research

Attention has been paid to the biological processes that may contribute to explaining such associations, particularly on the physiological level. Models of allostasis (McEwen, 2002) have largely influenced thinking in this domain as an allostatis framework provides a means to explain how physiological response systems may serve explanatory function in the link between psychosocial stress and parent behaviors during transractions with their children (Sturge-Apple, Skibo, Rogosch, Ignjatovic, & Heinzelman, 2011). Allostatis refers to the regulatory functioning of the physiological system to respond to perceived challenges in the environment. An adaptive response to challenge includes activation of physiological stress response systems to provide adequate energy to respond to the challenge, as well as the ability to disengage response systems and to return to homeostasis once the threat has been removed (McEwen, 2002). In the face of chronic and/or high-magnitude stress, the allostatic response systems may become overwhelmed, lead to physiological dysregulation, and subsequently interfere with parents' ability to regulate in response to the stressors of parent-child interactions. As such, individual differences in parent physiological arousal and regulation resulting from exposure to psychosocial adversity may help explain associations between contextual risk and maladaptive parenting (Mills-Koonce et al., 2009; Sturge-Apple, Davies, Cicchetti, & Cummings, 2009).

Importantly, an emerging literature provides empirical support for the hypothesis that allostatic models of stress physiology may be associated with maladaptive parenting behavior. For example, focusing on cortisol, a primary hormone in the stress response, heightened maternal cortisol levels or reactivity have been associated with greater maternal use of overreactive disciplinary practices (Lorber & O'Leary, 2005), negative and intrusive behaviors (Mills-Koonce et al., 2009), and disrupted communication (Schechter et al., 2004). Furthermore, Mills-Koonce et al. (2009) considered a second physiological system, maternal parasympathetic reactivity, and found that the association between maternal baseline cortisol and negative intrusive parenting was attenuated when mothers displayed parasympathetic withdrawal during a stressful laboratory task. As such, considerations of single physiological systems in association with parenting behaviors are likely incomplete. Building on an allostatic framework, Sturge-Apple et al. (2011) measured multiple aspects of maternal physiological regulation to identify profiles of sympathovagal functioning and examined how each profile was associated with psychosocial risk and parenting practices. As expected, three patterns of sympathovagal functioning emerged: normative arousal, hyperarousal, and hypoarousal, and each was associated with meaningful differences in parenting behavior. Moreover, findings provided empirical evidence to support the notion that physiological dysregulation is an important process in the relation between proximal risk factors and maladaptive parenting behavior (Sturge-Apple et al., 2011).

Genetic-Epigenetic Perspectives

Over the past two decades, recognition that children's development cannot be simply explained by either biological or environmental factors and that their coaction is essential to consider (e.g., Ellis & Boyce, 2008) has led to a major shift in research. Traditional approaches to behavior-genetics research and parenting, for example, were based on an additive model where heredity and environmental components were assumed to be independent and separable. An additive approach constrained the understanding of the role of parenting in child development for several reasons. First, with the rise of the field of epigenetics (see, e.g., Charney, 2012; Ho, 2012; Keller, 2010; Meaney, 2010; Slavich & Cole, 2013) and earlier work by Gottlieb and his colleagues on probabilistic epigenesis (e.g., Gottlieb et al., 2006) it has become clear that genes themselves function as only one component of an enormously complex biological ←→ environmental system and there can be no direct association between genotype and phenotype. DP theory has long espoused the importance of context and coactions between individual characteristics and environmental influences (Cicchetti, 1984, 2006; Cummings et al., 2000).

Children and Interparental Conflict: Family-Wide and Community Contextual Factors

The value of the DP perspective is evident for understanding the effects of the marital subsystem on child development, given the complexity and diversity of dynamic processes that are engaged by transactions between the child and family, including the interrelations among marital functioning, parenting, and broader levels of functioning, including community influence. Interparental conflict is among the most widely studied exemplars of the impact of the marital subsystem on child development, with extensive support for the impact of marital conflict on the development of adjustment problems in children (Grych & Fincham, 1990). In broad outline, marital conflict has direct effects on children through their exposure to these incidents and indirect effects through changes in parenting, which are widely documented as well as other family processes (e.g., sibling relations, Bascoe, Davies, & Cummings, 2012; peer relations, Bascoe, Davies, Sturge-Apple, & Cummings, 2009) and factors in the impact of multiple family problems (e.g., parental depression and alcohol problems on children, e.g., Keller, Rogers, Koss, Cummings, & Davies, 2011; Kouros, Papp, & Cummings, 2008) on children.

Given this history and the challenges for research, interparental conflict has long been studied from a dynamic, process-oriented perspective (Cummings & Cummings, 1988), including multiple perspectives on dynamic processes (e.g., physiological processes, El-Sheikh, Cummings, & Goetsch, 1989), with evidence long accumulating for the significance of specific contexts of marital conflict for the impact on child development and parenting (Harold, Shelton, Goeke-Morey, & Cummings, 2004; McCoy, George, Cummings, & Davies, in press; Sturge-Apple, Davies, & Cummings, 2006), the importance of studying the normal and abnormal together, adherence to diverse and inclusive methodological directions and for the effects of interparental conflict through multiple pathways (Cummings & Davies, 2010). Moreover, study of relations between marital conflict and child adjustment from a DP perspective have been extensively developed (Cummings et al., 2000), including an extensive treatment of the status of research on interparental conflict, family factors, and developmental psychopathology in the last published *Handbook of Developmental Psychopathology* (Davies & Cummings, 2006), with an update of the latest research findings consistent with a DP perspective (Cummings & Davies, 2010). In light of this voluminous published work, the current review will focus on the development of selected, specific themes that are a particular focus of research in this area from a DP perspective.

Advancing a Theoretical Model for Dynamic Explanatory Processes From a DP Perspective: Emotional Security Theory

In the study of interparental conflict and child adjustment, emotional security theory (EST; Davies & Cummings, 1994) uniquely proposes, from an systems perspective, a higher-order conceptualization of dynamic emotional, social, cognitive, and physiological regulatory processes that are specifically observable and testable and have been subject to rigorous hypothesis testing in the context of multiple measurement strategies (questionnaires and structured interviews completed by parents and children, analogue and experimental designs, diaries completed by family members in the home, dyadic and triadic observational assessments, multiple approaches to testing the role of multiple physiological regulatory systems, testing theoretical tenets in the context of prevention research, and short- and long-term longitudinal model testing based on autoregressive structural equation modeling and growth curve analyses) (Cummings & Davies, 1994, 2010). Moreover, EST is conceptualized based on constructs identified as central to stage-salient issues in child development, that is, children's emotional security about family relationships, with approaches to analyses flexibly allowing for changes in higher-order reorganizations of the construct during development, including assessments of past and current organizations of emotional security as dynamic influences on current functioning (Davies et al., in press).

EXTENDING PERSPECTIVES ON EMOTIONAL SECURITY BEYOND THE PARENT-CHILD DYAD

Building on a well-established developmental literature based on attachment theory (Bowlby, 1969), consistent with evolving conceptualizations of the theory and measurement of emotional security as a life-span construct relevant across multiple child development stages and contexts (Cicchetti, Cummings, Greenberg, & Marvin, 1990; Waters & Cummings, 2000), emotional security theory (EST) was proposed and progressively developed to extend attachment theory beyond the parent-child dyad to account for children's security and adjustment in the context of marital and family conflict (see Forman & Davies, 2005, for an organizational approach for assessing emotional security as a family-wide construct), and in the context of the community (Cummings et al., 2009; Goeke-Morey et al., 2009). Emotional security is conceptualized as a set goal, and when threatened, for example due to prolonged exposure to family conflict or community violence, the theory predicts that children are motivated to respond emotionally, behaviorally, cognitively, and physiologically, as an adaptive regulation response to regain emotional security. Such responses might include mediating in the threatening contexts of parents' conflicts and acting out to create a distraction or as an expression of behavioral and/or emotional dysregulation. Although adaptive in the short run, over long periods, heightened responding to threat may contribute to a youth's risks for psychopathology and other adjustment problems. For example, heightened emotional and behavioral arousal may foster effective responding to the threat of interparental violence, but may have a long-term cost in terms of sensitization to stress (i.e., overreactivity), elevating the risk for a youth's aggression or depression. Sensitization in response to repeated exposure to marital and family conflict is a particularly well-documented and established empirical finding (Davies, Myers, Cummings, & Heindel, 1999; Davies, Sturge-Apple, Winter, Cummings, & Farrell, 2006; Papp, Goeke-Morey, & Cummings, 2013). Although the child evaluates interpersonal contexts in relation to multiple goals, EST postulates that safety and security are among the most salient in the hierarchy of human goals throughout development, from infancy through adolescence, and perhaps across the life span (Cummings & Davies, 2010).

AN EST PERSPECTIVE ON MARITAL CONFLICT AS A RISK AND PROTECTIVE PROCESS

A useful analogy is to think of emotional security as a bridge between the child and the world. When family and community relationships are functioning well, they serve as a secure base, supporting the child's exploration and relationships with others. When destructive family and community relations erode the bridge, children may become hesitant to move forward and lack confidence, or may move forward in an uncertain way, unable to find appropriate footing within themselves or in interaction with others. However, on the positive side, consistent with the DP emphasis on examining risk and protective factors, there is now extensive support for the notion that some contexts of marital conflict are protective (i.e., constructive marital conflict), eliciting positive emotional responses even in the context of conflict occurring in the home, and long-term positive adaptation (e.g., Cummings, Goeke-Morey, & Papp, 2003; Goeke-Morey, Cummings & Papp 2007; McCoy et al., 2009), although the negative effects of exposure to destructive conflict may potentially outweigh exposure to constructive conflict (Davies, Cicchetti, & Martin, 2012).

Emotional security has received substantial empirical support as a key process mediating children's well-being or maladjustment in high-conflict settings, that is, emotional security can be looked at as a protective factor whereas emotional insecurity can be seen as a risk process (Cummings & Davies, 2010). Emotional *insecurity* is measured by a youth's observable regulatory processes of emotional (e.g., heightened fear), behavioral (e.g., elevated efforts to mediate in conflicts), cognitive (e.g., insecure cognitive models about family and community relationships), and physiological (e.g., elevated cortisol reactivity to conflict and violence) responses. Numerous cross-sectional and longitudinal studies support the core propositions of this theory (for tests, see Cummings, George, et al., 2012; Davies et al., in press; El-Sheikh, Cummings, Kouros, Elmore-Staton, & Buckhalt, 2008), beginning with Davies & Cummings (1998). For example, empirical tests have shown that emotional insecurity mediates the long-term effects of interparental conflict on children's adjustment from kindergarten through adolescence (Cummings & Davies, 2010).

FAMILY-WIDE AND COMMUNITY INFLUENCES ON EST AND CHILD ADJUSTMENT

Emotional security has been conceptualized and tested as a family-wide construct, with evidence supporting family-wide classifications of emotional security about family (e.g., Sturge-Apple, Davies, & Cummings, 2010; Winter, Davies, & Cummings, 2010). Moreover, evidence has emerged to support longitudinally bidirectional relations between children's emotional security and marital conflict shown longitudinally (Schermerhorn, Cummings, DeCarlo, & Davies, 2007) and dynamical systems analyses (Schermerhorn et al., 2010). From a conceptual perspective, we have elsewhere proposed a model for extending EST to replace and provide a more cogent process model for the so-called spillover hypothesis for why marital conflict has effects on parenting processes (Cummings & Davies, 2010).

Consistent with Bronfenbrenner's social ecological model (1977; see also Cicchetti & Lynch, 1993; Cicchetti & Valentino, 2006), there is also increasing support for the view that interparental conflict is also relevant for understanding the effects of the broader social and cultural contexts on children's normal development and development of psychopathology. An extended experience of insecurity may result in increased vigilance to threat, for example, sensitization to community violence (Cummings & Davies, 2010). Emotional insecurity is reflected in multiple levels of the social ecology (e.g., family, community) and can describe psychological processes that explain relationships between political violence and youth well-being, relevant to the capacity and disposition of youth to contribute to restoring civil societies. Cross-sectional and longitudinal studies now support the extension of EST outside the family system to explain how children's response of insecurity in the face of community conflict and violence in turn increases internalizing and externalizing symptoms (e.g., Cummings, Merrilees, et al., 2010, 2011; Cummings, Schermerhorn, et al., 2010), including distinguishing between contexts of community violence that affect children in contexts of political violence (Cummings, Taylor, et al., 2013), charting pathways of development associated with emotional insecurity about the community (Cummings, Merrilees, et al., 2013), and longitudinally tracing the effects of sectarian community violence on child adjustment through pathways including family conflict and children's emotional insecurity about family (Cummings, Merilees, et al., 2012).

Multiple Perspectives on Dynamic Processes, Including Biological Processes

Another rapidly emerging perspective on marital conflict and child adjustment consistent with the DP perspective has been the investigation of multiple and diverse processes as relevant to the impact of marital conflict on child adjustment, including multiple physiological and biologically related processes. Far from being content to investigate predictors of risk and protection for psychological maladjustment from simply the perspective of self-report, research on marital conflict and child development has long been concerned with the role of physiological and other biologically related processes (e.g., sleep) concerned with the dynamic processes in development that are linked with children's normal development and risk for the development of psychopathology and other adjustment problems (e.g., school functioning).

Substantial research has examined children's cortisol reactivity to marital conflict as processes related to child maladjustment, linking both high and low cortisol reactivity to increased risk for adjustment problems (Davies, Sturge-Apple, Cicchetti, & Cummings, 2007), and high cortisol reactivity specifically to children's psychological reactivity in the face of marital conflict (Davies, Sturge-Apple, Cicchetti, & Cummings, 2008; see also Koss et al., 2013). Some work further suggests interactions between cortisol reactivity and temperament in the implications for child maladjustment (Davies, Sturge-Apple, & Cicchetti, 2011). El-Sheikh, Keiley, Erath, & Dyer (2013) found that autonomic nervous system reactivity was a factor in relations between marital conflict and children's internalizing symptoms. Some work has called attention to the importance of considering interactions between physiological systems in considering relations between marital conflict and child adjustment. Koss, George, Cummings, and Davies (2014) examined interactions between children's autonomic nervous system activity and adrenocortical functioning in the context of marital discord. A key finding was that asymmetry among higher alpha-amylase and lower cortisol related to higher emotional insecurity and concurrent and subsequent maladjustment. In particular, support for the interactive model was most pronounced in the context of low cortisol and high sAA levels among children exposed to higher levels of marital conflict. Also suggesting interactions between physiological systems, El-Sheikh et al. (2009) reported interrelations between sympathetic and parasympathetic nervous system functioning in predicting relations between marital conflict and children's externalizing problems.

With regard to another biological process, marital conflict has also been associated with children's sleep, with sleep and other individual and family processes implicated in children's adjustment problems. For example, research has demonstrated relations between marital conflict, emotional insecurity, sleep problems, and diminished school performance (El-Sheikh, Buckhalt, Cummings, & Keller, 2007; El-Sheikh, Buckhalt, Keller, Cummings, & Acebo, 2007). As another example, El-Sheikh, Kelly, Buckhalt & Hinnant (2010) reported longitudinal relations between sleep problems and worse adjustment outcomes during development, with African American children and children from lower SES at particular risk. Kelly and El-Sheikh (2011) indicated, also based on longitudinal analyses, reciprocal relations between marital conflict and children's sleep problems. El-Sheikh, Kelly, Bagley, and Wetter (2012) found relations between parental depression and multiple indicators of children's sleep problems, with marital and parent-child conflict factoring in these relations over time.

Sibling Relationships

Sibling relationships are an often neglected context of development (Feinberg, Solmeyer & McHale, 2012; McHale, Updegraff, & Whiteman, 2012). Just as the interparental and parent-child subsystems are important contexts for child development and adjustment, so is the context of sibling relationships. In fact, data indicate that children in the United States are more likely to grow up with a sibling than with a father (McHale et al., 2006). Sibling relationships are an important part of the family system that have reciprocal influences on both parent-child and interparental family dynamics, including implications for child well-being and adjustment.

Likely contributing to the paucity of research on sibling relationships is the complexity involved in studying them. Sibling relationships are defined by several structural features including age spacing, gender constellation, and ordinal status, in addition to overall placement within the larger family constellation, that are difficult to account for in research designs. Initial sibling research focused heavily on evaluating how these structural characteristics affected child development rather than considering aspects of the relationships itself, such as relationship quality. However, studies that have examined links between structural characteristics and sibling relationship dynamics indicate that structure variables do not fully account for outcomes and underscore that relationship processes, including the quality of the sibling relationship, should be directly measured (e.g., Buhrmester & Furman, 1990).

Broadly, sibling *relationship*s may affect child development and adjustment in multiple ways, and these associations may be direct or indirect. Focusing on direct associations between sibling relationships and development, several studies have documented a positive influence of siblings on child well-being. In particular, sibling relationships may allow children to develop skills in emotion understanding, perspective taking, communication, and problem solving (Brown, Donelan-McCall, & Dunn, 1996; Dunn, 2007; Howe, Rinaldi, Jennings, & Petrakos, 2002). Moreover, these social skills, when learned in the context of close and supportive sibling relationships, appear to spill over into other relationships such as friendships and romantic relationships (Bank, Burraston, & Snyder, 2004; Updegraff, McHale, & Crouter, 2002). In contrast, negative sibling relationships, such as those characterized by aggression and violence, have been associated with delinquency and aggression, even after accounting for other forms of family violence (Button & Gealt, 2010). Similarly, even when controlling for the influences of parents and peers, several studies have documented sibling concordance in substance use during adolescence (Fagan & Najman, 2005; Windle, 2000). Moreover, longitudinal research has demonstrated that sibling conflict predicts increases in subsequent anxiety, depressed mood, and delinquency after accounting for maternal negativity and marital conflict (Kim, McHale, Crouter, & Osgood, 2007).

Moving beyond main effects, research has begun to identify pathways through which siblings indirectly contribute to child development and psychopathology. Regarding positive influences on development, supportive, close and warm sibling relationships may serve as a protective factor for child well-being in the face of negative experiences. For example, a positive sibling relationship has been show to buffer youth from the effects of a stressful life event (Gass, Jenkins, & Dunn, 2007). Similarly, Peltonen, Qouta, El Sarraj, and Punamäki (2010) demonstrated that among a sample of children exposed to war trauma, only those who reported poor sibling relationships (characterized by low warmth and high rivalry) showed a positive association between exposure to war and trauma symptoms. Additionally, sibling relationships may be related to child well-being indirectly through their influence on the development of positive peer relationships. Longitudinal research by Yeh and Lempers (2004) is consistent with this hypothesis, and demonstrated that adolescents who reported a positive sibling relationship at one time point had better friendships and higher self-esteem at a second time point, which in turn, was associated with less depression and loneliness at a third time.

Alternately, sibling relationships characterized by negativity and coercion may contribute to the development of psychopathology. For example, coercive sibling relationships are a stressor for parents (McHale & Crouter, 1996) and may derail or disrupt competent parenting practices (Brody, 2003; Dishion, Owen, & Bullock, 2004). Disrupted parenting may include reduced parental monitoring of sibling behavior, which has been linked to lower self-esteem and higher risk for depression (Jacobson & Crockett, 2000). Relatedly, Feinberg et al. (2012) proposed a process model for how sibling negativity and coercion may be linked to depression, delinquency, and substance abuse, which includes three primary processes. First, as mentioned previously, sibling coercion may lead to impaired parenting, which may include poor parental monitoring and may contribute to internalizing and externalizing problems. Second, coercive sibling relationships may reinforce a coercive individual style of interacting with others, (i.e., poor emotion regulation, conduct problems) that may contribute to school and peer relationship difficulties as well as subsequent externalizing problems and substance use. And third, sibling negativity and coercion may contribute to sibling deviance training, whereby siblings are influenced by each others' deviant behavior, leading to possible increased exposure to substances and delinquent peer groups as well as greater susceptibility to peer pressure (Feinberg et al., 2012). Such a model represents substantial advancement by considering the specific developmental processes through which sibling relationships may contribute to psychopathology and in providing a testable framework for subsequent research in this domain.

Much progress has been made regarding the sibling context of development, however, much remains to be accomplished. With the availability of more sophisticated data-analytic techniques, researchers are now in a position to be able to evaluate ordinal status, developmental timing, and other structural characteristics of siblings in tandem with measures of relationship quality. For example, Campione-Barr, Basset-Greer, and Kruse (2013), utilized actor-partner models in the longitudinal evaluation of sibling relationships quality in relation to child outcomes. Importantly, considerations of ordinal status (older versus younger) and gender pairings were moderators of the association between sibling relationships and child adjustment, underscoring the need to consider both structural characteristics and relational processes in sibling research. Beyond including sibling structural and relationship process variables in sibling research, future research should strive next to examine associations with the larger family and sociocontexual conditions (McHale et al., 2012). For example, sibling research would benefit from a greater consideration of cultural context, as most of the research in this area to date involves European American families and biological siblings. Finally, sibling research has much promise for informing prevention and intervention efforts to improve child well-being (see Feinberg et al., 2012, for review). Beyond their utility in potentially reducing risk for psychopathology, interventions that target improving sibling relationships provide opportunities to test causal hypotheses regarding sibling dynamics and child developmental trajectories.

Peer Influences

As children reach middle childhood and adolescence and are immersed in the school environment, peers become a powerful context of development. As such, the development and maintenance of successful peer relationships is considered a critical stage salient task with important implications for children's subsequent development. In particular, peers become increasingly influential throughout childhood, and susceptibility to this influence typically peaks during adolescence (Dishion et al., 2004; Steinberg & Monahan, 2007). Thus by the time children reach adolescence, they may use peers more so than parents to determine certain aspects of development, such as the pace of establishing behavioral autonomy (Daddis, 2011). Given this high degree of influence, it is not surprising that peer relationships play an important role in children's developmental trajectories, both positive and negative.

Peer experiences are generally classified into two categories: group experiences and dyadic experiences (Parker, Rubin, Erath, Wojslawowicz, & Buskirk, 2006; Rubin, Bukowski, & Parker, 2006). Group experiences refer to children's social status within a larger peer group. Within this context, peer acceptance (the extent to which other children hold positive views about a child) and peer rejection (the extent to which other children hold negative views about a child) are primary indicators of this status (Bukowski, Sippola, Hoza, & Newcomb, 2000). Dyadic experiences generally refer to children's friendships (Gifford-Smith & Brownell, 2003), though they also include romantic relationships. Both group and dyadic experiences have been associated with children's and adolescents' development, and these likely occur through different processes (Véronneau, Vitaro, Brendgen, Dishion, & Tremblay, 2010).

Research delineating the processes through which peer relationships (both group and dyadic) may have a positive influence on development has predominantly focused on interrelations with academic achievement. For example, at the group level, improved academic achievement has also been shown to improve children's level of acceptance in the peer group (Coie & Krehbiel, 1984). At the dyadic level, children high in academic achievement tend to affiliate with friends who are similarly high-achieving, and this affiliation predicts an increase in children's own academic achievement over time (Wentzel, 2005). Taken a step further, Véronneau et al. (2010) proposed that peer and academic domains are most likely reciprocally interrelated and hypothesized transactional links between children's academic achievement and group-level peer variables, as well as between achievement and friendship-level peer variables, and predicted that the relative influences of group-level versus friendship-level peer variables would vary across development from middle childhood to adolescence. Importantly, higher academic achievement predicted increases in peer acceptance and decreases in peer rejection over time, as well as increases in friends' achievement. Reciprocal processes between acceptance and achievement were not supported as peer acceptance did not predict children's later achievement. Peer rejection did predict a decrease in participants' academic achievement over time, supporting a transactional link between peer rejection and academic achievement.

Positive peer relationships may also act as an important buffer against the development of psychopathology. For example, children who have experienced maltreatment are at substantial risk for the development of both internalizing and externalizing disorders (Cicchetti & Valentino, 2006). Having high-quality friendships, however, may moderate the effect of maltreatment on children's developing self-esteem (Bolger, Patterson, & Kupersmidt, 1998). In particular, having a high-quality friendship in the form of a reciprocated best friend was associated with a greater increase over time in self-esteem among physically abused children and those who had experienced chronic maltreatment. Thus, peer friendships may help ameliorate some adverse effects of maltreatment on children's well-being. Furthermore, focusing on the group-experience level of peer relationships, Kim and Cicchetti (2010) tested an integrative longitudinal model that involved both peer relations (acceptance and rejection) and maladjustment in examining the roles of emotion regulation in the development of psychopathology among maltreated and nonmaltreated school-aged children. Across all children, higher initial emotion regulation was predictive of higher peer acceptance over time, which was related to lower internalizing symptomatology, controlling for initial levels of symptoms (Kim & Cicchetti, 2010). Thus, peer acceptance was the primary process through which adaptive emotion regulation exerted protective effects for the development of internalizing problems.

Just as positive peer relationships may benefit child development, negative peer relationships play a role in the development of maladaptive and psychopathological outcomes. As will be detailed in later sections, peer relationships have a central role in the development of delinquency, conduct disorder, and substance abuse. Broadly, relationships with deviant peers are facilitative of adolescent problem behavior and may account for growth in violent behavior (Dishion, Véronneau, & Myers, 2010). For example Dodge, Greenberg, Malone, and the Conduct Problem and Prevention Research Group (2008) utilized a cascade model to demonstrate a progression from antisocial behavior to more serious violence with drift into a deviant peer group as a key explanatory process. Involvement with a deviant peer group may relate to amplification of antisocial behavior due to "deviancy training." Deviancy training involves a process of heavy reinforcement within a friendship or group that is characterized by deviant stories, endorsement of deviant attitudes and norm violating behavior, and is a form of peer contagion that explains how friendships can exacerbate problem behaviors (Dishion & Tipsord, 2011). Dishion et al. (2010) demonstrated that violence at Age 18 was predicted by gang involvement at Age 14, and deviancy training was the primary explanatory process.

Peer contagion also appears to exist with regard to emotion and the development or amplification of depressive symptoms. For example, adolescent friends' depressive symptoms have been shown to predict future depressive symptoms in the adolescent, controlling for initial adolescent depressive symptoms (Stevens & Prinstein, 2005). Co-rumination may be one process by which peer contagion can lead to internalizing problems. Co-rumination refers to excessive discussion of problems with peers, which may exacerbate negative emotion (Rose, 2002). This process is more common among females than male, and has been linked to both depression and anxiety in longitudinal research (i.e., Rose, Carlson, & Waller, 2007), suggesting a possible bidirectional association between co-rumination and internalizing symptoms.

Overall, peer contagion appears to be a central construct for understanding how the context of peer relationships may be associated with the development of psychopathology, particularly during adolescence. Moving forward, it will be important for future research to increasingly address peer contagion in the context of interventions, especially in those utilizing a group format. Alarmingly, there is evidence that peer contagion can undermine intervention effectiveness, or even produce increases in problematic behavior, when interventions aggregate high-risk youth for preventive or intervention programs (Dishion & Tipsord, 2011, for review). It will be important for future research to continue identifying moderators of peer contagion effects (such as adult monitoring and self regulation), which may then be targeted in setting such as schools or juvenile corrections facilities to prevent the amplification of psychopathology.

NEW DIRECTIONS AND EMERGING THEMES

Another feature of the DP perspective is to seek to expand the boundaries of conceptualization and articulation of theory and research methods for studying normal development and the development of psychopathology. These efforts are driven by the efforts by investigators and research teams consistent with the DP perspective toward advancing the boundaries for research and understanding of developmental process, context, and psychopathology. A synergistic direction toward further promoting and fostering these advances are Special Issues of *Development and Psychopathology* devoted to emerging themes, which has been an aspect of this journal since it began. For example, special issues have been concerned with "Contributions of the Genetic/Genomic Sciences in Developmental Psychopathology" (2012, Volume 24, Number 4), "Gene-Environment Correlation in Developmental Psychopathology" (2013, Volume 25, Number 1), Allostatic Load (2011, Volume 23, Numbers 3 and 4), and "Precursors and Diverse Pathways to Personality Disorder in Children and Adolescence" (2009, Volume 21, Numbers 3 and 4). Space precludes covering all of these and other new directions and emerging themes in DP, but this element of this research direction is significant to the general themes of DP reflecting an expansive approach to uncovering processes and pathways relevant to normal development and the development of psychopathology. As a further illustration the authors provide coverage of one of these directions that have the subject of special issues; that is, developmental cascades.

Developmental Cascades

The authors have called attention to the centrality of the study of developmental pathways to the DP perspective. DP has made substantial contributions toward raising awareness of ways to conceptualize the role of developmental processes in normal development and the development of psychopathology to advance beyond underdeveloped notions of the pathways metaphor, such as examining developmental pathways as if they are deterministic or provide both prediction and explanation. The notion of developmental cascades, the focus of two issues of *Development and Psychopathology* (2010, Volume 22, Issues 3 and 4), is a concept that holds promise to advance the sophistication and comprehensiveness of directions for studying developmental pathways.

According to Masten and Cicchetti (2010):

> *Developmental cascades* refer to the cumulative consequences for development of the many interactions and transactions occurring in developing systems that result in spreading effects across levels, among domains at the same level, and across different systems or generations. Theoretically, these effects

> may be direct and unidirectional, direct and bidirectional, or indirect through various pathways, but the consequences are not transient: developmental cascades alter the course of development. (p. 491)

The notion of developmental cascades articulates the possibility that problems or competencies in early development may have effects that spread across levels of functioning in a multiplicity of ways over time, including relatively wide-ranging impacts on development. For example, some aspects of childhood success (e.g., cognitive competence) or difficulty (e.g., conduct problems) may predict or be strongly associated with adolescent or adult adjustment across multiple domains of functioning.

Masten and Cicchetti (2010) offer several additional propositions to further guide the conceptualization of cascade effects, including (a) effects may be positive or negative in implications for adaptive development, (b) effects may be complex, moving across domains of functioning and in interactions with processes associated with other systems in development, (c) success, or lack of success, in accomplishing stage-salient tasks in childhood or adolescence may be particularly relevant to the likelihood of far-reaching and wide-ranging implications for later development. Cascade notions thus have exciting implications for intervention designs, because of the possibility offered for targeting key mediating processes that have powerful implications for promoting later adaptive functioning across not just one domain, but across multiple aspects of later development. For example, if causal and stage-salient mediating processes can be identified and changed in prevention designs, there is the potential to initiate developmental pathways of positive effects across multiple domains of later functioning (Hinshaw, 2002). These approaches are most promising if also based on well-articulated theory to guide the timing and nature of intervention models.

Although a promising direction, developmental models for pathways of cascading effects are in an early stage of exploration, as are the development of intervention and prevention research designs based on these concepts. There are substantial challenges that need to be met to take full advantage of these concepts. First, a theory about change processes underlying cascade effects and how treatment should be initiated with regard to potential change processes is highly important. At present, however, theory about change processes in treatment approaches often lack a sufficiently sophisticated level of analysis (Hinshaw, 2002), including when and how it is best to implement prevention efforts from a developmental perspective (Masten, Long, Kuo, McCormick, & Desjardins, 2009). Second, there are multiple substantial statistical and methodological challenges, including (a) the difficulty of obtaining adequate longitudinal data, in terms of sufficiently repeated and appropriately timed assessments of multiple and relevant response domains, in order to test these models, (b) accounting for continuity and stability over time, in order to establish the existence of a unique cascade process, (c) differentiating cascade effects from other developmental elements of process that are also occurring at the same time, and (d) adequately ruling out possible third variable explanations (Masten & Cicchetti, 2010).

Models relevant to the concept of cascading developmental pathways are most evident in research on conduct problems, including the notion of intervening as early as preschool years to foster better later functioning in school, in terms of internalizing symptoms and with regard to general social competence. For example, beginning in kindergarten, and assessed at 12 time points though Grade 3, between 4 and 8 years of age, Lansford, Malone, Dodge, Pettit, and Bates (2010) reported support for a developmental cascade model of peer rejection, social information processing biases, and aggression whereby each construct had effects on the others, resulting in a snowballing effect over time. Given the escalating and cascading interrelations between maladaptive peer behaviors, the authors concluded the results indicated the importance of early prevention to interrupt these cycles of behavior from progressing over time. As another example, Patterson, Forgatch, and DeGarmo (2010), based on a theoretical model of social interaction learning, showed that the reducing the level of coercion in the family environment by parent training (i.e., the Parent Management Training—Oregon Model [PMTO]), increased positive interpersonal behavior in the family, and laid the foundation by multiple different sources of cascade effects for subsequent and multiple positive outcomes within and outside the family.

CONCLUSIONS

The framework for research and application provided by DP has stimulated much exciting work and provides many possibilities and directions for future work. This fact is inherent in principle in the expansive way in which the area is defined, which embraces multiple levels of analysis and multidisciplinary perspectives. Moreover, the area is seeking to encourage and promote cutting-edge new directions in research and application, building on the emerging work on understanding psychopathology from a developmental perspective.

In this context, it would be redundant, even gratuitous, to attempt to further outline the key themes of this approach and even more specific directions for future for research. A more relevant objective perhaps is to call attention to the need for more specificity on what is required for a research study to meet criteria for adequately advancing the themes of this approach, especially for developmental periods such as adulthood, not typically the subject of study from a DP perspective. This is an issue that could be especially beneficial for researchers schooled in adult clinical traditions interested in including study of developmental process in their new programmatic work, who may be attempting to grapple with exactly what is required in research design to offer promise for advances in understanding adult development.

Although the invitation to other disciplines to become participants in this great experiment is clear, meriting further emphasis arguably is the invitation to other traditions of developmental psychology now pursuing parallel directions, for example, developmental science and applied developmental psychology. Earlier in this chapter we briefly addressed the exciting features offered by these areas of study that are increasingly complementary with DP, but do not offer the analysis as definitive; it is another topic that would benefit from further clarification, to make best use of the many synergies that may be possible and promising across these areas, fostering the spirit of inclusiveness at the heart of the DP perspective.

The size and scope of the endeavor presented may seem overwhelming. For example, students newly exposed to the tenets of the discipline may wonder how all these highly ambitious goals can possibly be achieved. We have offered the notion of floating holism as a way to think about how the contributions of any one study can be interfaced with broader aims, but this is likely of limited solace to some and may even raise more questions, since the term is less than fully accessible as a construct. A question that arises is how and in what ways stock can be taken of what is known, not known, and perhaps even what can be known about research concerning the development of adjustment and maladjustment and specific psychopathologies. Relatedly, although researchers schooled in adult clinical traditions may well agree with the ambitious goals of DP with regard to more precise and fully articulated diagnosis and classification of mental health problems, questions may arise about the practicality and utility of these concepts. This chapter provides extensive coverage of these issues, relevant to clinical science and practice, and it is not the authors' intention at this point to oversimplify matters. However, a useful direction would be to further clarify steps along the way, interim steps in the process, and other related topics toward integrating practicality, feasibility, and integration in the short- and long-term of these elements into diagnosis and practice.

In closing, in a relatively short time DP has directly contributed, fostered, and inspired much great progress on understanding the dynamic processes and other factors relating to the development of psychopathology. However, numerous challenges for theory, research, and clinical applications lie ahead.

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CHAPTER 16

Positive Youth Development and Relational-Developmental-Systems

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The preparation of this chapter was supported in part by grants from the John Templeton Foundation, National 4-H Council, and the Thrive Foundation for Youth. We are also indebted to the colleagues collaborating with us on the 4-H Study of Positive Youth Development and on the many chapters and articles derived from this project that were coauthored with them. We are grateful for their contributions to this work. The presentation of these materials in the current chapter is, however, the full responsibility of the present authors.

Interests in the strengths of youth, the relative plasticity of human development ("the capacity of organisms to change in response to varying conditions"; Gissis & Jablonka, 2011, p. xiii), and the concept of resilience coalesced in the 1990s to foster the development of the concept of positive youth development (PYD; J. Lerner et al., 2013; J. Lerner, Phelps, Forman, & Bowers, 2009). As discussed by Hamilton (1999), the concept of PYD was understood in at least three interrelated but nevertheless different ways: (1) as a developmental process; (2) as a philosophy or approach to youth programming; and (3) as instances of youth programs and organizations focused on fostering the healthy or positive development of youth.

In the decade following Hamilton's (1999) discussion of PYD, several different models of the developmental process believed to be involved in PYD were used to frame descriptive or explanatory research across the adolescent period (e.g., Benson, Scales, & Syversten, 2011; Damon, 2004; Larson, 2000; R. Lerner et al., 2005). As we argue later, all of these models of the developmental process reflect ideas associated with what is termed the post-Cartesian Relational-Developmental-Systems paradigm (RDSP) of human development (e.g., Overton, 2013; Overton & Lerner, 2012).

In this chapter, which focuses on adolescent development and PYD, we use the tripartite conception of PYD suggested by Hamilton (1999) as a frame to review the literature on (1) the different theoretical models of the PYD developmental process, with a special emphasis on the model of PYD with the most extensive empirical support, the Five Cs Model of PYD (J. Lerner et al., 2012; R. Lerner et al., 2005; R. Lerner et al., 2009; R. Lerner et al., 2010; R. Lerner et al., 2011); (2) philosophical ideas about, or conceptual approaches to, the nature of youth programming; and (3) key instances of programs aimed at promoting PYD. We conclude this chapter by discussing the conceptual and practical problems in integrating these three facets of PYD scholarship, and point to the use of employing a Relational-Developmental-Systems paradigm (RDSP) of PYD as a means to promote thriving, character, and positive civic engagement among diverse youth.

PYD AS A DEVELOPMENTAL PROCESS

Developmental science seeks to describe, explain, and optimize intraindividual change and interindividual differences in intraindividual change across the life span (Baltes, Reese, & Nesselroade, 1977). The contemporary, cutting-edge theoretical frame for such scholarship involves the Relational-Developmental-Systems paradigm and theoretical models (Geldhof, Bowers, Johnson, et al., 2014; J. Lerner et al., 2012; Overton, 2010, Chapter 2, this *Handbook*, this volume; Overton & Müller, 2012) derived from this paradigm. These models emphasize that the basic process of human development involves mutually influential relations between the developing individual and the multiple levels of his or her changing context. These reciprocal bidirectional relations may be represented as individual ←→ context relations. This bidirectionality is the reason that Gottlieb and colleagues (e.g., Gottlieb, 1998; Gottlieb, Wahlsten, & Lickliter, 2006) and others (e.g., Overton, 2006) have argued that the concept of *coaction* or *transaction* should replace the term *interaction* except when referring to statistics of the linear ANOVA model. In this chapter we employ the terms *coaction* except when the reference is to linear statistical models, specific theoretical perspectives of others, or quotes from other sources. The reciprocal bidirectional relations regulate (govern) the course of development (its pace, direction, and outcomes). When these *developmental regulations* involve individual ←→ context relations benefitting both the person and his or her ecology, they may be termed *adaptive* (Brandtstädter, 2006).

Examples of these theories linked to RDSP include Bronfenbrenner's bioecological theory (e.g., Bronfenbrenner & Morris, 2006), action theoretical models of intentional, goal-directed behaviors (e.g., Baltes, 1997; Brandtstädter, 2006; Heckhausen, 1999), Elder's (1998) life-course theory, Magnusson's (1999; Magnusson & Stattin, 2006) holistic person-context interaction theory, and the Ford and Lerner (1992) and the Gottlieb (1998) developmental systems formulations.

History, or temporality, is part of the ecology of human development that is integrated with the individual through developmental regulations. As such, there is always change and, as well, at least some potential for systematic change and plasticity (i.e., the capacity to change in the context of varying conditions), across the life span (Baltes, Lindenberger, & Staudinger, 2006; R. Lerner, 1984). This potential for change represents a fundamental strength of human development. Plasticity means that change for the better or worse can characterize any individual's developmental trajectory. Nevertheless, a key assumption of the RDSP—and, as we note, of the use of these models in theoretical formulations aimed at understanding both adolescent development in general and to frame the positive youth development (PYD) conception of developmental processes more specifically—is that *the relational developmental system* is sufficiently diverse and complex such that some means may be found (by researchers and/or practitioners) to couple individual and context in manners that enhance the probability of change for the better, of promoting more positive features of human development (J. Lerner et al., 2012; R. Lerner, 2002, 2004).

There is an enormous number of individual and contextual changes characterizing the adolescent period. For example, changes in the prefrontal cortex, increases in the interconnectivity among brain regions, and increases in dopamine levels, provide both vulnerabilities to risk and opportunities for growth in cognitive control and self-regulation (Steinberg, 2010). At the same time, most youth in Western societies are experiencing great contextual changes, such as changing schools (e.g., Eccles, 2004) and the increased relevance of peer pressure for risk taking (e.g., Gardner & Steinberg, 2005). Moreover, in adolescence, the individual has the cognitive, behavioral, and social relational skills to contribute actively and often effectively to his or her own developmental changes (R. Lerner, 1982; R. Lerner & Busch-Rossnagel, 1981; R. Lerner & Walls, 1999; Ricco & Overton, 2011). Accordingly, adolescence is an ideal "ontogenetic laboratory" for studying the relative plasticity of human development and for exploring how coupling individual and contexts within the developmental system may promote positive development during this period.

Therefore, the RDSP (and the theories and models derived from this paradigm) provide the cutting-edge framework to guide adolescent development research that has predominantly been marked by incomplete conceptions/architecture of developmental processes over the past century. Framing research within a Relational-Developmental-Systems approach affects decisions including, but not limited to, the questions asked, the design adopted, and the analyses conducted.

RELATIONAL-DEVELOPMENTAL-SYSTEMS: AN OVERVIEW

The study of human development has evolved from a field dominated by either psychogenic or biogenic approaches to a multidisciplinary field that seeks to integrate variables from biological through cultural and historical levels of organization across the life span into a synthetic, coactional system (Elder, 1998; Gottlieb, 1997, 1998; Hood, Halpern, Greenberg, & Lerner, 2010). Reductionist accounts of development that adhere to a Cartesian dualism, and that accordingly pull apart (split) facets of the integrated developmental system, are rejected by proponents of the RDSP (Mistry & Wu, 2010; Overton, 2010, 2013, Chapter 2, this *Handbook*, this volume, Overton & Lerner, 2012; Overton & Müller, 2012). These reductionist views are deeply committed to such split formulations as nature versus nurture, continuity versus discontinuity, stability versus instability, or basic versus applied science (R. Lerner, 2002, 2006).

Today, such thinking is eschewed in favor of a relational meta-model that emphasizes the study and integration of different levels of organization as a means to understand life-span human development (R. Lerner, 2006; Overton, 2010; Overton & Müller, 2012). Thus, the conceptual emphasis of the post-Cartesian RDSP is placed on the nature of mutually influential relations between individuals and contexts, represented as individual ←→ context relations. All levels of the relational developmental system itself are integrated within models and theories constructed within the RDSP (R. Lerner, 2006; Overton, 2013), including a diversity of processes (e.g., biological/physiological, behavioral, and social relationship processes, and physical ecological, cultural, and historical processes [see Bronfenbrenner & Morris, 2006; R. Lerner, 2002]). We have also noted that the embeddedness of all levels within history imbues temporality into individual ←→ context relations, meaning there is the potential for plasticity, for organized and systematic change in these relations, across person, time, and place (Elder, 1998; R. Lerner, 1984, 2002, 2006).

Models and theories that are constructed within the RDSP focus on the *rules*, the processes, that regulate exchanges between individuals and their contexts. Brandtstädter (1998) terms these relations *developmental regulations* and notes that, when developmental regulations involve mutually beneficial individual ←→ context relations, they constitute *adaptive* developmental regulations. The possibility of adaptive developmental relations between individuals and their contexts, and the potential plasticity of human development, are distinctive features of this approach to human development.

These core features of the RDSP provide a rationale for making a set of methodological choices that differs in study design, measurement, sampling, and data analytic techniques from selections made by researchers using split, dichotomous, or reductionist Cartesian approaches to developmental science. Moreover, the emphasis on how the individual acts in the context, contributing to the plastic relations with it, fosters an interest in individual agency (or on intentional self-regulation; Gestsdóttir & Lerner, 2008)—on individuals as active producers of their own development (R. Lerner, 1982; R. Lerner & Busch-Rossnagel, 1981). This focus is best instantiated by person-centered (as compared to variable-centered) approaches to the study of human development (see von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume) and thus, as well, to the study of interindividual differences in intraindividual processes (Nesselroade & Molenaar, 2010).

In addition, the person-centered focus, as well as the emphases on relative plasticity and on mutually influential person ←→ context relations, has resulted in the RDSP being used as a frame for more specific understandings about the changing structure of ontogenetic trajectories, and has resulted in the view that developmental science is a nonergodic field (Nesselroade & Molenaar, 2010; Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume). The ergodic theorem holds that if data sets are marked by: (a) homogeneity across individuals in a three-dimensional matrix that involves persons, variables, and time; and (b) stationarity of individuals' scores on variables across time, then findings based on interindividual designs will be equivalent to findings based on intraindividual designs (Molenaar, 2007). Framed by Relational-Developmental-Systems thinking, however, developmental scientists understand that there is variation both across people within time and within people across time in their trajectories of *individual ←→ context relations* (i.e., across time differences). In other words, people differ in their paths across the life span. As such, the assumptions of homogeneity and stationarity of the ergodic theorem are rejected in contemporary developmental science (Molenaar, 2007, 2010). As a consequence of nonergodicity, developmental scientists place greater importance on not only person-centered research but, as such, change-sensitive methodologies for their descriptive and explanatory efforts.

In sum, the conceptual and associated methodological emphases of scholarship associated with the RDSP, and with models and theories constructed within this framework (see Overton, 2013, Chapter 2, this *Handbook*, this volume), have led developmental scientists within this perspective to draw on research from multiple disciplines (e.g., evolutionary biology, human genetics, developmental science, sociology, and anthropology) to better understand the integrated changes across the multiple levels of organization within the ecology of human development and, as well, to therefore document the logical and empirical shortcomings of split, biological reductionist (genetic or neuronal) models (e.g., sociobiology, evolutionary psychology, or behavioral genetics) and methods (e.g., adoption designs, MZ and DZ twin research, or heritability analysis). These developmental scientists have used Relational-Developmental-Systems-based ideas to explain that any facet of individual structure or function (e.g., genes, the brain, personality, cognition, or intelligence) is embodied, that is, is fused, with other features of the individual and with the characteristics of his or her proximal and distal ecology, including culture and history (e.g., see R. Lerner & Benson, 2013a, 2013b, for multiple examples).

Embodiment means that biological, psychological, and behavioral attributes of the person, in fusion with culture, also have a temporal (historical) parameter (Overton, 2006). As such, embodiment, the fusion among the levels of organization within the relational developmental system itself, has implications across both ontogeny and phylogeny (Ho, 2010; Jablonka & Lamb, 2005). These implications involve the concept of *epigenesis* (the process of qualitative change that emerges across the life span through the integration of organism and contextual levels of organization; R. Lerner, 1984, 2002) and, as well, the presence of relative plasticity in phylogeny and ontogeny that occurs because of the embodied acts that lead to change. In other words, relative plasticity characterizes the relations between organisms and contexts (R. Lerner, 1984) that, across time, create epigenetic processes within and across generations.

Embodiment, Evolution, and Ontogeny

Contemporary scholarship about the character of evolution reflects the concept of embodied change, which characterizes the relational developmental system itself. For instance, Bateson and Gluckman (2011) observe that,

> gene expression is profoundly influenced by factors external to the cell nucleus in which reside the molecules making up the genes: the deoxyribonucleic acid (DNA). A willingness to move between different levels of analysis has become essential for an understanding of development and evolution. (p. 5)

Similarly, Keller (2010) explains that:

> Not only is it a mistake to think of development in terms of separable causes, but it is also a mistake to think of

development of traits as a product of causal elements interacting with one another. Indeed, the notion of interaction presupposes the existence of entities that are at least ideally separable—i.e., it presupposes an a priori space between component entities—and this is precisely what the character of developmental dynamics precludes. Everything we know about the processes of inheritance and development teaches us that the entanglement of developmental processes is not only immensely intricate, but it is there from the start. From its very beginning, development depends on the complex orchestration of multiple courses of action that involve interactions among many different kinds of elements—including not only preexisting elements (e.g., molecules) but also new elements (e.g., coding sequences) that are formed out of such interactions, temporal sequences of events, dynamical interactions, etc. (pp. 6–7)

Moreover, Pigliucci and Müller (2010), in presenting what they term an "Extended Synthesis" of evolution, note that:

Far from denying the importance of genes in organismal evolution, the extended theory gives less overall weight to genetic variation as a generative force. Rather, [there is a] view of "genes as followers" in the evolutionary process, ensuring the routinization of developmental interactions, the faithfulness of their inheritance, and the progressive fixation of phenotypic traits that were initially mobilized through plastic responses of adaptive developmental systems to changing environmental conditions. In this way, evolution progresses through the capture of emergent interactions into genetic-epigenetic circuits, which are passed to and elaborated on in subsequent generations. (p. 14)

In turn, West-Eberhard (2003) argues that "the universal environmental responsiveness of organisms, alongside genes, influences individual development and organic evolution, and this realization compels us to reexamine the major themes of evolutionary biology in a new light" (p. vii). Linking the presence of relative plasticity across development with evolution, she makes three major points:

First, environmental induction is a major initiator of adaptive evolutionary change. The origin and evolution of adaptive novelty do not await mutation; on the contrary, genes are followers not leaders, in evolution. Second, evolutionary novelties result from the reorganization of preexisting phenotypes and the incorporation of environmental elements. Novel traits are not de novo constructions that depend on a series of genetic mutations. Third, phenotypic plasticity can facilitate evolution by the immediate accommodation and exaggeration of change. It should no longer be regarded as a source of noise in a system governed by genes, or as a "merely environmental" phenomenon without evolutionary importance. (West-Eberhard, 2003, p. 20)

Crystallizing the embodiment of variables from all levels of organization within the relational developmental system that create epigenetic change across generations, Jablonka and Lamb (2005) summarize evidence demonstrating that evolution involves four interrelated dimensions:

Molecular biology has shown that many of the old assumptions about the genetic system, which is the basis of present-day neo-Darwinian theory, are incorrect. It has also shown that cells can transmit information to daughter cells through non-DNA (epigenetic) inheritance. This means that all organisms have at least two systems of heredity. In addition, many animals transmit information to others by behavioral means, which gives them a third hereditary system. And we humans have a fourth, because symbol-based inheritance, particularly language, plays a substantial role in our evolution. It is therefore quite wrong to think about heredity and evolution solely in terms of the genetic system. Epigenetic, behavioral, and symbolic inheritance also provide variation on which natural selection can act. (p. 1)

Distinct from the use of the term *epigenesis* (see Gottlieb, 1997, 1998; R. Lerner, 1984, 2002; R. Lerner & Benson, 2013a, 2013b), the term *epigenetics* to which Jablonka and Lamb (2005) refer is:

A mechanism to modulate the hardwired information of genomes on longer timescales is via epigenetics. The Greek-derived "Epi" means "over" or "above," and epigenetic effects are defined as heritable changes in genome activity caused by mechanisms other than changes in DNA sequence. Epigenetic events are mediated by chemical modifications of DNA or core histones in complex patterns by methylation, acetylation, ubiquitination, phosphorylation, etc. These modifications alter gene expression by changing the chromatin surface and in this way affect the binding of regulatory factors. (Misteli, 2013, pp. 2010–2011)

Similarly, Meaney (2010) notes that:

Despite the reverence afforded DNA, a gene is basically like any other molecule in the cell; it is subject to physical modifications. These modifications alter the structure and chemical properties of the DNA, and thus gene expression. Collectively, the modifications to the DNA and its chromatin environment can be considered as an additional layer of information that is contained within the genome. This information

> is thus *epigenetic* (the name derives from the Greek *epi* meaning "upon" and *genetics*). (p. 56)

Moreover, Meaney (2010) goes on to note that:

> The classic epigenetic alteration is that of DNA methylation, which involves the addition of a methyl group onto cytosines in the DNA.... The methylation of DNA is an active biochemical modification that in mammals selectively targets cytosines and is achieved through the actions of a class of enzymes, DNA methyltransferases, which transfer the methyl groups from methyl donors. There are two critical features to DNA methylation: First, it is a stable chemical modification, and second, it is associated with the silencing of gene transcription. (p. 57)

Accordingly, in a book discussing the transformations of Lamarckian theory that have arisen in relation to the increasingly more active focus on epigenetic processes in the study of both evolution and development (Meaney, 2010), Gissis and Jablonka (2011) note that plasticity "is . . . a large topic, but, just as Lamarck anticipated, an understanding of plasticity is now recognized as being fundamental to an understanding of evolution" (p. xiii). In turn, and underscoring the links between plasticity of embodied relations among an organism and the multiple biological through ecological levels of its ecology and epigenetic change, they go on to note that:

> Experimental work now shows that, contrary to the dogmatic assertions of many mid-twentieth-century biologists that it could not occur, even a form of "inheritance of acquired characteristics" does occur and might even be said to be ubiquitous. In particular, new variations induced by stress are sometimes inherited. The molecular mechanisms that underlie such inheritance—the epigenetic inheritance systems—are now partially understood, and . . . the existence of various types of [such] soft inheritance affects how we see adaptive evolution and speciation. It also has implications for human health. (Gissis & Jablonka, 2011, p. xiii)

We return in the concluding section of this chapter to the implications of embodiment and epigenesis for health and positive human development. Here we may note, however, that the evidence concerning epigenetics, embodied action, and plasticity that today is understood as accounting for the character of evolutionary and developmental change necessarily leads to deep skepticism about, and, indeed the repudiation of, the "extreme nature" (Rose & Rose, 2000) of the claims of biological reductionists. For example, according to Rose and Rose (2000) evolutionary psychology (EP) claims that "everything from children's alleged dislike of spinach to our supposed universal preferences for scenery featuring grassland and water derives from [the] mythic human origin in the African savannah" (p. 2). These claims are predicated on the basis of the assertion that one can explain,

> all aspects of human behaviours, and thence culture and society, on the basis of universal features of human nature that found their final evolutionary form during the infancy of our species some 100–600,000 years ago. Thus for EP, what its protagonists describe as the "architecture of the human mind" which evolved during the Pleistocene is fixed, and insufficient time has elapsed for any significant subsequent change. In this architecture there have been no major repairs, no extensions, no refurbishments, indeed nothing to suggest that micro or macro contextual changes since prehistory have been accompanied by evolutionary adaption. (Rose & Rose, 2000, p. 1)

Clearly such assertions within evolutionary psychology are inconsistent with the now quite voluminous evidence in support of the role of epigenetics in the multiple, integrated dimensions of human evolution, discussed above (Gissis & Jablonka, 2011; Jablonka & Lamb, 2005) and, in this context, of the role of the organism's own active agency and of culture in creating change within and across generations.

Despite these and other examples (see, e.g., R. Lerner & Benson, 2013a, 2013b; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume) of misguided scholarship, EP articles continue to appear in the literature. Examples of the extreme nature of the claims of evolutionary psychologists pointed to by Rose and Rose (2000) occur in writing about what is termed *paternal investment theory* (e.g., Belsky, 2012; Belsky, Steinberg, & Draper, 1991; Draper & Harpending, 1982, 1988). For example, Ellis, Schlomer, Tilley, and Butler (2012) claim that

> Paternal investment theory links low male parental investment to more aggressive and hypermasculine behavior in sons and more precocious and RSB [risky sexual behavior] in daughters (Draper & Harpending, 1982, 1988). The assumption is that natural selection has designed boys' and girls' brains to detect and encode information about their fathers' social behavior and role in the family as the basis for calibrating sociosexual development in gender-specific ways. (p. 329)

The purported process for what Ellis et al. (2012) term this evolutionary-developmental phenomenon is that there is

> a unique role for *fathers* in regulating *daughters*' sexual behavior. The theoretical basis for emphasizing father effects is (a) that the quality and quantity of paternal investment is, and presumably always has been, widely variable across

> and within human societies; (b) this variation recurrently and uniquely influenced the survival and fitness of children during our evolutionary history . . . ; and (c) variability in paternal investment, much more than maternal investment, was diagnostic of the local mating system (degree of monogamy vs. polygyny) and associated levels of male-male competition. . . . The mating system is important because more polygynous cultures and subcultures are characterized by heightened male intrasexual competition, dominance-striving, and violence, with concomitant diminution of paternal involvement and investment (Draper & Harpending, 1982, 1988). In turn, female reproductive strategies in this context are biased toward earlier sexual debut, reduced reticence in selecting mates, and devaluation of potential long-term relationships with high-investing males, all of which translate into more RSB. (p. 329)

In contrast to these EP claims, within the Relational-Developmental-Systems perspective (RDSP) the transmission across generations is accounted for by the plastic embodied processes of the individual functioning in a reciprocal, that is, bidirectional (←→), relation with his/her physical and cultural context. Thus, within the RDSP, and in the context of contemporary evolutionary scholarship, (e.g., Gissis & Jablonka, 2011; Ho, 2010; Keller, 2010; Licklitter & Honeycutt, Chapter 5, this *Handbook*, this volume; Meaney, 2010), the "Just So" stories (Gould, 1981) of EP are conceptually and empirically flawed. Further embodiment constitutes the basis for epigenesis within the person's life span (Gottlieb, 1997, 1998), including qualitative discontinuity across ontogeny in relations among biological, psychological, behavioral, and social-cultural variables. Evidence for the relative plasticity of human development within the integrated levels of the ecology of human development makes biologically reductionist accounts of parenting, offspring development, or sexuality implausible, at best, and entirely fanciful, at worst.

In sum, the RDSP provides an approach to the study of evolutionary and ontogenetic change that capitalizes on the dynamic, mutually influential relation between developing individuals and their complex and changing ecology. The contributions of relational-developmental-systems thinking are in evidence in all contemporary models of PYD.

THE STUDY OF ADOLESCENCE WITHIN THE RELATIONAL DEVELOPMENTAL SYSTEM

Multiple dimensions of profound changes are prototypic for the adolescent period, involving levels of organization ranging from the physical and physiological, through the cognitive, emotional, and behavioral, and to the social, relational, and institutional. As already noted, plasticity represents a fundamental strength of the adolescent period (R. Lerner, 2005, 2009), in that it reflects the potential for systematic changes that may result in more positive functioning. If adaptive developmental regulations emerge or can be fostered between the plastic, developing young person and features of his or her context (e.g., the structure and function of his or her family, school, peer group, and community), then the likelihood will increase that the young person will thrive (that is, manifest healthy, positive developmental changes) across the adolescent decade.

Indeed, predicated on the RDSP, the links among the ideas of relative plasticity, adaptive developmental regulations, and positive development suggest that all young people have strengths that may be capitalized on to promote *thriving* (i.e., exemplary positive development; R. Lerner, 2004; Benson et al., 2011) across the adolescent years. An example of the emerging strengths of adolescents is their ability to contribute intentionally to adaptive developmental regulations with their context (Gestsdóttir & Lerner, 2008). Such intentional self-regulation may involve the selection of positive goals (e.g., choosing goals that reflect important life purposes), using cognitive and behavioral skills (such as executive functioning or resource recruitment) to optimize the chances of actualizing one's purposes and, when goals are blocked or when initial attempts at optimization fail, possessing the capacity to compensate effectively (Baltes & Baltes, 1990; Freund & Baltes, 2002).

Simply, through the lens of the Relational-Developmental-Systems paradigm, it is eminently reasonable to assert that youth represent "resources to be developed" (Roth & Brooks-Gunn, 2003a, 2003b). Increasingly, this strength-based view of adolescents has been used to study PYD within the United States (e.g., J. Lerner et al., 2009) and internationally (e.g., Gestsdóttir & Lerner, 2007; Silbereisen & Lerner, 2007). As we have noted, this research has been framed at a "meta-level" by the ideas of individual ←→ context relations of focus within the RDSP; in addition, the research has been influenced by interest in the characteristics of PYD that emerge from this relational process, by the individual and ecological bases of the development of these characteristics, and by interest in theoretically expected outcomes of the PYD process, for example, youth community contribution or active and engaged citizenship (e.g., Zaff, Boyd, Li, Lerner, & Lerner, 2010). Together, these interests by scholars in the PYD process reflect the first emphasis within the PYD field that was identified by Hamilton (1999).

APPROACHES TO PYD AS A DEVELOPMENTAL PROCESS

Current theoretical conceptions of the PYD developmental process have been framed within the RDSP (e.g., see Damon, 2004; Larson, 2000; J. Lerner et al., 2009). There are several different instantiations of this theoretical approach. We now turn to a discussion of these approaches.

William Damon and the Study of Purpose

Damon (2008) and colleagues (Bundick, Yeager, King, & Damon, 2010; Damon, Menon, & Bronk, 2003; Mariano & Damon, 2008) approach the study of the PYD process through an examination of the development of *purpose* in youth. Damon notes that a central indicator of PYD and youth *thriving* is engagement in pursuits that serve the common welfare and make meaningful contributions to communities. Damon assesses the ways in which youth go beyond their own self-centered needs and extend outward to the pursuit of goals that benefit the world.

To Damon (2008), a purpose is a stable and generalized intention to accomplish something that is at once meaningful to the self and is of intended consequence to the world beyond the self. It is an “ultimate concern” or overall goal for one’s life, helping to organize one’s life decisions and embodied actions, and is thus manifested in one’s behavior. The purpose is internalized, or “owned” by the individual, and therefore is central to his or her identity. As such, the operational criteria of purpose are:

> The person must have *all* elements of the definition: something to accomplish, a beyond-the-self rationale, plans for future action, meaningfulness to self, and incorporation into one’s identity (that is, behavior that is not driven by oughts);
> The concern must function to organize the person’s decisions and activities in support of the concern;
> The person must manifest the concern with visible action; and
> The person cannot imagine himself/herself without the concern, it is necessary to do the activities related to the concern. (Damon, 2008, pp. 33–34)

In their program of research at the Stanford Center on Adolescence, Damon and his colleagues (e.g., Damon et al., 2003; Mariano & Damon, 2008) have examined youth purpose through a series of studies with youth across the United States. To understand adolescents’ potential sources of purpose, they surveyed a diverse group of youth from Grades 6, 9, and 12 (that is, about 11-, 14-, and 17-year-olds), and college and asked respondents to indicate their level of dedication to 18 categories of purpose. A *category* refers to a life area that individuals find important, and in which they may be psychologically and actively invested. The categories included: family, country, personal growth, sports, academic achievement, good health, looking good, arts, making a lot of money, lifework, general leadership, romance, political or social issues, happiness, religious faith or spirituality, community service, friends, and personal values (Mariano & Damon, 2008).

Mariano and Damon (2008) indicate that contributions to community are a key indicator of positive youth development. They also present the idea that purpose is associated with increased prosocial behaviors and negatively associated with negative behaviors, and therefore is central to the study of PYD.

In extending Damon’s work, Mariano and Going (2011) emphasize the person (←→) context relationship in which individuals are constantly coacting with their environment and receiving resources and opportunities from a surrounding network. Mariano and Going (2011) argue that purpose helps young people express and satisfy their individual interests, strengths, and talents; that purpose in life can serve as a guide for adolescents, and a way of adapting to aspects of life that adolescents may view as threatening. Two of the outcomes associated with having purpose in one’s life are *coping mechanisms* and *psychological cohesion*. With respect to coping mechanisms, purpose helps adolescents cope by allowing them to experience the positive side of whatever challenge they may be encountering. Mariano and Going (2011) find that adolescents with a more comprehensive sense of purpose focus on future improvements and the positive states that can result from challenging situations, more so than is the case among adolescents with a less comprehensive sense of purpose.

The psychological cohesion outcome is understood as a complementary set of values that adds to one’s moral character, such as humility, integrity, and vitality. Purpose helps improve the psychological aspects of an adolescent’s life by acting as the “glue” that unifies these moral characteristics. An individual with strong psychological cohesion has character traits, morals, and values that all flow together positively because of having an identified purpose in life.

In addition to suggesting that purpose is central to youth thriving, Damon and colleagues (e.g., Mariano

& Damon, 2008) suggest that a youth's purpose in life can be defined by their religion and spirituality. King and her colleagues (e.g., King, Carr, & Boitor, 2011; see also Bundick et al., 2010) have also studied the role of religion, spirituality, and PYD in people's lives from a Relational-Developmental-Systems perspective. They assert that the constructs of religion and spirituality are complex and multidimensional, and include cognitions, emotions, behaviors, experiences, and social relationships. They maintain that the RDSP creates a perspective that allows for both the individual and context to be included in a unified fashion. Reflecting Damon's conception of purpose, King et al. (2011) define *spirituality* as a developing sense of identity that motivates youth to care for themselves and, as well, to contribute to the greater good. They note that transcendence, fidelity, and generative actions are all key to the development of spirituality. Transcendence exists when people think beyond the self, and attribute or see significance in something bigger than themselves. For example, this focus may relate to God or to a higher being with a sense of divinity, to humanity in general, or to specific communities (such as the church). Fidelity is the adherence to transcendence, where people consistently connect to a world beyond themselves. When one has acquired both transcendence and fidelity, he or she is motivated to produce generative actions in that they promote and develop one's own life as well as the lives in one's community.

King et al. (2011) note that spirituality and religiosity are linked to PYD in several ways. First, the abstract thought that develops during adolescence enables youth to begin to understand the notion of God and better understand religious beliefs. Spirituality combines one's values and beliefs together to form an individual identity, and help identify a purpose in life. These developments lead to behaviors indicative of thriving. Transcendence also aids this development through providing motivation to be altruistic and more understanding of devotion, responsibility, and commitment.

In a study of urban public high school students, Furrow, King, and White, (2004) found a positive relation between religious self-understanding, personal meaning, and prosocial personality. Differences existed in the relation of personal meaning to prosocial personality across age and gender cohorts. Furrow et al. (2004) found a positive association between personal meaning and prosocial concerns among boys, but no significant association among girls. This finding suggests that personal meaning may be more applicable for males than females. Overall these findings provide support for considering that, among youth, religion is a developmental resource associated with personal meaning and with concern and compassion for others.

Although Damon (2008) sees purpose as an indicator of PYD, he notes that a next step in his research will require a deeper understanding of the ways that young people are purposeful. Purposeful young people may indeed be contributing to something beyond themselves, but whether that contribution is for self-serving reasons and social approval, or an end in itself, may be an important distinction for understanding how purpose and contribution are associated with different facets of adolescent development.

Peter Benson and Search Institute and the Study of Developmental Assets

The work of Benson and his colleagues at Search Institute (e.g., Benson, 2008; Benson et al., 2011) has been integral in providing the vocabulary and vision about the strengths of young people and the communities in which they reside. Coining the term *developmental assets*, Benson and his colleagues describe *internal* or individual assets, which are a set of "skills, competencies, and values" of a young person. These assets are grouped into four categories: (1) commitment to learning, (2) positive values, (3) social competencies, and (4) positive identity (Benson et al., 2011). These individual assets represent the talents, energies, strengths, constructive interests, and "sparks" that every young person possesses (Benson, 2008). Thriving occurs as a result of aligning these individual strengths with a community's *external* or ecological assets, which are conceived as "environmental, contextual, and relational features of socializing systems" and are organized into four categories: (1) support (2) empowerment, (3) boundaries and expectations, and (4) constructive use of time (e.g., Benson et al., 2011).

In a series of studies, Benson and his colleagues found these assets to be predictive of seven behavioral indicators of *thriving* including: (1) school success, (2) leadership, (3) helping others, (4) maintenance of physical health, (5) delay of gratification, (6) valuing diversity, and (7) overcoming adversity (Leffert et al., 1998; Scales, Benson, Leffert, & Blyth, 2000). For example, achievement motivation and school engagement, which are internal assets, in combination with time spent in youth programs, which is an external asset, predicted school success for six different racial/ethnic groups of 6th- to 12th-grade students. In turn, higher levels of assets have been related to positive developmental outcomes such as higher school achievement, better physical health, lower levels of risk behaviors, and resilience (Reininger et al., 2003; Scales, Leffert, & Vraa, 2003).

Benson and colleagues have emphasized the practical application of research on the developmental assets by highlighting the role of communities in fostering well-being and positive development among young people. In the past two decades, the work of the Search Institute has been useful in helping communities to develop long-term goals for positive youth development. Today, more than 300 communities across the country have incorporated the Search Institute's asset-building framework.

In sum, Benson and colleagues' focus on research and applications aimed at sustaining the positive strengths of youth and building upon them, rather than on eliminating risk behaviors. Current work by Benson and colleagues (e.g., Benson et al., 2011) seeks to extend the developmental assets approach to diverse youth, both in the United States and internationally.

Jacquelynne Eccles, the Study of Stage-Environment Fit, and Expectancy-Value Theory

Eccles' work focuses on elucidating how a *fit* between contextual variables (e.g., schools, families, and youth programs) and individual characteristics (e.g., motivational constructs such as expectations and values) contributes to the healthy, positive development of adolescents (e.g., Eccles et al., 1993; Eccles & Wigfield, 2002; Gutman & Eccles, 2007). Through a focus on assessing early and middle adolescents' relationships within families, transitions to junior high or middle school, and participation in youth programs, Eccles and colleagues have forwarded a theoretically rich and empirically robust body of work indicating that social contexts must be developmentally appropriate for the youth populations they serve in order to ensure a (developmental) *stage-environment fit* that motivates adolescents and that promotes their positive development (e.g., Eccles, 2004). When youth develop in environments that respond to their changing needs, they are more likely to experience positive outcomes; youth in nonresponsive families, schools, or programs may experience difficulties and develop problems. Accordingly, when adolescents develop in settings reflecting stage-environment fit, positive and healthy changes occur. Such fit presupposes that youth and *context* act in mutually beneficial ways toward each other (e.g., Brandtstädter, 1998; R. Lerner, 2006)—that is, there are adaptive developmental regulations between youth and their contexts. Much of Eccles' work examines the variables that motivate adolescents to act in ways to promote their positive development.

Specifically, Eccles and colleagues use the *expectancy-value model* of achievement-related choices (e.g., Eccles, 2004) to understand youth ←→ context relations. This model holds that an individual's activity choice, persistence, and performance are related to his or her expectations of success and value for the activity which, in turn, are also associated with a variety of other personal and contextual factors (Eccles & Wigfield, 2002).

Using this model, Eccles and colleagues have identified the various characteristics of schools that better support an adolescent's expectancy for success and value for academic goals (Eccles & Roeser, 2009). For example, these school characteristics include teachers' expectations for high student achievement and the provision of structured after-school activities (e.g., Eccles & Gootman, 2002). Eccles and colleagues have also found that several characteristics common to the United States education system, most notably the transition into junior high or middle school, often have adverse effects on young adolescents' motivation, achievement, and positive development (e.g., Eccles & Roeser, 2009).

The work of Eccles and colleagues provides a theoretical model for and empirical evidence of the dynamic person ←→ context reciprocal coactions that result in positive outcomes for young people. That is, contextual variables influence youth characteristics which, in turn, affect the type of contexts with which youth are engaged. Whereas Eccles's primary focus has been on the school factors associated with youth motivation, we now turn to Larson's work on youth motivation within youth development programs.

Reed Larson and the Study of Motivation, Active Engagement, and Real-Life Challenges

For Larson (2006), PYD is "a process in which young people's capacity for being motivated by challenge energizes their active engagement in development" (p. 677). For positive development to occur, the motivational system must become activated, and remain engaged in multiple domains of development, while young people deal with everyday real life challenges. Larson characterizes a young person's *initiative* as both a key component of PYD and, as well, an important focal point for youth development programs seeking to promote PYD (Larson, 2000). Defining *initiative* as "the capacity to direct cumulative effort over time toward achievement of a long-term goal" (Larson, Hansen, & Walker, 2005, p. 160), Larson (2000) posits that initiative is a central requirement for "components of PYD, such as creativity, leadership, altruism, and civic engagement" (p. 170).

Larson's work looks at the match between the experiences of adolescents and the requirements of the adult world they are preparing to enter. He seeks to understand this integration by describing the diversity of developmental tasks, skills, and competencies adolescents need to develop in order to successfully transition into adulthood in different cultures. With his focus on agency and initiative, much of the work by Larson and colleagues focuses on how youth development programs can best facilitate the development of these and related skills in participating youth (e.g., Dawes & Larson, 2011). Larson has suggested that, across diverse programs, an important component for the development of initiative may be the concurrent development of personal connections with adult leaders or other participating peers.

Out-of-school-time activity (OST) is a context that Larson has studied in depth. Programs with structured activities are seen as contexts in which youth can act as producers of their own positive development (Dworkin, Larson, & Hansen, 2003; Larson et al., 2004; R. Lerner, 1982); such contexts offer opportunities to develop skills and competencies necessary for negotiating the real world (Mahoney, Larson, Eccles, & Lord, 2005). These skills and competencies include taking initiative, developing leadership, and learning responsibility, as well as strategic and teamwork skills (Larson, 2000; Larson, Hansen, et al., 2005; Larson & Hansen, 2005; Larson, Hansen, & Moneta, 2006; Larson & Walker, 2006; Larson, Walker, & Pearce, 2005). At the same time, participation in structured activities may be associated with negative experiences such as stress, inappropriate adult behavior, negative influences, social exclusion, and negative group dynamics.

In all types of programs, adults were found to play an important role in facilitating positive development (Larson & Hansen, 2005; Larson & Walker, 2006; Larson et al., 2004; Larson, Walker, et al., 2005). Successful adult leaders use techniques such as following the lead of youth, cultivating a culture of youth input, and monitoring and creating intermediate steps in task management (Larson et al., 2004). Larson and Angus (2011) identify youth programs as an ideal location for skill building, especially when the content of the program relates to skills of action (e.g., planning and creating events or strategies). Such programs are also a means of facilitating adolescent empowerment.

One of Larson's many contributions to the field of youth development is the close attention he has paid to the specific aspects of youth development programs, such as developmental opportunities and actions of adults that contribute to positive development. His focus on the developmental processes that occur with youth in successful programs articulates possible intrapersonal pathways toward positive youth development.

Margaret Beale Spencer and the PVEST Model

Spencer's *Phenomenological Variant of Ecological Systems Theory* (PVEST) is a dynamic systems approach to studying development that takes into account social structural factors, cultural factors, and individual experiences, as well as individuals' perceptions of these (Spencer, 2006b). A central feature of this theory is an emphasis on the ways in which youth make sense of their contexts, and the role that these interpretations play in their perceptions of events, people, and opportunities in their environments. Using PVEST as her interpretative theory, the work of Spencer, her colleagues and students, has focused on how youth act in environments, which are perceived as reflecting social inequities or injustices.

As it applies to the study of positive youth development, a particularly important feature of Spencer's theoretical model is the recognition that different youth perceive the same external events and settings through different lenses and this yields alternative understandings. For example, whereas an after-school homework club might promote academic competence for some youth, for others the same context might constitute disturbing reminders of earlier unavailability of resources, such as access to books and teacher help. The effectiveness of this asset, then, is likely to vary according to youth perceptions of this setting.

Although attention is paid to the importance of reciprocal bidirectional coactions of individual characteristics and ecological contexts, Spencer argues that the role of structural inequality must be considered as well. The framework of PYD and thriving is intended to be a general theory of human development that should be applicable to all youth. Spencer's model provides insight into the roles of phenomenologically shared and nonshared perceptions, and shared and nonshared social-cultural context in the Relational-Developmental-Systems study of PYD.

Spencer's research has focused particularly on youth of color and poor youth. In part, her scholarship is a critique of researchers' "failure to consider [youth of color's] unique human development experiences in socially constructed and culturally unique contexts" (Spencer, 2006a, p. 271; Spencer, Swanson, & Cunningham, 1991). The contexts of underserviced neighborhoods, impoverished communities, and families under stress that often characterize the lives of urban, and frequently, African American, children, and the life-long structural role of these contexts, are generally ignored or characterized as random error in developmental models (Spencer, Noll, Stoltzfus, & Harpalani, 2001). In addition, Spencer's work points directly to the need to study positive outcomes for all youth, defined within the cultures and contexts in which youth and their families find themselves (Spencer, 2006a). The PVEST model provides a nuanced structure in which to do this research. This contribution exists in part because the everyday experiences of race, that includes both overt and subtle racism with which people of color must learn to cope, and the demands of socialization, which all youth face, are explicitly acknowledged and modeled (Lee, Spencer, & Harpalani, 2003).

The work of Spencer and her colleagues brings notions of injustice and inequality into developmental models. Structural inequity, racism, and poverty are not individual characteristics, nor are they context-specific. They are pervasive facts of American life that affect all segments of the population in various, complex ways. At the same time, the actual experience is perceived at the individual level. What one adolescent experiences as stress may not affect his or her neighbor or sibling in the same way (Spencer, 1995).

Spencer argues that in order to effectively promote thriving, these factors will need to be understood better and incorporated into the models and methods of PYD. Her scholarship offers a powerful frame for such research. As well, it stands in many ways as the conscience for our field, as a means to keep issues of social justice and rigorous, theory-predicated developmental science integrated and at the forefront of our scholarly agenda. Consistent with the work of Spencer, other researchers have examined how positive development may occur in contexts that are marked by high-risk and adversity. One key focus has been on the study of resilience among youth.

Ann Masten and the Study of Resilience

Masten (2001) notes that to be considered *resilient*, an individual must not only be identified as experiencing adversity, but he or she must also be deemed as doing good or okay in terms of the quality of adaptation or of developmental outcomes. Accordingly, her work involves "understanding behavior problems in the full context of human development . . . focus[ing] on variations in adaptation" (Masten, 2004, p. 311). She argues that research on positive and maladaptive functioning and development are mutually informative (Masten, 2001, 2004).

Masten's work on determining what constitutes positive adaptation focuses on competence in age-relevant developmental tasks (e.g., Masten, 2001; Masten, Obradović, & Burt, 2006). Given that age is a rough marker of developmental status, resilience is a dynamic construct that incorporates developmental status, along with cultural and historical contexts. Competence in managing the relevant developmental tasks of one's sociocultural context is a multidimensional operationalization of adaptation, as there are multiple tasks during any given developmental stage in any given place at any given time. Within this framework, maladaptive development is operationalized as a failure to meet the expectations of a given society for several domains of development or for one major domain (Masten, 2001).

According to Masten (2001), resilience occurs as the result of mutually influential individual ←→ context relations. Therefore, young people whose lives are characterized as resilient may be identified not only by the competence they develop with respect to developmental tasks, but also by the quality of resources available to them. This conceptual orientation has led Masten to study the cascades of individual ←→ context relations that are linked to the presence of resilience in adolescent development. Masten argues that different coactions occur in developing systems and result in spreading effects across levels, among domains at the same level, and across different systems or generations. These different coactions have cumulative consequences for development (e.g., Masten & Cicchetti, 2010).

In her work with the Project Competence group (Masten et al., 1999) and in reviews of the resilience literature (Masten & Coatsworth, 1998), Masten specifies that three adaptive systems are crucial for the development of competence: (1) parenting, (2) self-regulation skills, and (3) cognitive functioning. For example, in the 10-year assessment of their urban sample (Masten et al., 1999), Masten and colleagues found evidence to support the position that cognitive functioning and parenting quality are fundamental adaptational systems, as they predicted current and future adaptation in children and adolescents (academic achievement, conduct, and peer social acceptance).

The work of Masten highlights the need to study dynamic person ←→ context relationships and the importance of relative plasticity for understanding the intraindividual changes and interindividual differences in intraindividual changes that mark human development. Findings from this person-centered approach would contradict an assumption that risk factors for the most part predict negative outcomes. Findings from resilience research demonstrate that risk factors are predictive of negative outcomes for only about 20% to 49% of a given high-risk population (Masten, 2013; Masten, Narayan, Silverman, & Osofsky, Chapter 18, this *Handbook*, Volume 4; Rutter, 1987, 2000; Werner & Smith, 2001). In contrast, the supports and opportunities that are thought to buffer the effect of adversity and enable development to proceed predict positive outcomes in high proportions of youth within a high-risk population. From resilience research such as Masten's, scholars and practitioners are provided information concerning supports and opportunities (i.e., assets) that can serve as protective factors not only for youth facing adversity, but for all young people.

Young people experience several transitions in which the supports and opportunities identified in Masten's research become especially relevant. In the next section, we review Hamiltons' work on the assets that support youth during a transition indicative of youth competence—the school-to-work transition.

Stephen Hamilton and Mary Agnes Hamilton and Positive Adolescent-to-Adult Transitions

The scholarship of Hamilton and Hamilton (e.g., S. F. Hamilton, 1994; M. A. Hamilton & Hamilton, 2005; S. F. Hamilton & Hamilton, 1999, 2006, 2009) describes the developmental processes that encompass the transition from adolescence to adulthood, with a particular emphasis on the school-to-work-transition and the role of adults, programs, and institutions in supporting this transition. The transition to adulthood is defined by changes in social roles, as adolescents shift from being dependent upon adults to being capable of caring for self and others. This shift is structured by the many contexts in which a youth is embedded—family, school, work, and society.

The Hamiltons provide theory and research that help frame our understanding of the issues faced by youth trying to connect school and work. In addition, the Hamiltons offer ideas for policies and programs useful for enhancing the school to work connection for all youth and, in particular, for those adolescents who seek full-time employment immediately after completion of high school. For example, studying adolescents and young adults from seven nations—United States, Germany, Japan, Austria, Switzerland, Denmark, and Sweden—Hamilton (1994) noted that "Adolescents who believe their current efforts will bring them closer to a desirable future are far more likely to work hard in school and avoid self-destructive behavior than those who are either unable to think about the future or who believe their prospects are beyond their control" (pp. 267–268).

To forge the link they desire between their adolescent school context and their young adult work context, adolescents must consider two key facets of the worlds of education and work/career: transparency and permeability. *Transparency* describes the extent to which young people can "see through" the intricacies of the stated and the unstated rules of the educational system and the labor market and, using this understanding, plan a course of action to move from where they are in the present (e.g., a senior in high school) to a goal they have for the future (e.g., employment as an electrical engineer, as an accountant, or as a beautician). *Permeability* involves the amount of effort needed to move from, say, a plan involving becoming an electrical engineer to a plan involving becoming an orthodontist or to a plan involving becoming a sales clerk if one has decided that one is no longer interested in becoming a beautician.

The Hamiltons' work highlights how subtle features of the contexts within which youth develop contribute to their positive development in several important ways. For example, for youth in poverty, the school-to-work transition is the best opportunity to rise above their current socioeconomic status (Hamilton & Hamilton, 2009). However, for this transcendence to occur, youth must reside in societies that allow social mobility and live during a time when this mobility is possible. The success of this transition is also dependent on individual characteristics, including educational and employment experiences. A poor youth born in a relatively mobile society such as the United States has varied chances of a successful transition to work depending on the era in which he or she was born, his or her race or ethnicity, and the ability to meet the requirements of a desired position. In short, the school-to-work transition is defined by normative and nonnormative changes in individual ←→ context relationships that are subject to individual, social, and historical influences.

We turn now to a model of PYD that incorporates these multilevel concepts into its framing of positive youth development. We discuss the Five Cs model of Lerner, Lerner, and colleagues.

Richard M. Lerner, Jacqueline V. Lerner, and Colleagues and the Study of Individual ←→ Context Relational Processes and PYD

The model or theory of the PYD process constructed by Lerner, Lerner, and their colleagues (e.g., J. Lerner et al., 2009; R. Lerner et al., 2005; R. Lerner et al., 2010; R. Lerner, Lerner, von Eye, Bowers, & Lewin-Bizan, 2011) explicitly has drawn on the individual ←→ context relational developmental systems conception as its foundation. This model has been elaborated in the context of the longitudinal study of PYD conducted by Lerner, Lerner, and colleagues; the 4-H Study of PYD (e.g., Bowers et al., 2010; R. Lerner et al., 2005). This research seeks to identify the individual and ecological relations that may promote thriving and, as well, that may have a preventive effect in regard to risk/problem behaviors. Within the 4-H Study, thriving is understood as the growth of attributes that mark a flourishing, healthy young person, (e.g., the characteristics termed the "Five Cs" of PYD—*competence, confidence, character, connection*, and *caring*; Eccles & Gootman, 2002; R. Lerner et al., 2005; Roth & Brooks-Gunn, 2003a, 2003b).

A key hypothesis tested in this approach to the developmental process of PYD is that, if: (a) the strengths of youth (e.g., a young person's cognitive, emotional, and behavioral engagement with the school context, having the "virtue" of hope for the future, or possession of intentional self-regulation skills such as Selection [S], Optimization [O], and Compensation [C]) can (b) be aligned with the resources for positive growth found in families, schools, and communities (e.g., the capacities of adults to provide for young people a nurturing, positive milieu in which their strengths may be enhanced and positively directed) (Benson et al., 2011; DuBois & Rhodes, 2006; Karcher, Davis, & Powell, 2002; Lewin-Bizan, Bowers, & Lerner, 2010; Rhodes & Lowe, 2009); then (c) young people's healthy development will be optimized (R. Lerner, 2004). A second hypothesis is, given that positively developing youth should be involved in adaptive developmental regulations, then a thriving young person should act to contribute to the context that is benefiting him or her; there should be contributions to self, family, community, and civil society (Jelicic, Bobek, Phelps, Lerner, & Lerner, 2007; R. Lerner et al., 2005).

In other words, if positive development rests on mutually beneficial relations between the adolescent and his or her ecology then thriving youth should be positively engaged with and act to enhance their world. Further, the adolescent should be less prone to engage in risk/problem behaviors. Figure 16.1 presents an illustration of the Lerner and Lerner conception of the PYD developmental process.

As indicated in Figure 16.1, the developmental process envisioned by Lerner and Lerner (e.g., R. Lerner et al., 2005) to be involved in PYD involves adaptive developmental regulations between the strengths of youth and the developmental assets present in their ecologies. These mutually beneficial individual ←→ context relations are depicted as being associated with PYD (and the Five Cs associated with this concept) and, in turn, with the enhanced probability of youth contributions to their ecology and with lowered probabilities of risk/program behaviors. The outcomes of these adaptive developmental regulations feed back to the individual and his or her context and thus create a basis for further adaptive developmental regulations. The figure illustrates as well that these adaptive developmental regulations and their positive and problematic sequelae exist within the broader ecology of human development. This ecology includes cultural and, as well, historical (temporal) variation, and thus introduces change at all levels of organization within the relational developmental system (Bronfenbrenner & Morris, 2006; Elder, 1998). Such changes are manifested by intraindividual change, by interindividual differences in intraindividual change, and by normative and nonnormative contextual variation (Baltes et al., 1977).

Empirical Support for the Five Cs Model of PYD

To test the ideas presented in Figure 16.1, researchers at the Institute for Applied Research in Youth Development (IARYD) at Tufts University launched the 4-H Study of Positive Youth Development in the fall of 2002. The 4-H Study of Positive Youth Development is a longitudinal investigation supported by a grant from the National 4-H Council and the Altria Corporation. Data were collected annually for Grades 5 through 12 (i.e., about 10- to 17-year-olds). The 4-H Study sought to study youth in their actual environments, rather than conducting randomized controlled trials. In these environments, youth and their parents, rather than research investigators, make decisions about how they spend their time.

We provide here only a brief description of the methodology of the study; full details of the methodology have been presented in numerous empirical publications (e.g., Bowers et al., 2010; Jelicic et al., 2007; R. Lerner et al., 2005; Phelps et al., 2007, 2009; Theokas & Lerner, 2006). The 4-H study uses a form of longitudinal sequential

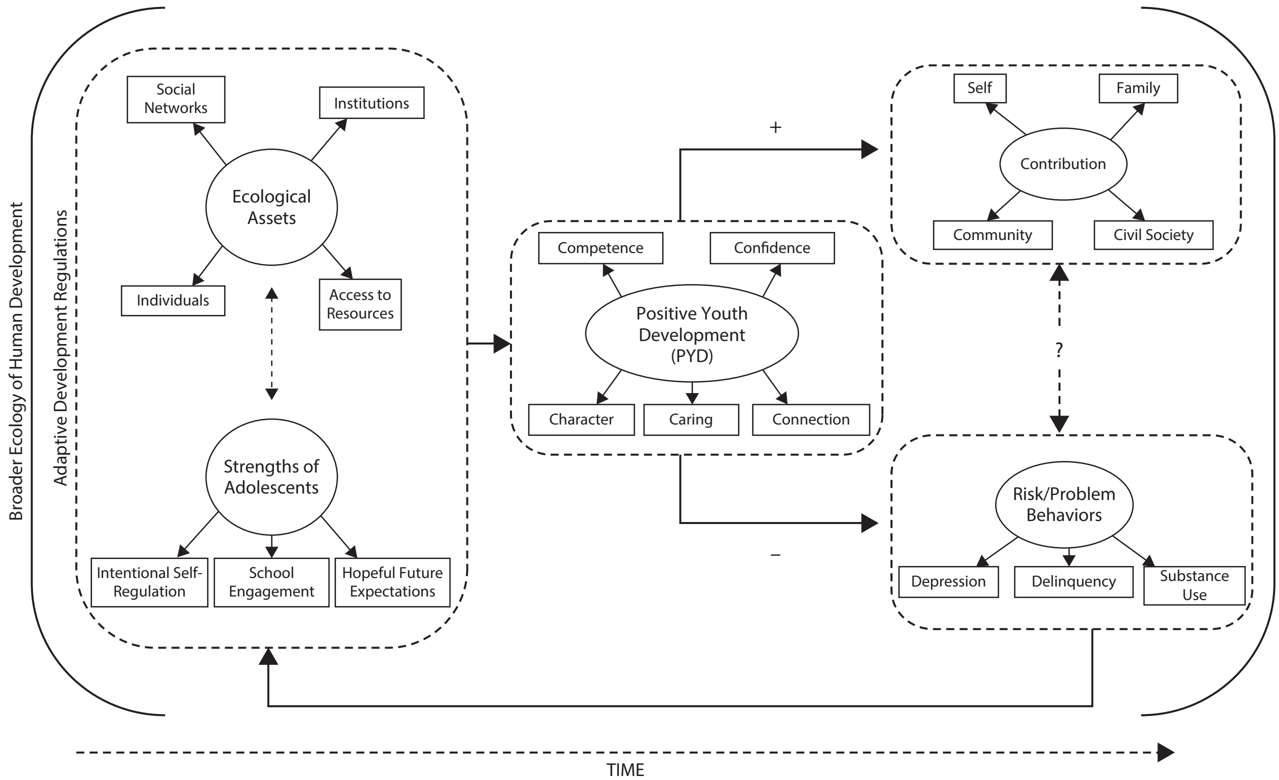

Figure 16.1 A Relational-Developmental-Systems model of the individual ←→ context relations involved in the Lerner and Lerner conception of the PYD developmental process.

design. Fifth graders, gathered during the 2002 to 2003 school year (which was Wave 1 of the study), were the initial cohort within this design. To maintain at least initial levels of power for within-time analyses and to permit assessment of the affects of retesting, subsequent waves of the study involved the addition of a new cohort (of youth of the current grade level of the initial cohort); this new cohort was then followed longitudinally. Overall, across eight waves of the study, approximately 7,000 youth and 3,500 of their parents from 44 states were surveyed. At all eight waves, the sample varied in race, ethnicity, socio-economic status, family structure, rural-urban location, geographic region, and program participation experiences.

Data were collected through the use of a student questionnaire, a parent questionnaire, and—to assess facets of the settings within which youth develop—from school district administrators and from web-based or census tract data, for example, about community and school resources and school climate. These data collection procedures enable the identification of the resources, or developmental assets, that exist in these settings of youth. In addition, through obtaining information about the young person's strengths (e.g., intentional self regulation, school engagement, and hopeful future expectations) the study assessed the individual strengths of adolescents.

Patterns of participation in OST activities are also assessed in this study. These activities include youth development programs (such as 4-H, Boys & Girls Clubs, Scouts, YMCA, and Big Brothers/Big Sisters), sports, arts and crafts, interest clubs, religious clubs, performing arts organizations, or service organizations. Information about civic engagement/civic contribution, future aspirations and expectations, relationships with parents, friends, and other adults, and values were also measured. In addition, parents were asked about the nature and composition of their household, their parenting style, and their education, employment, and neighborhood.

Key Discoveries to Date

Both the initial findings of the 4-H study, and later findings, have brought empirical data to bear on several key ideas within the Lerner and Lerner PYD theory. We discuss several discoveries about the key premises of the Lerner and Lerner PYD model, including the structure of PYD, its antecedents (youth strengths and ecological assets), and its functional significance for youth positive and problematic outcomes.

The Structure of PYD

Support for the structural model of PYD illustrated in Figure 16.1 has been provided by the 4-H study data set from the beginning of the adolescent period through, to date, Grade 12 (e.g., R. Lerner et al., 2005; Phelps et al., 2009; Bowers et al., 2010). For instance, Phelps et al. (2009) assessed the structure and development of PYD from Grade 5 to Grade 7 of the 4-H study and provided evidence of a latent construct of PYD that generalized across the early years of adolescent development and that could be operationalized by lower-order latent constructs representing the Five Cs. Bowers et al. (2010) extended these findings by demonstrating that the structure of PYD in middle adolescence (Grade 8 through 10) was comparable to the structure of this construct present across the early years of adolescence. Bowers and colleagues found that although the overall structure of PYD was maintained across Grade 8 through 10, the scales relevant to measuring the Five Cs were slightly different for two of the Cs during middle adolescence than for early adolescence. That is, reflective of developmental change, athletic competence was no longer a relevant indicator of competence during middle adolescence. In turn, physical appearance significantly loaded on the latent construct of confidence.

In a series of follow-up analyses, Geldhof, Bowers, Boyd, et al. (in press) suggested that rather than reflecting a second-order construct, PYD could be modeled using a bifactor structure. Rather than the strict downward-causality implied by the higher-order model of PYD (i.e., that each individual has a fixed level of a unidimensional construct called *PYD*, which then "causes" scores on each of the Five Cs), this bifactor model described PYD as the shared variation among all indicators of PYD. Thus the global PYD construct represents a latent-variable proxy for general adaptive functioning, while each of the Five Cs are also modeled and represent the covariation among C-specific items not related to the overall PYD construct. Results from these models show that both the global PYD and the residual Five Cs constructs correlated with criterion variables in meaningful ways (i.e., community contributions, depression, problem/risk behaviors).

The Strengths of Youth

From the Relational-Developmental-Systems PYD model, all young people have strengths that may be capitalized in ways that promote thriving across the adolescent years. One example of the emerging strengths of adolescents is their ability to contribute intentionally to adaptive developmental regulations with their contexts, for instance, as indexed through the use of selection, optimization, and compensation (SOC) behaviors (Freund & Baltes, 2002; Gestsdóttir & Lerner, 2007, 2008). Other instances of strengths are specific self-regulations in key contexts of adolescents, for example, school engagement (Li & Lerner, 2011), and youth beliefs and emotional structures pertinent to their futures (Schmid, Phelps, & Lerner, 2011). For instance, having a hopeful future orientation may energize the activation of the self-regulatory skills of youth, even in the face of challenges to their opportunities to contribute to the adaptive developmental regulations requisite for positive development.

Intentional Self-Regulation

Using the selection, optimization, and compensation (or SOC) measure developed by Baltes and colleagues (e.g., Baltes, 1997; Freund & Baltes, 2002) to index intentional self regulation (ISR), Gestsdóttir, Lerner, and their colleagues have found that SOC, conceptualized as reflecting the individual's "contribution" to adaptive individual ←→ context relationships, covaries positively with positive youth development and negatively with problem behaviors (e.g., Gestsdóttir & Lerner, 2007; Gestsdóttir, Bowers, von Eye, Napolitano, & Lerner, 2010; Gestsdóttir, Lewin-Bizan, von Eye, Lerner, & Lerner, 2009; Zimmerman, Phelps, & Lerner, 2007, 2008). Lerner and colleagues have also identified the structure of SOC over the adolescent period. They found that in early adolescence (Grades 5, 6, and 7) SOC was best represented as a global structure rather than three differentiated processes (Gestsdóttir & Lerner, 2007) but, by Grade 8, the tripartite, elective selection, optimization, and compensation structure of SOC was identified (Gestsdóttir et al., 2009) and by Grade 10, Gestsdóttir et al. (2010) confirmed the presence of a four-component structure of intentional self-regulation: elective selection, optimization, compensation, and loss-based selection (LBS; but see Geldhof, Bowers, Napolitano, & Gestsdóttir, in press). In each study, SOC scores correlated positively with indicators of PYD and negatively with substance use, delinquency, and depressive symptoms.

Using a global index that combines aspects of goal selection, optimization, and compensation, Bowers, Gestsdóttir, et al. (2011) examined the development of intentional self-regulation across 7 years of adolescence (Grades 5 to 11). These analyses helped ascertain if distinctive patterns of ISR development existed, whether these trajectories differed in relation to several Grade 5 parenting characteristics, and whether ISR trajectories were linked to positive and negative developmental outcomes at Grade 11. Across the developmental period spanning Grade 5 to Grade 11, four distinct trajectories of global SOC development could be identified—*Steady Decline*, *Elevated*, *Pronounced Decline*, and *Late Onset*. The majority of youth in the sample experienced a steady decline in global SOC. Lower levels of parental warmth, monitoring, and school involvement at Grade 5 predicted late-onset ISR development while pronounced-decline adolescents reported lower levels of PYD and contribution at Grade 11.

These findings highlight the importance of recognizing the principles of multipotentiality, equifinality, and multifinality (Cicchetti & Rogosch, 1996; von Bertalanffy, 1968) when conducting developmental research. That is, initially disparate ISR groups arrived at similar developmental outcomes through different pathways whereas groups who reported similar global SOC levels at the onset of adolescence were significantly different at Grade 11.

Hopeful Future

Emotions, such as hope for one's future, along with the cognitive and behavioral skills youth need to activate SOC skills to achieve future goals, may also play important roles in the development of positive and problematic characteristics manifested across adolescence. Using data from youth participants from Grades 7, 8, and 9 of the 4-H study, Schmid et al. (2011) assessed the role of a hopeful future in predicting growth trajectories of positive and negative developmental outcomes, including PYD, contribution, risk behaviors, and depressive symptoms. The SOC measure was also included as a covariate to predict developmental outcomes. Controlling for sex and SES, higher levels of both hopeful future and SOC significantly predicted membership in the most favorable trajectories. Hopeful future was a stronger predictor than SOC for each of the outcomes assessed. In a subsequent study exploring the developmental associations between hopeful future expectations and SOC, Schmid et al. (2011) found that although both constructs were strong predictors of PYD in middle adolescence, the results indicated that earlier hopeful expectations for the future may be influential for later intentional self-regulation abilities.

School Engagement

School engagement is a person ←→ context relational construct that depicts the way in which the individual cognitively, emotionally, and behaviorally coacts with the school setting (Li, Lerner, & Lerner, 2010) and, as such, school engagement may mediate the associations between ecological and personal assets and academic competence. Using structural equation modeling, Li, Lynch, Kalvin, Liu, and Lerner (2011) examined relations between school engagement and academic competence using Grades 5 and 6 data from the 4-H study. Confirmatory factor analyses provided evidence for two school engagement components, behavioral and emotional. These two factors mediated the relation between assets and academic competence in different ways. Emotional engagement was indirectly linked to academic competence via behavioral engagement. Behavioral and emotional engagement also had different individual and contextual antecedents. Behavioral engagement was predicted by the individual assets of ISR and educational expectations, whereas emotional engagement was predicted by the ecological assets of parental involvement, maternal warmth, peer support, and school climate.

In subsequent studies, Li and colleagues (Li & Lerner, 2011; Li, Zhang, et al., 2011) have assessed the development of the two facets of school engagement and their relation to both positive and problematic youth outcomes. Using a semiparametric mixture model, four trajectories for behavioral school engagement and four trajectories of emotional engagement were identified across Grades 5 to 8. Li and Lerner (2011) were also able to identify several sex, race/ethnicity, and family SES differences with regard to membership in both behavioral and emotional engagement trajectory groups. In general, boys, youth of color, and youth from less advantaged families tended to be in less favorable trajectory groups for both behavioral and emotional engagement. Findings suggested that associations between behavioral engagement and nonacademic outcomes exist as youth who experienced more positive pathways of behavioral or emotional engagements tended to have better grades, were less depressed, and were less likely to be involved in delinquency and drug abuse than youth who followed less favorable trajectories.

Li and her colleagues also estimated discrete-time survival analyses to assess the effect of behavioral and emotional school engagement on the subsequent initiation of drug use and delinquency (Li, Zhang, et al., 2011). Results indicated that, controlling for demographic variables, higher degrees of behavioral and emotional school engagement predicted a significantly later onset of substance use and involvement in delinquency.

Finally, the contextual predictors of behavioral and emotional school engagement have been reported (Li, Bebiroglu, Phelps, & Lerner, 2009; Li, Lynch, et al., 2011). Li, Lynch, et al. (2011) found that girls and youth of higher family SES reported higher behavioral and emotional engagement on average than boys and, as well, youth from less advantaged families. Peer support positively predicted behavioral and emotional school engagement, whereas associating with problem-behaving friends and bullying involvement were negatively associated with both aspects of school engagement. Li et al. (2009) also indicated that "hanging out" with friends without set plans and excessive media use were associated with lower behavioral engagement with school, lower academic achievement, and higher rates of risk behaviors. However, youth who ate dinner with their families reported higher levels of emotional engagement, lower depression and risk behaviors, and better grades while engagement in civic activities was associated with higher levels of emotional engagement.

Ecological Assets and PYD

The relations among observed ecological assets in the families, schools, and neighborhoods of youth with positive and negative developmental outcomes were assessed among fifth-grade youth from the 4-H Study (Theokas & Lerner, 2006). Ecological asset indicators were categorized into four categories: (1) human, (2) physical or institutional, (3) collective activity, and (4) accessibility. These indicators were measured equivalently across the three contexts. Different dimensions of the family, school, and neighborhood settings had the most comprehensive impact on the different developmental outcomes, specifically collective activity in the family, accessibility in school, and human resources in the neighborhood. However, in all settings, assets associated with individuals were the most potent predictors of PYD. Family assets were most important in the lives of youth as one of the strongest predictors of PYD was eating dinner together as a family.

Subsequent analyses of the youth from Theokas and Lerner's work (2006) indicated that dimensions of the neighborhood coact with adolescent extracurricular activity involvement to predict PYD, depressive symptoms, and risk behaviors (Urban, Lewin-Bizan, & Lerner, 2009). The direction of these relations differed for boys and girls. Girls who lived in lower asset neighborhoods exhibited higher levels of PYD and lower levels of depressive symptoms and risk behaviors when they engaged in extracurricular activities. At high levels of activity involvement, girls in high asset neighborhoods exhibited increased levels of risk behaviors, particularly if they lived in neighborhoods with abundant physical resources. The opposite relations were seen in boys. Moderate to high levels of activity involvement predicted lower levels of PYD and higher levels of risk behaviors for boys living in lower asset neighborhoods. For boys living in high asset neighborhoods, activity involvement was generally beneficial. Increased activity involvement was associated with increased levels of PYD and decreased levels of risk behaviors. The findings from this study pointed to the need to consider the manner in which multiple contextual features are associated with developmental change.

Analyses by Bowers, von Eye, et al. (2011), also following up on the Theokas and Lerner (2006) work, assessed the relations between these ecological assets and trajectories of positive and problematic development. Assets at the family, school, and neighborhood levels differentiated goal-optimization trajectories, whereas factors at the school level differentiated delinquency trajectories. However, an ecological asset was not found that consistently differentiated both goal-optimization trajectories and delinquency trajectories. The results indicated that collective activity in the family best predicted membership for the five goal-optimization trajectories that were identified, whereas school-based assets (physical resources and accessibility) differentiated the four delinquency trajectories that were identified.

The 4-H Study data have been used also to examine specifically the ecological assets of parenting and youth programs in relation to the youth strength of intentional self-regulation. For example, using data from Grades 5 to 8 from the 4-H study, Lewin-Bizan, Bowers, & Lerner (2010) found a developmental cascade wherein positive parenting (as indexed by warmth and monitoring) was a major contextual asset predicting subsequent intentional self-regulation, and intentional self-regulation predicted subsequent scores for PYD and, in turn, PYD positively predicted later youth Contribution scores.

Using person-oriented configural frequency analysis (von Eye, 2002), Napolitano, Bowers, Gestsdóttir, Depping, et al. (2011) examined patterns of parenting (warmth, monitoring, school involvement) and the development of goal selection processes across Grades 9 to 11, conceptualized and measured by the selection subscale of the SOC measure. The researchers also assessed the relation of these patterns to the positive development of youth. Across analyses of maternal warmth, parental monitoring, and parental school involvement, Napolitano and colleagues found that the most common pathway to Grade

11 thriving involved a youth having stable, consistently above-median selection scores and above-median levels of the parenting variables for at least two times of measurement. However, the findings also indicated that a higher than expected number of youth with consistently low levels of selection had above-median PYD at Grade 11, regardless of their perceptions of maternal warmth, parental monitoring, or parental school involvement.

Youth relationships with adults outside of the home have also been found to promote positive youth development. For example, using data from youth in Grades 10 through 12 from the 4-H study, Bowers et al. (2012) modeled the relations among quantity and quality of youth relationships with important nonparental adults (INAs), intentional self-regulation, hopeful future expectations, and the Five Cs of PYD (competence, confidence, connection, character, and caring). Results indicated that the quantity of INA relationships predicted youth confidence, character, and caring indirectly through hopeful future expectations. Emotional closeness with an INA also predicted youth confidence via hopeful future expectations. Finally, youth intentional self-regulation predicted changes in character.

As noted, several studies have also used the 4-H study data set to examine possible interactions between self-regulatory processes and OST activity participation. For example, Urban, Lewin-Bizan, and Lerner (2010) found that both the strengths of youth and the resources of their contexts are involved in thriving. Urban et al. (2010) employed data from Grades 5 to 7 to explore if youth intentional self-regulation abilities moderated the effect of participation in OST activities on PYD among adolescents living in neighborhoods with relatively low levels of ecological assets. Overall, Urban et al. (2010) found that youth in these settings who had the greatest capacity to self-regulate (i.e., youth with the highest SOC scores) benefited the most from involvement in OST activities, in terms of PYD, depressive symptoms, and risk behaviors. These relations were particularly strong for girls.

Mueller et al. (2011) used data from Grades 8, 9, and 10 of the 4-H study in order to examine the relation between adolescents' SOC abilities and their participation in youth development (YD) programs across Grades 8 and 9 in predicting Grade 10 PYD and Contribution. Results indicated that whereas self-regulation skills alone predicted PYD, self-regulation and YD program participation both predicted Contribution. In addition, Grade 8 YD participation positively predicted Grade 9 SOC, which, in turn, predicted Grade 10 PYD and Contribution.

Trajectories of Positive and Problem Behavior

Initial formulations of the PYD perspective suggested that if PYD is promoted, then risk and problem behaviors would be in turn diminished (e.g., Benson, Mannes, Pittman, & Ferber, 2004; Pittman, Irby, & Ferber, 2001). Findings from the 4-H study have shown a more complex pattern of positive and negative developmental trajectories; these pathways are not simply inversely related (Lewin-Bizan, Lynch et al., 2010; Phelps et al., 2007).

Phelps et al. (2007) assessed the patterns of change associated with indicators of PYD and of risks/problem behaviors through use of data from the first three waves of data (Grades 5, 6, and 7) from the 4-H study. They identified several different trajectories of positive and problematic/risk behaviors. Only about one-sixth of all youth in the sample manifested a pattern of change marked by the coupling of increases in PYD and decreases in risk/problem behaviors. Other youth remained stable over time, showed increases in PYD and risk, and declined in PYD.

In turn, Lewin-Bizan, Lynch, et al. (2010), using the 4-H study data across Grades 5 to 10, found that youth who were high in PYD (i.e., the group of youth with increasing-to-stable-high PYD) were also more likely to be in a group of youth having risk behaviors that increased (and later decreased), than in a group having the lowest risk-behaviors. Thus, negative trajectories are not simply the "other side of the coin" of positive trajectories.

Schwartz et al. (2010) examined the association of PYD with the likelihood of tobacco, alcohol, marijuana, hard drug, and sex initiation for youth in Grades 5 to 10 of the 4-H study. Survival analysis models indicated that PYD was significantly and negatively associated with the initiation hazards for tobacco use, marijuana use, and sex initiation for girls only, and with hard drug use for both genders. PYD was also positively associated with the odds of condom use across genders. Schwartz and colleagues also found that PYD was positively related to the timing of alcohol use initiation for boys, but not for girls. Perhaps surprisingly, for a one standard deviation increase in PYD, the odds of boys initiating alcohol use during the study would be expected to increase by 24%. Thus, consistent with the idea that relations between positive and negative behaviors is not straightforward, the findings of Schwartz et al. (2010) point to the need for future research assessing the bases of these variations. Overall, the multiplicity of patterns of conjoint trajectories for PYD and risks/problem behaviors constitutes a challenge for both developmental theory and applications aimed at enhancing resilience and positive development among adolescents.

Conclusions

The results of the 4-H study of PYD provide important insights into what constitutes PYD and what individual and contextual factors might relate to adolescent thriving. We believe that the Relational-Developmental-Systems approach taken by 4-H study researchers has been useful in understanding, first, the relative plasticity of human development and, second, the importance of dynamic relations between adolescents and their real-world ecological settings.

As we turn now to a review of PYD as a philosophy to understanding, or conceptualizing, youth programs, it is important to note that, although there is some substantial variation in the focus of different conceptions of the PYD process, all models we have described highlight the adaptive individual ←→ context relations that constitute the basic, relational process of development. In essence, all models reflect the PYD process depicted in Figure 16.1.

PYD AS A PHILOSOPHY OR APPROACH TO YOUTH PROGRAMMING

The second component of Hamilton's (1999) definition of PYD is that it is a philosophy or approach to youth programming. There are numerous excellent examples of this second facet of PYD, the most prominent and influential being the Eccles and Gootman (2002) National Academy of Sciences report on community programs to promote youth development. The report discusses the design, implementation, and evaluation of community programs for youth and conceptualizes PYD in regard to the skills, knowledge, and other personal and social assets required to successfully transition from healthy adolescence into competent adulthood.

Eccles and Gootman (2002) based their report on the work of scholars who contributed to the National Academy of Sciences' Committee on Community-Level Programs for Youth. These scholars defined four domains of individual assets that represent health and well-being in adolescence: physical development, intellectual development, psychological and emotional development, and social development. They noted that positive development does not require possession of all assets. Having more assets, however, is better than having fewer and it is beneficial to have assets in all four domains. Eccles and Gootman (2002) indicated that these assets do not exist in a vacuum and do not themselves ensure the well-being of adolescents. Youth need access to contexts that facilitate their development through exposure to positive experiences, settings, and people, and to contexts that provide opportunities to develop and refine real-life skills. It is important for every community to have an array of programs for youth that, taken together, offer all features of positive developmental settings.

Some of the features that characterize such positive developmental settings include physical and psychological safety, appropriate structure, and positive social norms. These contexts provide opportunities to enjoy supportive relationships, to belong, to build skills, and to feel empowered by experiencing efficacy and a sense of mattering. Moreover, these settings need to be synergistic with efforts and perspectives of the adolescents' families, as well as with the communities in which both the programs and the adolescents reside. While acknowledging the list as provisional, Eccles and Gootman (2002) suggested that youth-serving professionals take these factors into consideration when planning, designing, and evaluating programs for the youth with whom they work.

In addition to Eccles and Gootman's framework (2002), there are several other "philosophies" of youth programs (e.g., Blum 1998, 2003; Roth & Brooks-Gunn, 2003a, 2003b). For example, in 2003, Roth and Brooks-Gunn investigated community-based programs to understand what, exactly, is meant by the term *youth development program*. They identified the three critical characteristics that youth development programs should have. Based on the existing literature, Roth and Brooks-Gunn (2003a, 2003b) concluded that specific program activities, atmosphere, and goals are the three defining aspects of youth development programs that differentiate them from other programs for adolescents. The goals of youth development programs go beyond prevention to include promotion of positive development. Youth development programs are characterized by an atmosphere of hope, caring, safety, cultural appropriateness, and respect of adolescents' abilities to make choices and bear responsibility. Further, program activities provide opportunities for active involvement and meeting new challenges.

Similarly, Blum (2003) identified four elements critical to successful youth interventions: people, contributions, activities, and place. Successful interventions are those that build strong adult-youth relationships (People), include active involvement of youth in giving back to family, school, and community (Contribution), offer productive and recreational opportunities for youth (Activities), and provide a safe environment free from drugs and violence with adult supervision (Place).

Many other philosophies/approaches to youth programs exist (e.g., see Dryfoos, 1990; Dukakis, London, McLaughlin, & Williamson, 2009; Heck & Subramaniam, 2009). For instance, the Positive Youth Development Evaluation Project (e.g., Catalano, Berglund, Ryan, Lonczak, & Hawkins, 1999, 2004) reviewed the literature on youth development programs to generate an operational definition of positive youth development and identify characteristics that mark effective youth development programs. Their review, in general, affirmed Eccles and Gootman's (2002) framework, as it defined positive youth development programs as those that promote of foster at least 5 of 15 outcomes in youth: (1) bonding, (2) resilience, (3) social competence, (4) emotional competence, (5) cognitive competence, (6) behavioral competence, (7) moral competence, (8) self-determination, (9) spirituality, (10) self-efficacy, (11) clear and positive identity, (12) belief in the future, (13) recognition for positive behavior, (14) opportunities for prosocial involvement, and (15) prosocial norms. Nineteen of the 25 programs that were reviewed significantly increased positive youth behaviors, and all but one of the programs significantly decreased problem behaviors. Effective youth development programs also had a structured curriculum and measured reductions in problem behaviors, increases in positive behavior or, ideally, both types of outcomes. These effective programs were delivered over a period of at least 9 months and were implemented with quality, consistency, and fidelity to the standards established by the program's model (Catalano, Berglund, et al., 2004).

Building on the work of both Roth and Brooks-Gunn (2003a, 2003b) and Blum (2003), as well as others (e.g., Rhodes, 2002), R. Lerner (2004) argued that there are three fundamental characteristics of effective PYD programs. These *Big Three* characteristics are:

1. Positive and sustained adult-youth relations between a young person and an adult who is competent, caring, and continually available for at least one year, such as a mentor, coach, or teacher.
2. Life-skill building activities (e.g., enhancing skills pertinent to the selection, optimization, and compensation skills we discussed earlier).
3. Opportunities for youth participation in and leadership of valued family, school, and community activities.

R. Lerner (2004) argued as well that these features of youth programs needed to be simultaneously and integratively present for PYD to be effectively promoted.

In turn, Heck and Subramaniam (2009) described five other youth development program philosophies, or development frameworks, which they defined as a conceptualization that "helps give direction and purpose to a program" (p. 2). The five frameworks are: (1) targeting life skills, (2) developmental assets (as conceptualized by Search Institute; e.g., Benson et al., 2011; Benson, Scales, Hamilton, & Semsa, 2006), (3) the four essential elements, (4) the Five Cs, and (5) the community action framework for youth development. We describe each of these below.

The *Targeting Life Skills* model details the life skills encapsulated by 4-H's Heart, Hands, Head, and Health (Hendricks, 1996); this model is meant to serve as a plan for youth programming. Each of the four components is composed of two general categories of skills, with the two categories composed of more specific life skills. For example, "Hands" is divided into working and giving; giving is further divided into community service, leadership, responsible citizenship, and contributions to group effort; working is further divided into marketable skills, teamwork, and self motivation. The model helps to identify specific skills that a youth-based program should focus on, rather than being a theoretical model of development (Heck & Subramaniam, 2009).

As we have noted earlier in this chapter, the *Developmental Assets* model as conceptualized by the Search Institute (e.g., Benson et al., 2011) identifies resources available to young people that promote positive development. Benson and colleagues have generated a list of 40 developmental assets, both internal and external to young people, which have been linked to positive youth outcomes. As indicated as well in the approach forwarded by Eccles and Gootman (2002), higher levels of assets have been related to positive developmental outcomes, such as higher school achievement, better physical health, lower levels of risk behaviors, and resilience (e.g., Benson et al., 2011). Heck and Subramaniam (2009) reported that research (and evaluation) about the application of the Developmental Assets model to youth programs is sparse.

The *Four Essential Elements of Youth Development* are identified as (1) belonging, (2) mastery, (3) generosity, and (4) independence, and were originally proposed as the *Circle of Courage* (Brendtro, Brokenleg, & Van Bockern, 1990). These four elements were further subdivided into eight elements that were identified as critical to developing positive youth outcomes in youth development programming (Peterson et al., 2001). Belonging includes having relationships with caring adults, and an inclusive and safe environment; mastery includes opportunities for mastery and engagement in learning; generosity consists of the opportunity to value and practice service for others; and independence includes opportunities to see oneself as an active participant in the future and the opportunity for self-determination.

The *Community Action Framework for Youth* (Gambone & Connell, 2004; Gambone, Klem, & Connell, 2002) includes five hierarchical organized strategies for use by both practitioners and scientists. These five strategies are (1) building community capacity and conditions for change, (2) implementing community strategies to enhance supports and opportunities for youth, (3) increasing supports and opportunities for youth, (4) improving youth development outcomes, and (5) improving long-term outcomes in adulthood. To implement these strategies, programs must meet five key requirements: adequate nutrition, health, and shelter; multiple supportive relationships; challenging and engaging activities and experiences; meaningful opportunities for involvement; and physical and emotional safety. The Community Action Framework for Youth is intended to create communities in which all young people can optimize their potential. The framework is meant to be a systematic approach to planning, implementing, and evaluating programs and resources for youth. In this regard, the framework does enumerate supports and opportunities that overlap with the elements of effective youth programs presented in other approaches.

In turn, as noted earlier in the discussion of Lerner and colleagues' Relational-Developmental-Systems model of the PYD process (e.g., R. Lerner et al., 2005), the Five Cs model of youth development conceptualizes PYD as composed of Five Cs—competence, confidence, connection, character, and caring. The Cs are a means to operationalize the developmental characteristics that a youth needs to become a successful and contributing member of society. These Five Cs were linked to the positive outcomes of youth development programs reported by Roth and Brooks-Gunn (2003a, 2003b). In addition, these Cs are prominent terms used by practitioners, adolescents involved in youth development programs, and the parents of these adolescents in describing the characteristics of a "thriving youth" (King et al., 2005).

Heck and Subramaniam (2009) indicate that each of the five approaches they reviewed has varying levels of empirical support. However, none of the frameworks have been linked to research that provides evidence of universal applicability, although from a Relational-Developmental-Systems perspective, such universality is not even possible, given that the world is seen as variegated and changing (R. Lerner, 2002; Overton, 2010). As evidenced by our earlier review of the 4-H study results, Heck and Subramaniam (2009) indicated that the Five Cs model of PYD is the most empirically supported framework to date.

However, as we turn to the third facet of PYD research—youth programs—it is important to note that although the Five Cs model may be an empirically useful means to study the PYD process, it is not clear from the conceptualization of the Five Cs model how to translate it into a specific youth development program. Work on such translation is beginning in regard to coaching youth sports programs (e.g., Haskins, 2010) and to mentoring programs for youth (Liang, Spencer, West, & Rappaport, 2012; Napolitano, Bowers, Gestsdóttir, & Chase, 2011).

PYD AS INSTANCES OF YOUTH PROGRAMS AND ORGANIZATIONS

Literally thousands of community-based programs seek to promote PYD in the United States (e.g., Dryfoos, 1990; Mahoney, Vandell, Simpkins, & Zarrett, 2009; Roth & Brooks-Gunn, 2003a, 2003b) or its theoretically related outcomes (e.g., active and engaged citizenship; Zaff, Kawashima-Ginsberg, & Lin, 2011). As well, there are numerous national organizations that seek to provide such programs throughout the United States, including 4-H, Boys & Girls Clubs, Big Brothers/Big Sisters, Boy Scouts, Girl Scouts, YMCA, and Girls, Inc. (e.g., Zaff et al., 2011). Discussing these programs or organizations in detail is obviously beyond the scope of this chapter. The purpose here is to illustrate the third instance of Hamilton's (1999) tripartite definition of PYD and point to the current nature of the connections between this facet of PYD and the other two facets we have discussed.

There are many instances of programs that are effective in promoting PYD, operationalized, for instance, in regard to the links between program characteristics and the development or enhancement of one or more of the Five Cs (e.g., see Roth & Brooks-Gunn, 2003a, 2003b). Accordingly, we will use several exemplary PYD programs as sample cases of the sorts of programs to which Hamilton (1999) pointed. We focus on the scholarship of Catalano, Hawkins, and colleagues (e.g., Catalano, Haggerty, Oesterle, Fleming, & Hawkins, 2004; Hawkins, Brown et al., 2008; Hawkins, Catalano, Arthur, & Egan, 2008), Kurtines and colleagues (Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Briones, et al., 2008; Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Silverman, et al., 2008), and Flay and colleagues (Flay, 2002; Flay & Allred, 2003), as examples of such exemplary PYD programs.

Richard Catalano, J. David Hawkins, and the Social Development Research Group

Catalano, Hawkins, and colleagues in the Social Development Research Group (SDRG) at the University of Washington have conducted work that has reflected the integration of the prevention science and PYD approaches (Catalano, Haggerty, et al., 2004; Catalano, Hawkins, Berglund, Pollard, & Arthur, 2002). The interventions developed, implemented, and tested by the SDRG are framed within the prevention science model and, therefore, they necessarily have a primary focus on "preventing" negative developmental outcomes rather than promoting positive ones (Catalano et al., 1999). However, their work has included key components of the PYD model, such as the building of youth connections to family, school, and community and, as well, indices of positive adjustment, functioning, and well-being. These features of their work reflect the growing recognition that preventing disease or behavioral problems does not constitute the provision of health or the actualization of positive development (Damon, 2004; R. Lerner, 2005; R. Lerner, Fisher & Weinberg, 2000). Two longitudinal intervention programs the SDRG has overseen are the Community Youth Development Study and the Raising Healthy Children (RHC) projects.

The Community Youth Development Study began in 2003 and consists of 12 pairs of matched communities across seven states (e.g., Fagan, Hanson, Hawkins, & Arthur, 2009; Hawkins, Brown, et al., 2008; Hawkins, Catalano, et al., 2008). In each pair, one community receives the Communities That Care (CTC) prevention system, which seeks to promote and sustain positive youth development, and the other community serves as a control. CTC serves as a system for planning and managing community-based prevention activities. Among fifth- to eighth-grade adolescents, results indicate that the CTC prevention system reduced tobacco and alcohol use and prevented delinquent behavior within 4 years of implementing the CTC program.

There are five stages in the CTC prevention system: (1) Get Started—assessing community readiness to undertake collaborative prevention efforts (2) Get Organized—getting a commitment to the CTC process from community leaders and forming a diverse and representative prevention coalition, (3) Develop a Profile—using epidemiologic data to assess prevention needs and evaluating gaps in current services related to those needs, (4) Create a Plan—choosing tested and effective prevention policies, practices, and programs based on assessment data, and (5) Implement and Evaluate—implementing the new policies, programs, and practices with fidelity (in a manner congruent with the program's theory, content, and methods of delivery) and evaluating progress over time.

Raising Healthy Children (RHC) seeks to investigate risk and protective factors for PYD through a longitudinal study of 1,000 youth initially in first and second grade, their parents, and their teachers (e.g., Catalano, Haggerty et al., 2004; King, Fleming, Monahan, & Catalano, 2011). Based on prior work from Catalano and colleagues, the RHC project intervenes in several developmental contexts across a significant portion of time to affect several psychosocial indicators in youth. The project provides research-based parenting workshops in which parents learn ways to encourage positive behavior and family bonding, as well as academic success. In addition, the project includes home visits in which additional services that aid in the development of the student are offered. Staff development for teachers seeks to contribute to the development of the child as well. Teacher training seeks to help teachers identify ways to keep students interested and involved in learning. Home visits with youth and parents are also scheduled through the high school years to serve as reinforcement of the parenting workshops.

Results from the RHC study indicated that childhood bullying is significantly associated with violence, heavy drinking, and marijuana use at Age 21 (Kim, Catalano, Haggerty, & Abbott, 2011). The researchers also found that greater self-control problems and attentional problems in the 6th grade, and increases in these problems over time, were associated with higher levels of substance use at 11th grade (K. King et al., 2011). Other findings suggested that risk factors in early adolescence resulted in outcomes relating to depressive symptoms, risky sexual behavior, and cigarette smoking (Mazza, Fleming, Abbott, Haggerty, & Catalano, 2010; White, Fleming, Catalano, & Bailey, 2009; Kim, Fleming, & Catalano, 2009).

The work of Catalano, Hawkins, and colleagues in the SDRG is reflective of the "Big Three" characteristics of effective youth programs as discussed by R. Lerner (2004). Both the CTC and RHF programs emphasize the role that strong, healthy connections to prosocial families, schools, and peers have on youth development. This impact occurs through the provision of opportunities to actively engage these contexts, inculcation of the skills to engage contexts successfully, and recognition of youth contributions.

The use of such integrative approaches to promoting PYD is also illustrated in the next exemplary program discussed.

William Kurtines and the Miami Youth Development Project

Similar to the RHC project, the programs of the Miami Youth Development Project (YDP; Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Briones, et al., 2008; Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Silverman, et al., 2008), such as the Changing Lives Program (CLP), approach youth development from an RDSP-derived framework. The Miami YDP is a university-community collaborative outreach research program that draws on what Kurtines and colleagues term developmental intervention science (Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Briones, et al., 2008; Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Silverman, et al., 2008). Developmental intervention science is an integration of the developmental science, intervention science, prevention science, outreach research, and positive youth development literatures. Developmental intervention science seeks to describe, explain, and optimize intraindividual change and interindividual differences in intraindividual change across the life span (Baltes et al., 1977) through the development of community-supported interventions. Kurtines and colleagues see this integrative approach as having

> the potential to bring together (a) a more empowering model of knowledge development for research involvement in the community, one that includes meeting both community and youth needs as well as knowledge development needs; (b) a nuanced and contextualized notion of youth and their development; and (c) methodologies that richly reflect rather than reduce the experiences of young people whose development we seek to promote. (Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Silverman, et al., 2008, p. 258)

The Miami YDP began in response to the needs of at-risk young people in the Miami community, especially those from immigrant groups from Central and South America and the Caribbean. As a community-supported program, the Miami YDP aims to realize long-term community-valued developmental goals for its youth by generating knowledge of strategies that are effective, practical, and sustainable in "real world" settings (Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Briones, et al., 2008).

Among the programs developed as part of this university-community partnership is the Changing Lives Program (CLP; Eichas et al., 2010; Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Briones, et al., 2008). The CLP targets youth with multiple problems in alternative high schools by creating contexts in which youth can take responsibility for their lives and their communities. The immediate focus in implementing CLP is on addressing identified, presenting problems through counseling services (e.g., addressing depression, anger management, substance use). The long-term focus is on promoting positive development. With the specific aim of promoting positive identity development, CLP services work to build skills and strengths in youth that will help them to change themselves and the contexts in which they are embedded. Thus, youth work to directly build positive characteristics that will lead to a reduction in problematic outcomes. This individual strength-based approach complements prevention models that seek to affect the contextual level such as parents, peers, and school.

Drawing on outcomes-mediation evaluation models in the prevention science literature (Silverman, Kurtines, Jaccard, & Pina, 2009), Eichas and colleagues assessed whether the CLP program, which was specifically designed to promote PYD, also had an effect on untargeted problem outcomes. In a sample of 178 African American and Latino/a adolescents, the results of SEM analyses indicated that participation in CLP was directly related to gains in positive identity development. The evaluation of the CLP indicated that the intervention resulted in significant increases in the outcome of interest, that is, participants' feelings of personal expressiveness. Analyses also indicated CLP participation led to positive changes in identity exploration and identity commitment, with the effect on personal expressiveness partially mediated by identity exploration, as measured by seeking out and utilizing self-relevant information. The CLP intervention also had a differential impact on changes in identity resolution for African American versus Latino/a youth. As hypothesized, participation in CLP was related to positive changes in identity resolution among Latino/a youth relative to the comparison group; however, contrary to expectations, African American youth in CLP reported a decrease in identity resolution relative to the comparison group.

In regard to the relation between CLP participation and problematic outcomes, results indicated that gender moderated the effect of the CLP intervention on internalizing problem behaviors. For females, participation in CLP was related to a reduction in internalizing behaviors, whereas males reported no greater change in internalizing problem behaviors than did males in the comparison group.

The findings also identified several possible pathways through which the intervention may have had an effect on both internalizing and externalizing problem behaviors. The CLP intervention seemed to lead to increases in personal expressiveness (partially mediated by identity exploration), which led to decreases in internalizing problems. Changes in internalizing problems then led to changes in externalizing problems.

The work of researchers on the Miami YDP has provided important findings regarding the potential for integrative interventions to both promote positive outcomes and decrease or prevent problematic outcomes. As indicated in research based on the 4-H study of PYD (e.g., Lewin-Bizan, Lynch, et al., 2010; Phelps et al., 2007) the relation between PYD and problematic outcomes is not simply an inverse one—a more complex pattern exists. Dynamic models of human behavior and development are needed to understand, first, the relative plasticity of human development and, second, the importance of individual ←→ context relations as the bases of variation in the course of human development (Baltes et al., 2006; R. Lerner, 2005; Silbereisen & Lerner, 2007). The third program discussed also illustrates the links that may exist between positive and problem behaviors as outcomes of youth programs.

Brian Flay, Carol Allred, and the Positive Action Program

Flay and colleagues (e.g., Flay, 2002; Flay & Allred, 2003) have presented a comprehensive youth program that focuses on promoting healthy, positive development of children and youth in many domains, including academics, problem behaviors, and family relationships. Flay (2002) argues that PYD requires comprehensive health promotion programs. He explains that "to prevent problem behaviors and promote positive behaviors [we need] comprehensive, coherent, and integrated approaches" to youth programs (p. 407).

Accordingly, Flay and Allred (2003) illustrate such a program by describing the long-term effects of the "Positive Action" program. Features of this school-based program include interventions with the individual child or adolescent, the school, and the family. At all levels, the interventions within the program focus on the same broad concept (feeling good about oneself when taking positive actions). The specific content includes six units: (1) self-concept, (2) positive actions for body and mind, (3) social/emotional positive actions for managing yourself responsibly, (4) social/emotional positive actions for getting along with others, (5) social/emotional positive actions for being honest with yourself and others, and (6) social/emotional positive actions for improving continually.

A 2006 review by the National Registry of Evidence-based Programs and Practices (NREPP) noted that the Positive Action program is indeed an integrated and comprehensive program. The review pointed to evidence that the program is effective in improving academic achievement and school attendance and, in turn, in diminishing problem behaviors such as substance use, violence, suspensions, disruptive behaviors, dropping out, and sexual behavior.

Evaluations of the effectiveness of comprehensive PYD programs like this are limited (see Catalano et al., 1999). Indeed, most youth development programs in the United States are not evaluated (e.g., see Roth, Brooks-Gunn, Murray, & Foster, 1998). However, the evaluation data pertinent to the Positive Action program, such as that provided by Beets et al. (2009), demonstrates that students who participated in the program are less likely to engage in substance use, violence, and sexual activity than students who do not participate in the intervention. These findings were derived from both student self-report and teachers' reports. This evaluation, however, had limitations in terms of sample; it included only young adolescents (fifth-grade students) in a specific geographical and cultural setting (Hawaii).

Nevertheless, despite such limitations of a particular evaluation research study, the Positive Action program has demonstrated effectiveness and is an excellent example of the third facet of the definition of PYD discussed by Hamilton (1999). Moreover, in including in its design a comprehensive, individual and contextual approach to intervention, the Positive Action program reflects key ideas found within instances of the other two facets of Hamilton's (1999) tripartite definition of PYD.

Conclusions

The work of the investigators who focus on designing, implementing, and evaluating youth development programs highlights the importance of the dynamic relations between the person and context in the study of positive youth development. Supporting the use of the RDSP in understanding the relative plasticity of human development and the importance of relations between individuals and their real-world ecological settings as the bases of variation in the course of human development (Baltes et al., 2006;

R. Lerner, 2005; Silbereisen & Lerner, 2007), there are consistencies between actions that occur within actual, exemplary PYD programs and the two other facets of the Hamilton (1999) tripartite conception of PYD.

However, these connections are often not drawn explicitly by practitioners who implement PYD programs. Indeed, across the work associated with these three facets of Hamilton's (1999) definition, these domains of the PYD field function as circles in a Venn diagram whose degrees of overlap remain uncertain. This lack of specification, and the incomplete integration of the domains of basic and applied scholarship pertinent to PYD that it reflects, constitutes a challenge to advancing knowledge of how to understand and promote thriving among diverse youth. There are several problems involved in increasing the integration among the three domains of scholarship pertinent to PYD. The final section of this chapter addresses potential future direction of the PYD field by discussing the problems in integrating these facets of PYD.

PROBLEMS IN INTEGRATING THE THREE FACETS OF PYD SCHOLARSHIP

The lack of integration between the processes, philosophies, and programs of PYD scholarship represents one of several important obstacles to creating a fully reciprocal relation between practice and theory-predicated research in the service of the promotion of PYD. For example, it is not always clear which particular model of developmental process is explicitly used in the "philosophical" approaches to youth programming pertinent to PYD or in the particular instances of youth programs designed to foster PYD. In addition, it is ironically the case that, when such a connection seems evident (e.g., as appears to be the case with both the Developmental Assets framework and the Five Cs model; Heck & Subramaniam, 2009), it may nevertheless be unclear how these theories of process provide a specific approach to (i.e., a particular logic model) for youth programs.

As we have noted, work on this translation is only in its nascent period (Haskins, 2010; Napolitano et al., 2011). Despite some correspondence between components of the theoretical models and some features of the philosophy/approach to youth programming, more clarity about the connections between theories and philosophies, as well as between philosophies and particular instances of programs, are needed. This integration rests on the success of several facets of PYD scholarship. Most fundamentally, there are several methodological issues pertinent to understanding the course of development from a Relational-Developmental-Systems perspective (e.g., see Molenaar, Lerner, & Newell, 2014), and research about PYD that is framed by the Relational-Developmental-Systems paradigm (RDSP) constitutes a prominent sample case of the need to attend to these issues.

METHODOLOGICAL PROBLEMATICS OF PYD RESEARCH FRAMED BY RDS MODELS

We have thus far discussed how PYD as a theoretical approach framed by the RDSP. We have not, however, discussed how PYD researchers actually apply the tenets of the RDSP when generating and testing research hypotheses. To preview a key point about the fit between theory and research within this area of scholarship, it remains the case that many developmental scientists argue for relational theories while simultaneously using data collection and analysis methods that are not consistent with the complexity and nuance that the RDSP implies. Therefore, we describe the interrelated conceptual and methodological problematics that currently pertain to PYD research derived from the RDSP (see Geldhof et al., 2014, for a fuller discussion of these issues). In particular, we discuss implications related to the assumption that (a) development involves interrelated changes in a complex, multilevel system, (b) developmental trajectories of all individuals remain relatively plastic across the life span, and (c) examining relations in the presence of such complexity requires multimethod integration. Faithfully conducting research that follows from the RDSP requires that theoretical ideas be actualized through methodological choices related to research design, data collection, and analysis methods. This obligation is characteristic, as R. Lerner and Overton (2008) note, of "good science—selecting all features of one's methodology based on the nature of the (theoretically predicated) questions asked" (p. 250).

Development Occurs in a Complex Person-Context System

The RDSP approach to developmental science emphasizes *holism* as a fundamental guiding principle. In opposition to a fixed, atomistic reality composed of elements that preserve their identity regardless of context (Overton, 2010, 2013, Chapter 2, this *Handbook*, this volume), holism views objects and events as necessarily related to the context in which they are embedded. The whole exists as an organized and self-organizing system of parts, each defined by its relations to other parts and to the whole itself (Overton, 2013; Chapter 2, this *Handbook*, this volume). The key empirical question for developmental scientists interested in describing, explaining, and promoting positive human development in the context of a complex holistic system is therefore composed of five interrelated "whats": *What* attributes of *what* individuals, in relation to *what* contextual conditions, and at *what* points in ontogenetic, family or generational, and cohort or historical, time can be integrated to promote *what* instances of positive human development?

Armed with appropriate RDSP-informed research questions, researchers must make methodological decisions that acknowledge (a) that relational developmental systems are embedded (Overton, 2010, 2013), that is they are characterized by holism; (b) that individuals as relational developmental systems actively participate in the production (i.e., direct) of their own ontogenetic development; and (c) that systematic plasticity is present across the life span (Overton, 2010). We provide more details concerning each of these ideas.

Focus on the System

Once researchers embrace the concepts underlying the RDSP, the types of questions that they ask must necessarily shift, as exemplified in the multicomponent "what" question. A research framework informed by the RDSP must include multiple components that together account for the relative plasticity and dynamism that constitute ontogeny. For such research to match the complicated theory from which it derives, researchers must consider the complex and dynamic relational developmental system, which constitutes the person and person ←→ context relation.

Several studies derived from the 4-H study illustrate how to frame and test research questions that recognize the reciprocal bidirectional relations between developing persons and their changing contexts. As noted earlier, Urban et al. (2010) demonstrated that both the strengths of youth and the resources of their contexts are involved in youth thriving. Urban et al. (2010) explored whether youth intentional self-regulatory skills moderated the effect of participation in out-of-school-time (OST) activities in predicting PYD and risk outcomes among adolescents in low-resource neighborhoods. These neighborhoods were classified as low-resource because, using census data, the authors found that the opportunities available to youth in their ecological contexts along dimensions of human resources, physical or institutional resources, collective activity, and accessibility, were limited compared to other neighborhoods (see Theokas & Lerner, 2006, for more information on how this measure was derived). Urban et al. (2010) found that youth who reported the highest self-regulatory capacity benefitted the most from involvement in OST activities. The strength of these relations was most evident in girls.

Future research should consider additional person- and context-level variables that might explain specific trajectories of youth development. For example, the findings of Urban et al. (2010) indicate sex differences, which might be explained more fully by accounting for additional person-level variables such as age, race, socioeconomic status, religion, and household structure in future studies. Although Urban et al. (2010) considered ontogenetic time, the relative impact of generational, cohort, or historical time might also explain why this evidence in support of the RDSP-based PYD model seems more strongly supported for adolescent girls than for adolescent boys (Way, 2011). Additionally, future research could account for more context-level variables—such as indicators of social capital and social networks. Such complexity implies that understanding how characteristics of individuals coact with aspects of their contexts requires a research focus on person ←→ context relations rather than simple aggregations of person- and context-level attributes.

Person ←→ Context Relations as Units of Analysis

Development is affected by aspects of the individual and context, but the impact of any given personal or contextual characteristic can only be interpreted as part of a larger person-context system. A specific level of competence may represent positive person ←→ context relations for some individuals in some contexts, but the same level of competence may represent neutral or even negative person ←→ context relations for other individuals or in other contexts (Masten & Coatsworth, 1998). In other words, person ←→ context relations will vary between individuals (Molenaar, 2007; Tobach & Greenberg, 1984). As such, the goal of RDS-derived research is to capture and understand relations among the meaningful adaptive person ←→ context relations (i.e., adaptive developmental regulations) that characterize development across diverse populations.

Accurately capturing the oftentimes idiographic nature of developmental regulations requires that researchers consider the contexts in which their participants are embedded, as well as which coactions with those contexts are adaptive. This problem can be tackled through idiographic research designs and analyses (see below for a more detailed discussion of this issue; see also Molenaar & Nesselroade, 2014; Nesselroade & Molenaar, 2010), or they may alternatively be represented as a statistical interaction between self-reported measures of internal assets and objectively measured indices of contextual resources (e.g., Theokas et al., 2005).

Perhaps more appropriately, researchers can obtain and analyze nomothetic information through surveys, which require that participants interpret survey questions idiographically (e.g., Nesselroade, Gerstorf, Hardy, & Ram, 2007). For instance, researchers interested in assessing participants' connection to their communities can obtain more useful information from a Likert-scaled item such as "How involved are you in your community?" than by averaging several Likert-scaled items about community service, connection to a religious group, or participation in school-related organizations. The first question allows flexibility in how participants interpret community involvement, whereas the later set of questions constrains the possible domains in which connection can occur. Asking both types of questions, however, would enable researchers to ascertain empirically the links between the ideographically phrased item and the domain-specific items.

The Five Cs model of PYD presents one example of how person ←→ context relations can be the target of both theoretical and empirical consideration when incorporated in a nomothetic research design. The Five Cs model emphasizes the importance of adaptive developmental regulations and discusses each C as a strength arising from person ←→ context relations. High levels of each C requires not only the presence of a personal strength (e.g., ability), but also requires the successful application of strengths within each individual's unique context. These strengths represent broad multidimensional domains that allow youth to display qualitatively distinct yet equifinal pathways to thriving. For example, high scores on the C of competence require the successful application of personal strengths in one or more contexts. Although additive (e.g., high levels of competence in multiple domains leads to a higher competence score than high levels in fewer domains), the 4-H study's measure of competence allows youth to display competent behavior in any combination of academic, social, and physical domains. Similarly, the C of connection implies relationships between an individual and his or her context but allows individuals to display connection to components of their context such as their schools, communities, families, and peers. Each of the Five Cs, then, represents person ←→ context relations as the unit of analysis.

Individuals as Active Producers of Their Own Development

Developmental scientists aim to optimize contexts in ways that promote positive development, but recognize that individuals must also regulate their behavior in ways that take advantage of available resources. As noted earlier, developmental regulations represent the reciprocal bidirectional (←→) ways individuals influence and are influenced by their contexts (e.g., R. Lerner, 2002). Individuals' active participation in their developmental regulations (i.e., self-regulation) enable them to intentionally influence their own developmental outcomes (Brandtstädter & Lerner, 1999; Lerner, 2002). When individuals intentionally contribute to their development in such a way that successfully aligns their interests, desires, and needs with available contextual resources, their intentional self-regulation is viewed as adaptive (e.g., Baltes et al., 2006; Brandtstädter, 1998, 2006; Gestsdóttir, & Lerner, 2008).

The 4-H study of PYD has systematically investigated the processes through which adolescents intentionally and adaptively self-regulate, and thus actively contribute to the production of their developmental outcomes (e.g., Gestsdóttir & Lerner, 2007, 2008). Researchers involved in the 4-H study have argued that a process of selecting goals, optimizing resources in order to achieve these goals, and adjusting expectations and strategies when they encounter obstacles toward achieving goals may explain how youth draw resources from their contexts in ways that positively facilitates their development (Gestsdóttir & Lerner, 2008). This process of selecting, optimizing, and compensating (SOC; e.g., Freund & Baltes, 2002) has been found to be a key asset for individuals to achieve future positive developmental outcomes (Baltes et al., 2006).

For this reason, the 4-H study has used measures of SOC to assess self-regulation in youth. For example, Schmid et al. (2011) assessed whether measures of SOC and hopeful future expectations, another self-regulatory strength, predicted positive and negative trajectories of youth development across Grades 7 to 9. They found that both SOC and hopeful future expectations were associated with positive developmental trajectories. That is, youth with higher self-regulatory strengths, such as hopeful future expectations and SOC, were more likely to have the most favorable trajectories of PYD, contribution and trajectories involving fewer depressive symptoms. Bowers et al. (2012) similarly found that hopeful future expectations mediated the relation between the quantity and quality of positive relationships youth have with adults and the development of aspects of PYD. Together, these studies illustrate that intentional self-regulation and hope can make important contributions to positive developmental across adolescence, and thus potentially enable adolescents to direct their lives in meaningful ways.

As has been noted throughout the 4-H study, the relation between intentional self-regulation and PYD appears to apply to adolescents regardless of demographic differences. However, examining the ways diverse youth contribute to their own development and utilize the resources to which they have access to will require that researchers gain more information from youth about the contextual resources to which they have access and how much they value these resources (Leventhal & Brooks-Gunn, 2000; Leventhal, Dupere, & Brooks-Gunn, 2009).

In interpreting these findings, researchers must view the above findings as occurring during a specific developmental period, for a particular sample of adolescents living in a specific historical epoch. Person ←→ context relations intertwine individuals and contexts across time in highly complex ways. Acknowledging and accounting for temporal complexity both facilitates and complicates the tasks of developmental scientists, however, as temporal complexity presents its own set of methodological problematics (R. Lerner, Schwartz, & Phelps, 2009; Wohlwill, 1973).

The Temporality of Complex Developmental Processes

Complexity in development implies that the developmental trajectories of all individuals remain relatively plastic across the life span (Lerner, 1984). Research derived within the RDSP accordingly acknowledges the existence of inter- and intraindividual variability in development. For instance, the stated goal of the PYD perspective is to optimize the trajectories of all youth, an objective that depends on the presence of plasticity in intraindividual change. The acknowledgment of such plasticity has an impact on research derived from the RDSP in many ways. We highlight key ideas related to developmental plasticity that are especially important for PYD researchers to consider.

PREDICTING DEVELOPMENTAL PHENOMENA REQUIRES CHANGE-SENSITIVE MEASUREMENT TOOLS

Development and its plasticity can only be examined using tools that are themselves sensitive to change. Although not surprising at first glance, this statement suggests that the tools used to study development must be able to detect changes over a period of interest, which potentially excludes many scales designed to display high test-retest stability. For example, research derived from the 4-H study often treats the Five Cs of PYD as indicators of a single higher-order latent construct (e.g., Bowers et al., 2010). This higher-order construct tends to show generally flat developmental trajectories (e.g., Schmid et al., 2011), which suggests that the higher-order PYD construct is stable. The indicators of PYD encompass a very wide array of constructs (i.e., PYD is really an overarching concept), and it is difficult to discern whether item- or subscale-level changes correspond to meaningful changes at the higher-order construct (i.e., PYD) level. More research is needed to examine these alternatives, but a higher-order PYD construct that is not sensitive to item-level changes may explain why research predicting change in global PYD is markedly absent from the literature (or suggests only weak relations, e.g., Lewin-Bizan, Bowers, et al., 2010).

Researchers must also be cognizant that the very structure, or qualitative meaning, of a scale or construct may vary across time and place (Elder, 1998). This possibility underscores the importance of quantitative invariance testing and qualitative exploration of ecological validity across time and place. Bowers et al. (2010) have found support for the invariance of the Five Cs of PYD across Grades 8 through 10, for instance; yet, they also suggest that what constitutes PYD differs between early and middle adolescence. Although prior work suggests a relation between athletic competence and the C of competence among early adolescents (Phelps et al., 2009), the results of Bowers et al. (2010) study indicates that athletic competence does not indicate the C of competence in middle adolescence (but see Geldhof, Bowers, Boyd, et al., in press).

Factorial invariance of a scale, however, does not necessarily mean that the construct of interest is itself invariant. In other words, the items in a particular scale may be invariant because of the strategy used to build the scale itself, or they may be invariant because the observed invariance truly reflects a property of the underlying construct. Many questionnaires are specifically designed to measure stable attributes, and so change-sensitive items are omitted during scale creation due to a lack of longitudinal reliability. Invariance for a scale that was specifically designed to be invariant over time says more about the scale's construction than about the target construct's actual meaning across the life span.

Qualitative research, which often includes interview or narrative data from participants (Denzin & Lincoln, 2005), can also inform the development of a construct and/or the development of a quantitative measure for examining a particular construct across large populations of people. Qualitative research can also explore the presence of a construct at different points of development. Qualitative interviews, for example, often require participants to reflect on their current and past life experiences. The retrospective data garnered in this context provides another means through which time effects of particular phenomena can be approximated. For example, when participants are asked to think about how their behavior in high school differed from their behavior in college, information about developmental changes that occurred as a function of person ←→ context relations (such as participants' time varying relationships with their teachers and peers) is being reported by the people who experienced these changes directly. Asking participants about changes they experienced and why the changes occurred often elicits a close examination of person ←→ context relations that may be hard to measure with quantitative scales, especially when the phenomenon of interest develops in a complex, nonlinear way.

Developmental Trajectories May Be Nonlinear

The trajectory of a plastic relational developmental system necessarily entails coactions within and between all levels of the system's integrated structure. Development can involve nonlinear interactions (e.g., quadratic relations) or may even follow nonlinear functional forms. From a quantitative perspective, linear models may be helpful for roughly approximating such complex development; in truth, however, development likely extends beyond additively concatenated relations among variables (Little, 2013). In fact, given the dynamic self-organizing and self-regulating character of the relational developmental system, nonlinearity is the rule rather than the exception (Overton, 2013, Chapter 2, this *Handbook*, this volume).

Researchers may, therefore, benefit from applying statistical techniques that explicitly assume nonlinearity, including many of the techniques presented in this *Handbook*. Grimm and Ram (2009) similarly discuss the application of structured latent curve models (e.g., Blozis, 2004; Browne, 1993), the parameter estimates of which do not necessarily correspond to additive relations. For instance, Grimm and Ram (2009) provide an example that specifies Gompertz-shaped growth. The Gompertz function represents S-shaped growth, which allows researchers to more accurately model developmental trajectories with lower and upper local asymptotes. Despite the many potential uses for such models in the PYD literature (e.g., modeling S-shaped development of community contribution), such models have been markedly absent from the literature. Extending the application of nonlinear models is therefore an important direction for future research framed by a relational metatheory.

Time Is a Proxy for Development

Adding another layer of complexity to the RDSP-derived approaches to development is that development is simultaneously affected by processes that occur on multiple, loosely coupled time scales. Modeling complex developmental trajectories requires that researchers explicitly account for the many ways that time can be manifested in a relational developmental system. As noted by several authors (e.g., Elder, 1998; Lerner, Schwartz, & Phelps, 2009; Little, Card, Preacher, & McConnell, 2009; Wohlwill, 1973), the concept of time can mean many different things in relation to a person's development. Time might represent chronological factors (e.g., age in years), generational changes (e.g., people changing from an F2 to an F1 generation), historical factors (e.g., the Great Depression), idiographic experiential factors (e.g., years in school), nomothetic episodic factors (e.g., months since September 11, 2001), or idiographic episodic factors (e.g., years since the onset of puberty), for instance. These instantiations of time are of course all involved in life course changes, and developmental researchers must pay close attention to how they conceptualize, measure, and analyze development as a function of the multiple meanings of time (Wohlwill, 1973).

Disentangling the effects of various instantiations of developmental time requires careful methodological forethought, both in terms of study design and data analysis. For instance, Schaie (e.g., 1965) and Baltes (e.g., 1968) discuss multiple study designs that allow researchers to disentangle the integrated effects of chronological time, age, and birth cohort. Among these, the cohort-sequential design longitudinally follows participants from multiple birth cohorts and is often heralded as a key method that not only helps researchers make inferences about age-related changes across and between cohorts (e.g., Baltes et al., 1977), but also allows researchers to study developmental change in an accelerated fashion (Collins, 2006). The emphasis of the RDSP on complexity and integration highlights the importance of implementing such sophisticated research methods.

The 4-H study represents a form of cohort-sequential design that replaces the traditional concept of a birth cohort with the concept of a test-retest control cohort. In other words, the 4-H study followed individuals from a single birth cohort but added previously unmeasured participants in each wave to allow for the examination of possible retest effects. This design, however, confounds factors that have an impact on human development with factors that specifically affected development within this birth cohort. Generalizing findings from the 4-H study beyond the single birth cohort examined thus requires additional research that examines alternative birth cohorts of various types (e.g., multiple birth cohorts across multiple cultural settings).

Acknowledging that different instantiations of time can affect development has implications for how data are analyzed and how hypotheses are tested. Researchers must ensure that they measure and analyze instantiations of time in a metric that is meaningful to the phenomenon of interest and at a rate that allows for the accurate representation of that phenomenon's development (Lerner et al., 2009; Wohlwill, 1973). Although studies of PYD have explicitly considered multiple metrics for measuring the progression of development, PYD research has been less effective at specifying and measuring phenomena at intervals consistent with their anticipated rate of development. For instance, Lerner et al. (2009) drew on data gathered as part of the 4-H study of PYD to show the implications of treating development as a function of either age or pubertal status.

Like most large-scale longitudinal studies, the 4-H study only assessed participants annually (e.g., Lerner et al., 2005). Annual assessments may be appropriate for examining some developmental phenomena, but the choice of annual measurement in the 4-H study was made for reasons of practicality and funding rather than a theory of the *x*-axis. That is, annual assessments were not made because of a theoretical specification of the rate or form of change. Data from the 4-H study might accordingly be appropriate for examining the development of some constructs but may only offer an initial glimpse into phenomena that develop over intervals shorter than 1 year.

Understanding Complex Development Requires Multimethod Integration

The integrative and iterative nature of Relational-Developmental-Systems science highlights the importance of triangulation, or the "attempt to map out, or explain more fully, the richness and complexity of human behavior by studying it from more than one standpoint" (Cohen, Manion, & Morrison, 2000, p. 254). Although several researchers have drawn attention to the benefits of rigorous mixed-methods research in developmental science (e.g., Yoshikawa, Weisner, Kalil, & Way, 2008), general adoption of these techniques has been slow. Moreover, although several studies of PYD include the collection of both quantitative and qualitative forms of data, the majority of these studies are dominated by one form of data collection and analysis over another. Most commonly, qualitative interview data are collected to "supplement" or illustrate substantial quantitative data collection and analyses (i.e., mixed methods "lite"; Greene, 2012).

Although this design can be informative, developmental scientists have yet to take full advantage of the array of mixed-methods designs available to them, several of which call for substantial and rigorous qualitative and quantitative data collection and analyses (Creswell & Plano Clark, 2011). We believe that approaching PYD research from an RDS paradigmatic framework requires developmental scientists to embrace a more pragmatic approach by collecting multiple forms of data while considering the ways data are integrated in the discussion of findings. Of the multiple mixed-methods designs identified in social science research, a convergent parallel mixed-methods design may hold significant promise for future research in developmental science. Informed by the paradigm of pragmatism (Creswell & Plano Clark, 2011) this design prevents researchers from becoming "the prisoner of a particular [research] method or technique" and from simply presenting findings derived through different methods alongside each other but discussing them separately (Robson, 1993, p. 291; see also Felizer, 2010).

Truly mixed-method designs require much more than simple triangulation of quantitative and qualitative methods, and we discuss below additional methodological dichotomizations that RDSP researchers must fuse if they wish to obtain a broad understanding any phenomena of interest.

Integrating Ideographic and Nomothetic Perspectives

Since Allport (e.g., 1942) introduced Windelbrandt's terms *idiographic* and *nomothetic* to psychology's vocabulary (see Marceil, 1977, and Holt, 1962, for reviews), researchers and theorists have debated whether the province of psychology is to study common (i.e., nomothetic) characteristics shared by all people or the idiosyncratic (i.e., idiographic) characteristics that make each person unique. Emmerich (1968) added a group differential focus to this discussion. In addition to arguing that each person is like all other people (the nomothetic approach in the classic Kluckhohn & Murray, 1948, formulation) or that each person is like no other person (the ideographic approach in the Kluckhohn & Murray, 1948, formulation), Emmerich (1968) added that each person is like only some other people (in the Kluckhohn & Murray, 1948, formulation). As Holt (1962) commented more than 50 years ago, the idiographic versus nomothetic debate is, "[o]ne of the hardiest perennial weeds in psychology's conceptual garden," (p. 376) and indeed it remains a source of considerable discussion to date (e.g., Lamiell, 2009).

Marceil (1977) notes that the implications of this debate extend beyond psychology's conceptual purpose to include the specific methods researchers use to investigate research questions and test hypotheses. From a methodological perspective, RDSP-based positions such as the PYD perspective take a middle road (see also Kluckhohn & Murray, 1948) by acknowledging that developmental science requires a synthesis of idiographic, group differential, and nomothetic methods. In practice, unfortunately, such synthesis is rare. Nomothetic analyses have remained the primary tool in the methodological arsenals of developmental researchers interested in PYD (as well as across psychological research in general; Molenaar, 2004, 2007; Nesselroade & Molenaar, 2010) from a quantitative perspective.

Most large-scale longitudinal studies of youth development are designed to address nomothetic issues. The 4-H study is typical of these studies in that it relied on measuring a large sample of youth annually. This data collection schedule optimally facilitates nomothetic quantitative analyses such as growth curve analyses, and the data also may be used for the comparison of analytically derived, differential groups through techniques such as cluster analysis (e.g., Zarrett et al., 2009) and mixture modeling (e.g., Bowers et al., 2011). These types of analyses provide important information about development; when applied to many participants across relatively few time points, however, they cannot provide truly idiographic information.

Data collection methods that support idiographic analyses involve collecting data from fewer individuals but across more occasions (e.g., Nesselroade & Molenaar, 2010). These types of data are commonly collected in several areas of psychological research, although they often are analyzed using nomothetic methods (e.g., growth curve analyses). For example, diary and experience sampling methods often are used in health and mental health research (e.g., Myin-Germeys et al., 2009), personality research (Conner, Tennen, Fleeson, & Barrett, 2009), and the study of relationships (Laurenceau & Bolger, 2005). Similar techniques have been used with adolescent samples (e.g., time use studies such as Larson & Verma, 1999) but are rarely used to study developmental phenomena from an idiographic perspective. These types of data, however, could provide valuable information about development from a RDSP perspective. The use of truly idiographic quantitative analysis methods such as dynamic factor analysis (Molenaar & Lo, 2012), the idiographic filter (Nesselroade et al., 2007), and integrations of these techniques (Molenaar & Nessleroade, 2012) could enable researchers to more fully understand the nature of developmental phenomena such as PYD and how these constructs change across adolescence.

Interindividual qualitative analyses can also provide valuable and rich information about groups of youth in a particular program, but they may fall short of promoting a truly idiographic and nuanced understanding of an individual's experiences of a phenomenon or developmental context. Within the broad range of qualitative data collection and analysis methods, however, are several person-centered techniques that could be used within RDSP-informed PYD research. Narrative inquiry, for example, provides one way to examine the experiences of, and stories told by, "particular actors, in particular social places, at particular times" (Abott, 1992, p. 428). In addition to focusing on the particular, this ideographic approach allows researchers to highlight the diverse ways in which people participate in the production of their own development. Moreover, such an approach can lead to the possible discovery of developmental phenomena unique to a person or differential group. If, for instance, PYD research focused more on the experiences of minority youth in the United States, who often feel alienated from civic institutions and less politically efficacious than youth who are part of the majority and middle-class culture in the United States (Kirshner, 2009), we could possibly discern facets of PYD, such as critical consciousness, that may be an essential part of optimizing the positive development of all youth, and especially of marginalized youth in the United States and internationally (Hershberg & Lykes, 2012). This construct might be an important C of PYD that could encourage youth participation and contribution while simultaneously enabling researchers to identify forms of youth participation and contribution that are often overlooked in the research—that is, organizing and activism—that have been identified as arenas where marginalized young people contribute to their communities, civic processes, and their own development by attacking social problems head on (Ginwright, Noguera, & Cammarota, 2006). In addition, inclusion of this potential C in the PYD model may elicit research regarding the already established Cs in the model, and explain *why*, rather than simply conclude that marginalized youth reportedly experience low levels of them (e.g., Hart & Atkins, 2002). The issue of idiographic versus nomothetic measurement also has implications for researchers' choice of correlational versus experimental research designs, to which we turn next. Although both approaches offer some degree of flexibility between idiographic versus more nomothetic measurement, experimental designs explicitly control environmental conditions in order to uncover nomothetic laws of human development. As such, supplementing nomothetic findings with the findings from idiographic studies may require additional integration of experimental and correlational research designs.

Experimental Versus Correlational Research Designs

Relational-Developmental-Systems science may represent a paradigm shift from traditional psychogenic ideas in psychology and the traditional focus in this field on experimental methods designed to disentangle simple additive unidirectional cause-effect relations (Overton & Lerner, 2012). As Cattell (1966) notes, a great deal of psychological research has followed in the experimental tradition and has accordingly focused on data derived from rigidly controlled experiments.

Although not denying the importance of experimental methods and analyses, individuals represent more than simple summative aggregations of base-level components (e.g., neurons, personality traits). Stressing embodiment (Overton, 2013) in Relational-Developmental-Systems science points to the deep and complex relations that connect all possible units of analysis into a synthetic and developing whole. Relational-Developmental-Systems scientists, therefore, tend to favor integrative multivariate analyses and the simultaneous use of contextualized inductive and deductive analytical techniques over experimental methods that attempt to "wash out" individual differences and the role of the ecologically valid environment. As such, Relational-Developmental-Systems researchers often implement correlational methods derived from the traditions of Pearson and Galton (see Cattell, 1966). Common methods may emphasize partial and semipartial relations (e.g., multiple regression models) or treat multiple related items as imperfect indicators of underlying latent constructs (e.g., factor analysis, structural equation modeling).

The complexity of the relational developmental system, however, suggests that some relations will be difficult to capture through such ecologically valid observational work. Research that draws information from the natural ecology may make it especially difficult to focus on subtle, nuanced, infrequently occurring, or internalized or "private" facets of the relational developmental system. Developmental scientists may therefore draw on the strengths of experimental methods to help ascertain such attributes involved in, as well as the outcomes of, PYD-focused programs and activities. For example, Tierney, Grossman, and Resch (1995) used an experimental design to evaluate the Big Brothers/Big Sisters program, a community-based mentoring intervention. The study addressed nine PYD constructs (including social, emotional, cognitive, and behavioral competencies, positive identity, and prosocial norms). Researchers randomly assigned participants to the intervention condition or a wait-list control group. The evaluation demonstrated positive results on behavioral and attitude measures in key impact areas. Although such uses of experimental design are insufficient to describe, explain, or optimize change in the relational developmental system, careful coordination of experimental and correlational designs might provide a more nuanced picture of the relational developmental system as a whole.

As such, RDS research has been generally approached from a correlational framework, with occasional experimental studies used to support correlational findings. Correlational analyses better capture development as a complex phenomenon; such studies also allow for more flexibility in hypothesis generation. Thus, rather than approaching data from a framework that specifies experimental deduction, correlational studies more easily allow for the dynamic interplay between induction and deduction, which we discuss next.

Induction, Deduction, and Abduction in RDSP Research

Just as prerelational theories often led scientists to artificially split parts from the theoretical whole (i.e., genes versus environment; see Overton, 2010, 2013), in prerelational developmental systems researchers commonly emphasized the independence of inductive versus deductive logic when deriving and testing hypotheses. Taken to extremes, strict application of only inductive or deductive logic can respectively lead to verificationism or an unrealistically strict form of empiricism (Little, 2013). Neither extreme aligns well with the tenets of Relational-Developmental-Systems science. Relational-developmental system theories specify development as occurring through nonrecursive relations between separate components of a larger system, and from these theories it follows that the practice of Relational-Developmental-Systems science progresses through a reasoning process that eschews conventional induction or deduction and, in turn, embraces abduction. As explained by Overton (2013), in abduction, all background ideas (the disciplinary matrix or paradigm and theoretical terms) are a necessary part of the process, and empirically supportive abductive explanations become a part of an ever-widening body of background ideas.

Future Directions

RDS models of human development such as the PYD perspective emphasize that changes in the mutually influential relationships between individuals and the multiple levels of their contexts constitute the basic process of human development (Overton, 2010, 2011, 2013, Chapter 2, this *Handbook*, this volume; Overton & Müller, 2012). As the present chapter has detailed, the RDSP entails several conceptual and methodology considerations. Over the past decade, the PYD perspective has been adopted by researchers studying adolescence, practitioners in youth development, and policy makers concerned with improving the lives of youth and their families (J. Lerner et al., 2012). Therefore, the tenets and assumptions of RDS models, and thus, the PYD perspective, have implications for the work of researchers and practitioners interested in promoting the positive development of all young people, and thus for contributing to the promotion of social justice (Lerner & Overton, 2008). In particular, we have discussed three assumptions that are most relevant for this work: (1) development involves interrelated changes in a complex, multilevel system; (2) developmental trajectories of all individuals remain relatively plastic across the life span; and (3) examining relations in the presence of such complexity requires multimethod integration.

Taking these assumptions into account, to frame and test a set of questions within RDS models is a formidable challenge for researchers. Such framing requires multilevel, multivariate, and multimethod longitudinal research that must attend to both intraindividual change and interindividual differences in intraindividual change. Therefore, research derived from RDS models entails considerable commitment, both in time and resources, of an interdisciplinary team of researchers. In addition, well-designed RDS research entails gaining the commitment and engagement of research participants in order to obtain the data necessary to test RDS-derived questions and hypotheses.

For example, in RDS model research, bidirectional individual ←→ context relations constitute the fundamental unit of analysis and the individual is an active producer of his or her own development. Therefore, rather than focus on the socially defined contexts (e.g., family, school, neighborhood) that mark much of the research on development, researchers should also collect information about the active individual's attributes in relation to the subjective social context that the individual deems important.

A concurrent challenge when deciding how to design and implement a study that appropriately addresses all of these issues is that researchers must also consider the political, financial, and academic climate within which a study is conducted. That is, research should not only be conducted *with* an RDS model framework, but it should also be recognized that research is conducted *within* an RDS model framework. What would be the most feasible, practical, and fundable research agenda given the current policy and funding priorities? As systems science methods are meant to complement traditional research methods (Urban, Osgood, & Mabry, 2011), would it make more sense to conduct a series of small studies that focus on particular variables within a broader framework, or would a more comprehensive study that accounts for multiple variables at multiple levels over multiple time points be the appropriate agenda to follow?

The goal of applied developmental science is to describe, explain, and optimize human development. Often, optimizing development involves designing and implementing research-based interventions; however, conducting intervention studies framed within an RDSP approach to applied developmental science raises questions about the use of randomized control trials (RCTs) in tests of simple causality. There are a number of financial, practical, and ethical concerns inherent in conducting an RCT in an applied setting. In addition, there are also methodological and conceptual shortcomings in undertaking an RCT, such as limited external validity, contamination, endogeneity, and the infrequent use of the Solomon four-group design, which involves two control groups other than the typical one involving pretest and posttest but no manipulation (i.e., there is a control group that involves no pretest but includes the manipulation and the posttest—as a control for the reactive effects of pretesting; and there is a control group that includes only the posttest as a control for maturation) (Solomon & Lessac, 1968). For example, an RCT is not appropriate when researchers seek to determine whether an intervention prevents rare events or when the intervention requires active participation, both of which would be the case for many PYD-derived interventions.

An overarching challenge to conducting research in the current era is that many funding mechanisms require the use of RCTs unless there is a strong justification for a quasi-experimental design. The prevailing commitment to RCTs by some funding organizations adversely affects researchers who work in applied settings and who recognize that an RCT design may be inappropriate, impossible, or inadequate for the situation in which they conduct research. A PYD researcher must work to provide justification to overcome a mind-set in both the research and practice communities that claims that RCTs are the "only way to be sure about cause and effect." Overcoming, in both communities, the archaic mind-set that the discovery of classical Newtonian linear *efficient causes* represents some ultimate goal of science is a further important task for the PYD researcher (Overton, 2013; Witherington, 2014).

Fiduciary issues also arise in considering the work of practitioners as RDS-derived programs become more popular with individuals working to enhance the positive growth of young people (Beets et al., 2009; Duerden, Witt, Fernandez, Bryant, & Theriault, 2012; Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Briones, et al., 2008). It is not always clear what particular developmental processes are explicitly used in the "philosophical" approaches to youth programming pertinent to PYD or in the particular instances of youth programs designed to foster PYD (Lerner et al., 2011). This uncertainty most likely occurs because most youth programs in the United States are not evaluated (see Catalano et al., 1999) and, most critically, a theory of change and an evaluation design logic model (Weiss, 1972) are absent from most programs (e.g., see Roth et al., 1998). These omissions may be a result of a lack of understanding about the essential need for such frames for programs, but they may also be a casualty of the limited budgets of youth-serving programs. Practitioners often choose to spend funds on programming elements in which youth participate rather than on scientifically rigorous evaluation. Even if funds were available to practitioners, programs framed by the PYD perspective would entail a level of complexity and oversight that can be identified in, let alone attained by, only a select few programs (e.g., Catalano et al., 2004; Flay & Allred, 2003; Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Silverman, et al., 2008). A review of these programs illustrates that university-community collaborations are critical for RDS-derived scholarship and practice success (Kurtines, Ferrer-Wreder, Berman, Cass Lorente, Silverman, et al., 2008; R. Lerner & Simon, 1998).

Therefore, academic institutions as well as policy makers and funding institutions should work to establish and develop real collaborations with partners in the community. These partners, in turn, must recognize the importance of research-based designs and scientifically rigorous evaluation and also work to recruit and accept the resources available at academic institutions. Both sides must work to identify the mutually beneficial relations that can produce programs and research agendas that are practical, efficient, fundable, and thus, sustainable (R. Lerner & Overton, 2008). With such researcher-community collaborations, RDSP-based theories such as our PYD theory (J. Lerner et al., 2012) can enhance the quality of the information obtained about youth, can provide a more likely-to-be-deployed basis for evidence-based practice, and may afford more, and more ecologically valid, contributions to promoting social justice for the diverse young people of the world.

OPTIMIZATION WITHIN THE RELATIONAL-DEVELOPMENTAL-SYSTEMS PARADIGM OF DEVELOPMENTAL SCIENCE

The lack of integration within and across each domain of PYD scholarship provides uncertainties in regard to understanding how to optimize PYD. In regard to the theoretical models of the PYD process, there is a lack of integration of both the structural and measurement models framing empirical tests of the models. For instance, the measurement of ecological developmental assets differs between the research of Lerner and Lerner and their colleagues (e.g., see Theokas & Lerner, 2006; Urban et al., 2010) and the research of Benson and colleagues at Search Institute (e.g., Benson et al., 2011). Similarly, variation exists in regard to the conceptualization and measurement of the motivational, purposive, or goal-oriented behaviors of interest to Damon (2008), Eccles (e.g., Eccles & Roeser, 2009; Eccles & Wigfield, 2002), and Larson (2000). Even more abstractly, there is little information about whether, across theoretical models, there exist similar views about the actions that are integrated within individual ←→ context relations of interest in all theories.

The focus on diversity in regard to describing and explaining developmental change that is emphasized within theories derived from the RDSP also involves the expectation that, as a consequence of health-supportive alignments between people and settings, positive changes can be promoted across all instances of variation in individual ←→ context relations. With this stance, diversity becomes the necessary subject of inquiry in developmental science. That is, to understand and promote individual ←→ context relations that may be characterized as healthy, positive, adaptive, or resilient development—which are relations reflecting the maintenance or enhancement of links that are mutually beneficial to individuals and context—scholars must ask a complex, multipart question (R. Lerner et al., 2013; R. Lerner, Schmid, et al., 2012). Specifically, researchers must ascertain:

- *What fundamental attributes of individuals* (e.g., what features of biology and physiology, cognition, motivation, emotion, ability, physiology, or temperament); among individuals of
- *what status attributes* (e.g., people at what portions of the life span, and of what sex, race, ethnic, religious, geographic location, characteristics); in relation to
- *what characteristics of the context* (e.g., under what conditions of the family, the neighborhood, social policy, the economy, or history); are likely to be associated with
- *what facets of adaptive functioning* (e.g., maintenance of health and of active, positive contributions to family, community, and civil society)?

Moreover, proponents of the RDSP argue that the relative plasticity of individual ←→ context relations creates a synthesis between the explanatory and optimization goals of developmental science (Baltes et al., 1977; Lerner, 2002). To test explanations of developmental change, scholars need to institute or evaluate programs that are aimed at altering the bidirectional relations expected to facilitate changes in behavior and development. These actions must necessarily be embedded in the actual ecology of human development in order to have generalizability to the lived experiences of individuals and, as such, they constitute intervention (applied) research and, at the same time, research testing basic explanatory processes of human development. As such, in contemporary developmental science, the commonly regarded split between basic and applied research is also regarded as flawed holdovers from earlier eras (Fisher, Busch-Rossnagel, Jopp, & Brown, 2012; R. Lerner & Overton, 2008). In short, the application of developmental science (optimization) is a coequal partner with description and explanation within contemporary developmental science.

The emerging approach to developmental science also brings to the fore a concern for promoting social justice (Fisher et al., 2012; R. Lerner & Overton, 2008). Arguably, the most arduous test of the integrated explanatory/optimization scholarship conducted by developmental scientists involves efforts to bring to scale changes in the relational developmental system for diverse individuals. If our explanatory models can fully account for the system of individual ←→ context relations that alter the course of development for all individuals, then we should be able to promote more positive development among all individuals. Developmental scientists should be able to specify what characteristics, of what individuals, should be integrated with what features of the ecology of human development, at what points across ontogeny, to facilitate what instances of (more optimal) changes in behavior and development. Longitudinal projects, such as the Berlin Aging Study (Baltes et al., 2006) or the 4-H Study of Positive Youth Development (J. Lerner et al., 2012), involve such specifications: there findings illustrate the importance of research framed by theories derived from the RDSP in explaining the course of development and generating rich ideas for optimization strategies.

Accordingly, rather than optimize their theories to promote success of a "generic" or "ideal" person, the within-individual Relational-Developmental-Systems approach should be able to be applied to enhance the likelihood that diverse individuals will be on better (i.e., healthier, more positive) trajectories. Answering the above noted "what" questions is essential if scholars are to use their integrated explanatory/optimization work to create a more socially just world for diversity of individuals in our global community (Fisher et al., 2012).

Given such variation, there is no certainty that similar empirical referents exist in regard to information about the PYD process. Such uncertainty makes it problematic to achieve any consensus about what variables, from what levels of organization within the relational developmental system, must be integrated in what specific ways, at what points in adolescence, to optimize what specific outcomes. Clearly, in the face of this uncertainty, what is needed is cross-laboratory integration of measurement models, perhaps through the use of a multitrait-multimethod matrix method (Campbell & Fiske, 1959). However, the practical challenge of gaining the funds for such field-integration research is itself a major problem constraining the advancement of knowledge about PYD.

Similar problems can be raised in regard to integrating the different philosophies of or approaches to PYD programming. What are the fundamental defining characteristics of an effective PYD program? Do scholars use different terms for the same latent construct? For instance, when Roth and Brooks-Gunn (2003a, 2003b) think of program characteristics they believe to instantiate PYD-promoting activities, atmosphere, and goals, are they pointing to the same actions as those envisioned by Blum (2003) when he discusses people, contributions, activities, and place or by R. Lerner (2004) when he discusses positive and sustained adult-youth relations, life skill–building activities, and opportunities for participation in and leadership of valued activities? The answer is not certain. Accordingly, it may be that there should be a "conceptual meta-analysis," perhaps undertaken in the context of a working group of scholars and practitioners involved in a thorough review of the theoretical and empirical bases from which their philosophies/approaches were derived. Again, however, issues of funding make such an undertaking problematic.

Moreover, a similar lack of integration exists in regard to the numerous instances of PYD programs. Are actions labeled in the same way actually implemented identically? In different instantiations of the "same" program, is there high fidelity of implementation? Here, answers are particularly difficult to attain because, again, most youth programs in the United States are not evaluated and, as well, key elements of any effective program—most critically, a theory of change and a logic model—are absent from most programs (e.g., see Roth et al., 1998). Such errors of omission preclude scientifically rigorous evaluation, and make empirical comparisons across different programs or among different instantiations of the same program highly problematic if not impossible.

CONCLUSIONS

The Relational-Developmental-Systems paradigm (RDSP) provides the foundation necessary to devise and generatively study an integrative model of adolescent development. In future research about the promotion of PYD, we believe it would be useful if scholars adopted a common language and system of measurement for individual and contextual assets. There is a need to differentiate individual assets from indicators of PYD since some constructs (e.g., executive functions related to ISR) may be seen as both outcomes and predictors. In addition, the characteristics of contexts other than youth development programs and of the adults who promote PYD in youth, such as peer groups and neighborhoods, should also be studied.

Furthermore, it will be useful to broaden the scope of contexts within which PYD is investigated. Currently, the role of families, schools, and community-based programs in promoting PYD receives substantial attention in the literature. There are other important contexts, such as workplaces or faith institutions, where young people spend portions of their time (Greenberger & Steinberg, 1986; King et al., 2011). The assets and developmental opportunities available in these contexts need to be considered more by researchers for further elaboration of the role of ecological features in PYD. On the level of practice, professionals working with families and schools, as well as employers who hire youth, would benefit from being educated about possible applications of PYD perspective in these settings.

The idea that the development of positive behaviors will lead to the reduction of negative ones should also continue to be part of the research agenda, and as the 4-H study results reveal, youth who are developing positively are also engaging in some level of risk behaviors. This relation means that risk behaviors need to be studied along with positive ones. The multiple trajectories of development seen in the 4-H study support the idea that efforts should be aimed at understanding the factors that contribute to these individual differences.

In sum, in the past two decades, there has been a surge of research focused on the positive view of human development. In the adolescent literature, this focus has been aimed primarily at replacing the deficit view of youth as "problems to be managed" with the view that youth are "resources to be developed" (Roth & Brooks-Gunn, 2003a, 2003b), and current evidence suggests that an integrative preventive-promotive focus may be the best course to pursue in increasing the likelihood that youth will thrive. To appropriately pursue such an integrative approach, a multipart integrative question may be most useful to address: What interventions, with what components, of what duration, with what youth, at what age or developmental levels, in what communities, at what historical time, will result in what positive individual psychological, social, cognitive, and physical outcomes?

It has been more than 10 years since Hamilton initially formulated the three facets of PYD. Perhaps it is too much to expect that such a young area of scholarship would have the level of integration to which we are pointing. Nevertheless, we believe that as all members of the PYD scholarly community—both researchers and practitioners—come together in the service of making such integration a high-priority agenda item, it will be crucial for funders of PYD scholarship and application to take actions to support and extend such integrated work. If such support is forthcoming, we are hopeful that in the next 10 years we will see enhanced integration and have more knowledge to answer the complex multipart questions pertinent to promoting PYD. We are optimistic that a more mature field of PYD is possible given the theoretical and methodological tools of contemporary developmental science.

More generally, we believe that the application of developmental science to promote positive development and health across the life span, and to contribute to social justice for all individuals and groups, will continue to be a core and integrated concern of developmental scientists. The theoretical orientations and interests of new cohorts of developmental scientists, the requirements imposed by funders for producing scholarship that matters in the real world, and the needs for evidence-based means to address the challenges of the 21st century will coalesce to make Lewin's (1952) quote, that "There is nothing so practical as a good theory" (p. 169), an oft-proven empirical reality. Indeed, we believe that the scientific and societal value on which the developmental science of the future will be judged will be whether its metatheoretical, theoretical, and methodological tools are productive at promoting positive human development across the life span for the diverse people of the world. Therefore, developmental science as a means for promoting social justice will, we believe, be the most significant lens through which the future contributions of developmental science will be viewed.

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CHAPTER 17

Systems Methods for Developmental Research

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This seventh edition of the *Handbook* contains a number of references to Jean Piaget's eminent scientific work, including the well-known stage-wise developmental model, which, as is shown later, can be conceived of as an instance of a dynamic systems model. Piaget's main method is the *méthode clinique* (Piaget, 1947), which is a special instance of the intensive measurement designs underlying dynamic systems approaches. It therefore would not seem to be too far-fetched to characterize Piaget as one of the founding fathers of not only developmental psychology but also of dynamic systems approaches in developmental science. In what follows many aspects of dynamic systems approaches are addressed, ranging from a fundamental discussion of their rationale to considerations of the implications for experimental design and key applications in child psychology and developmental science.

The term *system* has many uses (behavioral system, response system, neural system, action system, social system, structural system, functional system, relational developmental system, cognitive system, etc.; see Molenaar, 2001, for a concise overview of systems theory). It is difficult to provide a general definition of "system," which covers the manifold uses of the term. Klir (1991) gives the following definition: A system is comprised of a set of things, together with a set of relations between these things. Klir adds an important qualification: A system should not be conceived of as a natural category but instead as a convenient epistemological construction. If the relations mentioned in Klir's definition are dynamic relations, such as expressed by differential or difference equations, then we arrive at the following initial definition of a dynamic system: A dynamic system is comprised of a set of coupled differential or difference equations describing the evolution

This work was supported by National Science Foundation Grant 1157220 to PCMM and by Award Number AG034284 of the National Institute on Aging to JRN. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute on Aging, the National Institutes of Health, or the National Science Foundation. JRN gratefully acknowledges the long-time support of the Max Planck Institute for Human Development, Berlin, Germany.

of the system state, where the system state constitutes the complete formal representation of the system's behavior. This initial definition, which is elaborated and interpreted in what follows, shows that a dynamic system is the perfect mathematical tool for the analysis of developmental processes in that it focuses on the dynamic rules governing the evolution of such processes as function of age.

For years the authors of this chapter, along with many others, have been promoting a systems perspective as a general orientation to the study of behavior and have emphasized the important role to be played therein by appropriate methodological developments and innovations, especially dynamic ones (Boker, Molenaar, & Nesselroade, 2009; Molenaar, 2004; Nesselroade & Ford, 1987; Nesselroade & Molenaar, 2010). As with most attempts to supplant or even slightly alter the ordained approaches, the arguments often fall on somewhat deaf ears and the more radical efforts can take on a Sisyphean character. Nevertheless, many desirable methodological innovations have been forthcoming and signs of acceptance of newer ways of thinking about key matters are encouraging. That a chapter on dynamical systems was commissioned for this *Handbook* (see Witherington, Chapter 3, this *Handbook*, this volume) is further evidence of the ascendance of these newer approaches to the study of behavior that we believe are beginning to populate the landscape.

In this chapter a broad variety of aspects of dynamic systems approaches are discussed, including heuristic descriptions of the methodological issues, experimental designs, and mathematical models associated with such approaches. We start with a breakthrough in psychometrics and statistical modeling, which has fundamental consequences for developmental science. It concerns the impact of a general powerful mathematical theory for our field (Molenaar, 2004). It is shown that this mathematical theory, called *ergodic theory*, puts dynamic systems approaches and the intensive measurement designs on which these approaches are based at the center of statistical modeling in developmental science. A general dynamic factor model is presented, which captures most of the statistical models that are appropriate in linear dynamic systems approaches. In linear dynamic systems change is a linear function of the component processes, whereas in nonlinear dynamic systems this change is a nonlinear function of the component processes. For instance, $x(t+1) = \beta_{11}x(\mathrm{t}) + \beta_{12}y(t)$, $y(t+1) = \beta_{21}x(t) + \beta_{22}y(t)$ is a bivariate linear dynamic system in discrete time $t = 0, 1, 2, \ldots$ because the changes from $x(t)$ to $x(t+1)$ and $y(t)$ to $y(t+1)$ are linear functions of the two component processes $x(t)$ and $y(t)$. In contrast, $x(t+1) = \exp[\beta x(t)]x(t)$, where exp denotes the exponential function, is a univariate nonlinear system because the change from $x(t)$ to $x(t+1)$ is a nonlinear function of $x(t)$ (see, e.g., Tong, 1993, for an accessible discussion of linear and nonlinear systems). The chapter closes with an extensive discussion of the implications of nonlinear dynamic systems approaches for an important topic in developmental science: the analysis of stage-wise development.

This chapter is methodologically oriented, focusing on statistical dynamic systems models that are directly fitted to appropriate empirical data. Dynamic systems models often have been used in other, more heuristic ways in the developmental scientific literature. For instance, graphical representations of phase space have been used (grid state space; Hollenstein, 2012; Witherington, Chapter 3, this *Handbook*, this volume), which provide pictorial impressions but do not involve parameter estimation in explicit dynamic systems models. Also nonlinear dynamic systems models have been related to empirical data only in indirect ways, based on derived qualitative features obtained from computer simulation studies (van Geert, 1993). In this chapter much emphasis is given to explaining the important functions and the relevant statistical aspects of distinct dynamic systems models. A special feature of this chapter is that ample attention is given to *linear* dynamic systems models in addition to the nonlinear dynamic systems models, which historically have figured most prominently in the applied developmental scientific literature (e.g., Thelen & Smith, 1994). Linear dynamic systems models not only constitute the basis for nonlinear dynamic systems, but also are much more flexible and easier to fit to the data, providing excellent local approximations of nonlinear systems.

The majority of the statistical dynamic systems models considered in this chapter only recently have come to the forefront (see Molenaar, Lerner, & Newell, 2013; Molenaar & Newell, 2010; Newell & Molenaar, 1998; Valsiner, Molenaar, Lyra, & Chaudary, 2009), hence there does not yet exist a large literature on their applications to developmental processes. However, now that the implications of ergodic theory have been made explicit for data analysis in developmental science and beyond (see later), the necessity to base analysis of developmental processes on dynamic systems modeling of intraindividual variation no longer can be neglected. Therefore this chapter is of direct relevance for the required further extension of standard statistical modeling in developmental science with dynamic systems modeling of intraindividual variation.

STATISTICAL ANALYSIS OF DYNAMIC SYSTEMS MODELS: FOUNDATIONS

Systems perspectives always have been important in developmental science. The Romantic era with its focus on organicism and systems thinking (Beiser, 2003) was an important formative time for developmental science, as witnessed by the work of early thinkers such as Carus and Tetens (see Baltes, 1979). Several traces of this early worldview recur in Developmental Systems Theory (Ford & Lerner, 1992; Gottlieb, 2001; Johnston, 2010; Lerner, 2002) and its most recent version, Relational-Developmental-Systems (Lerner, 2006, 2011; Lerner & Overton, 2008; Overton, 2006, 2010, 2013, 2014, Chapter 2, this *Handbook*, this volume; Overton & Lerner, 2012), the dominant theoretical metamodel in current developmental science. In this section, foundational methodological-statistical aspects of this approach are examined and for this purpose only selected aspects of this metamodel have to be considered.

The features of the approach to systems thinking that are important for the present purposes are the following: (a) Development is conceptualized as the result of multiple coacting influences, which are context sensitive and contingent. This idea implies that development is inherently subject-specific and stochastic (probabilistic or random) because the contexts within which a subject develops have contingent subject-specific effects that continuously build up within the developing system due to ongoing interactions (see Gottlieb, 2001). (b) A second important feature is that development is understood to be a constructive process in which nonlinear epigenetic influences play central roles (see Lickliter & Honeycutt, 2010, Chapter 5, this *Handbook*, this volume). The most successful class of mathematical-biological models explaining such epigenetic influences are the so-called nonlinear reaction-diffusion models (explained later). These are nonlinear dynamic models generating emergent qualitative developmental changes that are not caused by genetic or environmental influences but instead are the result of dynamic self-organization (see Meinhardt, 1982; Murray, 2002). Such nonlinear epigenetic influences create substantial subject-specific variation, which reinforces the subject-specific effects due to contingent contextual influences. (c) A third highly important feature is a focus on the potential for change evolving at multiple time scales and at multiple levels (e.g., Newell, Mayer-Kress, Hong, & Liu, 2010; L. B. Smith & Thelen, 2003). This implies that dynamic systems models will include time-varying parameters located at different levels and changing with different rates. In sum, our discussion of dynamic systems models focuses on subject-specificity (see also von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume), as well as pervasive stochastic change.

In what follows, the generality of the discussion allows us to use the terms *system* and *person/subject* interchangeably, as well as the terms *age* and *time*. We first consider a general mathematical theory, ergodic theory, which specifies necessary conditions for a valid statistical analysis of dynamic systems. Although ergodic theory was founded more than a century ago, its profound relevance to psychometrics in general, and developmental science in particular, has been made explicit only recently (Molenaar, 2004). As is explained in the next section, ergodic theory is about the formal relations (if any) between results obtained in statistical analyses of intersystem variation and results obtained in analogous statistical analyses of intrasystem variation. In its most basic form the statistical analysis of dynamic systems is based on intrasystem variation, namely time series analysis of intensive repeated measurements of the same dynamic system (e.g., Tong, 1993). Yet analysis of intraindividual variation is not the standard psychometric approach to the study of developmental processes. In contrast, the standard psychometric approach is based on analysis of interindividual variation. This raises the important question whether the standard psychometric approach is appropriate for dynamic systems modeling of developmental processes.

THE RELATION BETWEEN INTER- AND INTRAINDIVIDUAL VARIATION

As a tool for making the concepts being discussed more concrete, we first introduce a design heuristic that has proven to be very useful for several decades of psychological research—the data box (Cattell, 1952) or Basic Data Relations Matrix (Cattell, 1966). The essential data box is a cube defined by an axis for persons, one for variables, and one for occasions of measurement. Each element in the data box is a datum representing an intersection of axes and is thus a single score for a given person on a given variable at a given occasion of measurement. Bill Smith's time in the hundred-yard dash at last Saturday's track meet exemplifies such a datum. In Figure 17.1, a data box is depicted (panel d) in a four-step build-up of data organized by person, variable, and occasion of measurement.

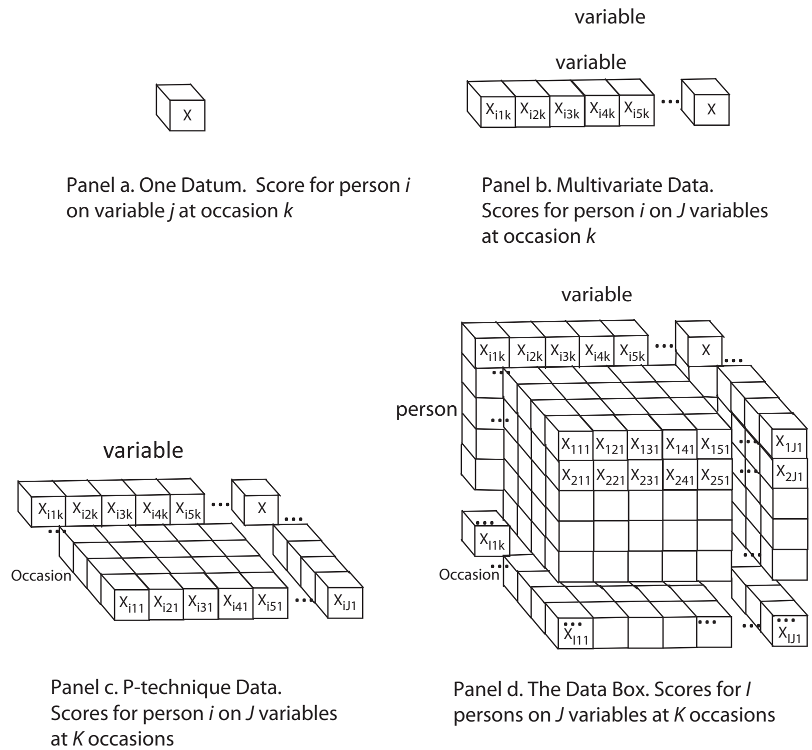

Figure 17.1 The Data Box (Cattell, 1952) constructed in four steps with scores for *I* persons measured on *J* variables at each of *K* occasions of measurement.

Consider each panel of Figure 17.1 in turn. Panel a contains a datum consisting of individual *i*'s score on variable *j* at measurement occasion *k*. Panel b augments the single datum with scores on additional variables for person *i* on occasion *k*, making the data multivariate even though they represents one person and one occasion of measurement. In panel c, the data have been augmented by including multiple occasions of measurement. Panel c now represents a two-way data matrix of scores—the kind of score matrix with which behavioral scientists often work. This particular matrix is a variables by occasions matrix of scores for one individual. In the multivariate analysis literature, such a data configuration is called a *P-technique data matrix*. It has been at the heart of much recent work aimed at the study of process (Molenaar, 2004; Molenaar & Nesselroade, 2012) and is commented on at various points in this chapter.

The data box depicted in Panel d, Figure 17.1 can be "sliced" in three different ways—parallel to each of its two-dimensional planar surfaces, as is portrayed in Figure 17.2. Taking a person by variables slice (one occasion thick) results in a two-way data matrix usually characterized as "cross sectional." Cattell (1952) demonstrated how the elements in this two-way matrix could be covaried between variables over persons—the usual way to compute correlations—or persons could be covaried over variables. The former (variables by variables) covariance matrix could be factor analyzed as an R-technique analysis and the latter (persons by persons) covariance matrix could be factor analyzed as Q-technique factor analysis. The latter technique is sometimes used to examine data for types of individuals. Slicing out a two-way matrix of scores for one person yields a variables by occasions data matrix that can be the basis for covarying variables over occasions (P-technique) or occasions over variables (O-technique). Historically, O-technique has not been used much but its counterpart P-technique has been a mainstay in the study of intraindividual variability (Cattell, 1963; Jones & Nesselroade, 1990; Luborsky & Mintz, 1972; Molenaar, 2004; Nesselroade & Ford, 1985). P-technique data are also recognizable as multivariate time series data. A slice of the data box taken in the third plane is a one-variable thick persons by occasions data matrix. Scores on successive trials of a learning task for a sample of persons exemplifies such data. Covarying occasion scores over persons and factor analyzing was named *S-technique* and covarying persons over occasions was called *T-technique* (Cattell, 1952).

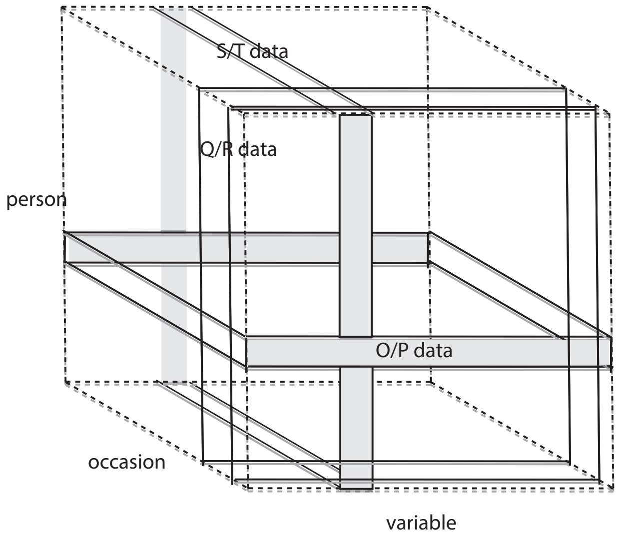

Figure 17.2 The data box emphasizing the samples of data from which six covariation designs can be implemented (O, P, Q, R, S, and T techniques).

Source: Adapted from "Application of Multivariate Strategies to Problems of Measuring and Structuring Long-Term Change" (p. 202) by J. R. Nesselroade, in *Life-Span Developmental Psychology: Research and Theory*, L. R. Goulet and P. B. Baltes (Eds.), 1970, New York, NY: Academic Press.

The six techniques derivable from dissecting portions of the data box provide a systematic summary of possibilities for extracting information from the data box via covariation techniques. The data on which each depends are depicted in Figure 17.2.

P-technique data play a dominant role in the remainder of this chapter because of their pertinence to the study of intraindividual variability. Because P-technique data represent the intensive, repeated measurement of the individual case on multiple variables they lend themselves to answering the kinds of questions about change and process that are so central to building a better understanding of development. P-technique data permit the modeling of intraindividual variability at both the manifest and latent variable levels—emphasizing the individual as the primary unit of analysis. Coupled with the appropriate measurement methods, design conditions, and modeling techniques, such data are the key ingredients for a powerful approach to the study of developmental processes.

The standard approach to statistical analysis in psychology is to draw a random sample of subjects from a presumably homogeneous population of subjects, analyze the structure of interindividual variation in this sample, and then generalize the results thus obtained to the population. Such analyses of interindividual variation underlie all standard statistical techniques in psychology, including analysis of variance, regression analysis, factor analysis, multilevel (latent growth curve) modeling, mixture modeling, and so on. Consequently, the standard approach to psychological data analysis aims to describe the state of affairs at the population level, not at the level of individual subjects. Accordingly, the individuality of each of the persons in the sample and population is deemed immaterial: The subjects are considered to be replications devoid of individuality. This is expressed by the assumption that subjects are homogeneous in all respects relevant to the analysis. This essential homogeneity assumption allows for the averaging (pooling) of the scores of the sampled subjects in the estimation of statistics (means, variances, correlations, etc.) to be generalized to the population. Pooling across subjects, often indiscriminately, is the hallmark of analyses of interindividual variation.

According to our initial definition, a dynamic system is comprised of a set of coupled differential or difference equations describing the evolution of the system's behavior. This implies that a dynamic system model is a model of intrasystem variation, that is, it models the time-dependent changes of the system's behavior. In a similar vein, a dynamic systems model of a developmental process is a model of intraindividual variation, that is, it models the time-dependent changes of an individual's behavior. Given that the standard psychometric approach to the analysis of developmental processes is based on interindividual variation, not intraindividual variation, the fundamental question arises whether such a psychometric approach is valid. This question has been addressed before, for instance in Wohlwill's (1973) masterpiece (see also Nesselroade & Molenaar, 2010). Here we present a definitive negative answer.

The standard psychometric approach to dynamic systems modeling of developmental processes based on analysis of interindividual variation can be shown to be incorrect if these processes do not obey stringent conditions (Molenaar, 2004). The proof is based on classical ergodic theory; a set of theorems of extreme generality which apply to all measurable processes irrespective of their content (see Choe, 2005, for a modern proof of the first, so-called individual ergodic theorem of Birkhoff, 1931). To appreciate the implications of these theorems, it is helpful to first characterize the elementary methodological situation in psychological measurement. Instead of postulating an abstract population of subjects, consider an ensemble of actually existing human subjects whose measurable psychological processes are functions of time and space. To simplify the following discussion, without affecting its generality, the focus is on time as the basic dimension along which psychological processes are evolving. The ensuing basic scientific representation of each human subject in psychology therefore is in terms of a high-dimensional dynamic system generating a set of time-dependent processes. The system includes important functional subsystems such as the perceptual, emotional, cognitive, and physiological systems, as well as their dynamic interrelations. The complete set of measurable time-dependent variables characterizing the system's behavior can be represented as the coordinates of a high-dimensional space referred to as the behavior space. The behavior space contains all the scientifically relevant information about a person (see De Groot, 1954).

Within the behavior space, *interindividual* variation is defined as:

- Select a fixed subset of variables.
- Select one or a few fixed time points as measurement occasions.
- Determine the variation of the scores on the selected variables at the selected time points by pooling across subjects.

Analysis of interindividual variation thus defined is called R-technique by Cattell (1952). In contrast, *intraindividual* variation is defined as:

- Select a fixed subset of variables.
- Select one or more fixed subject(s).
- Determine the variation of the scores of each single subject on the selected variables by pooling across a sampled time interval.

Analysis of intraindividual variation thus defined is called (*replicated*) P-technique by Cattell (1952).

With these preliminary specifications in place, the following heuristic description of the content of Birkhoff's (1931) individual ergodic theorem can be given. This theorem details the conditions that must be met in order to generalize from analyses of interindividual variation to analyses of intraindividual variation, and vice versa. In contrast, a process is nonergodic if the results of analyses of interindividual variation do not generalize to the level of intraindividual change over time, and vice versa. In what follows we only consider Gaussian (normally distributed) processes. The criteria that Gaussian processes must meet in order to be ergodic are twofold (see Hannan, 1970).

1. The process has to be *homogeneous in time*, having constant mean levels, no cycles and sequential dependencies that only depend upon relative time differences (lags). Such a process is called *weakly stationary*.
2. The process has to be *homogeneous across different subjects* in the population. That is, each subject in the population (ensemble) has to obey exactly the same dynamic model.

In the context of factor analysis, for instance, the latter criterion implies that each subject has to obey the same factor model in which the number of factors, the factor loadings, the measurement error variances, and the factor score intercorrelations are invariant across subjects.

In case a Gaussian process is either nonstationary (violating the homogeneity in time criterion), or heterogeneous across subjects (violating the homogeneity across subjects criterion), or both, then this process is nonergodic. This means that there is no lawful relation between the process structure of interindividual variation at the population level and the structures of intraindividual variation at the level of individual subjects belonging to the population. Put another way, if the conditions of ergodicity are violated, no lawful relations exist between results obtained in an analysis of interindividual variation (R-technique) and results obtained in an analogous analysis of intraindividual variation (P-technique).

The consequences of the classical ergodic theorems affect all psychological statistical methodology (Borsboom, 2005; Molenaar, Huizenga, & Nesselroade, 2003). Because the concept of development generally implies that some kind of growth or decline occurs, developmental processes are almost always nonstationary (violating the homogeneity in time criterion for ergodicity) and are, therefore, nonergodic. Generally, developmental scientists consider change that occurs in average or mean levels of a process. However, change may also occur in variances of variables across repeated measurement occasions or change of sequential dependencies of variables at consecutive measurement occasions as function of time. All these changes violate the homogeneity in time criterion for ergodicity. The consequent nonergodicity of developmental processes implies that their analysis has to be based on intraindividual variation in order to obtain valid information at the level of individual development. It is argued later that starting with analyses of intraindividual variation does not preclude valid generalization across subjects. In fact, a successful new method is presented to accomplish just this, even if the subjects concerned are also heterogeneous (violating the homogeneity across subjects criterion; Gates & Molenaar, 2012).

Nonergodicity Due to Nonstationarity

In the remainder of this chapter we consider ways to deal with violations of the two criteria for ergodicity of Gaussian processes. To begin with, the statistical analysis of nonstationary developmental processes is addressed. The best way to proceed is to first outline the analysis of weakly stationary processes, after which this analysis is generalized to nonstationary processes. In what follows the focus is on dynamic factor models because this class of models encompasses a wide variety of time series model types as special cases.

DYNAMIC FACTOR ANALYSIS OF STATIONARY PROCESSES

Dynamic factor analysis is factor analysis of single-subject multivariate time series. A time series consists of a sequence of repeated assessments of a single subject at ideally a large number of measurement occasions. The assessments at each measurement occasion are obtained with the same set of instruments (e.g., tests). If the assessment at each measurement occasion consists of a p-variate vector of scores then the time series thus obtained is called univariate if $p = 1$ and is called multivariate if $p > 1$. Dynamic factor analysis constitutes a generalization of Cattell's P-technique (Cattell, 1952) in that it takes account of lead-lag patterns in the dynamic relations between latent factor series (to be defined shortly) and observed series. Such lead-lag patterns imply that the effect of a latent factor series at each time t on the observed series not only occurs instantaneously at t, but wears out over consecutive time points $t + 1$, $t + 2$, etc. In physics this is called *momentum*. As is illustrated later, such lead-lag effects are important in neurocognition, for instance. In contrast, P-technique involves straightforward application of standard factor analysis to multivariate time series without accommodation of lead-lag sequential dependencies; the reader is referred to Molenaar and Nesselroade (2009) for further discussion of the domain of application of P-technique.

To reiterate, in what follows time series are assumed to be normally distributed (Gaussian series) and also are assumed to be observed at equidistant discrete time points. Generalizations of these restrictive assumptions are discussed in the concluding section of this chapter. Presently it is also assumed that the series are weakly stationary (to be defined shortly). Boldface lowercase letters denote column vectors; boldface uppercase letters denote matrices; an apostrophe attached to vectors or matrices denotes transposition. Latent variables, whether random or fixed, will be denoted by Greek letters. Latent variables are variables in statistical models which have not been measured (observed). Fixed latent variables are called *model parameters* (for instance, factor loadings and measurement error variances in factor models); examples of random latent variables in factor models are factor scores and measurement errors. Please note that we use matrix algebra only as a convenient language to express multivariate models; no special expertise in matrix algebra is required to understand these expressions.

Let $\boldsymbol{y}(t) = [y_1(t), y_2(t), \ldots y_p(t)]'$ be a p-variate time series, $p \geq 1$, observed at equidistant time points $t = 1, 2, \ldots, T$. The mean of $\boldsymbol{y}(t)$ at each time point t is: $E[\boldsymbol{y}(t)] = \boldsymbol{\mu}(t)$, where $E[.]$ stands for the Expectation. Considered as function of t, $\boldsymbol{\mu}(t)$ denotes the p-variate mean function (trend) of $\boldsymbol{y}(t)$. If $\boldsymbol{\mu}(t) = \boldsymbol{\mu}$, that is, if the mean function is constant in time, then $\boldsymbol{y}(t)$ is said to have a stationary mean function. The sequential covariance of $\boldsymbol{y}(t)$ between a given pair of time points t_1 and t_2 is defined as: $\Sigma(t_1, t_2) = \text{cov}[\boldsymbol{y}(t_1), \boldsymbol{y}(t_2)']$, where cov[.] stands for covariance. Considered as function of two-dimensional time t_1, t_2 $\Sigma(t_1, t_2)$ denotes the (p, p)-variate covariance function of $\boldsymbol{y}(t)$. If $\Sigma(t_1, t_2)$ only depends on the relative time difference, called lag, $t_1 - t_2 = u$, that is, $\Sigma(t_1, t_2) = \Sigma(t_1 - t_2) = \Sigma(u) = 0, \pm 1, \ldots, \pm T - 1$, then $\boldsymbol{y}(t)$ has stationary covariance function depending only on lag u. If both the mean function and covariance function of $\boldsymbol{y}(t)$ are stationary then $\boldsymbol{y}(t)$ is called a weakly stationary p-variate time series. Hence the statistical characterization of a weakly stationary p-variate series consists of the specification of its p-variate mean level $\boldsymbol{\mu}$ and the sequence of (p, p)-dimensional covariance matrices $\Sigma(u), u = 0, \pm 1, \ldots \pm T - 1$ specifying the sequential dependencies. Because Gaussian series are completely characterized by the first two moment functions, weakly stationary Gaussian series are also (strongly) stationary in the distributional sense.

In the first publication on dynamic factor analysis in psychology, the following model for stationary multivariate Gaussian series was considered (Molenaar, 1985):

$$\boldsymbol{y}(t) = \boldsymbol{\mu} + \boldsymbol{\Lambda}(0)\boldsymbol{\eta}(t) + \boldsymbol{\Lambda}(1)\boldsymbol{\eta}(t-1) + \ldots + \boldsymbol{\Lambda}(s)\boldsymbol{\eta}(t-s) + \boldsymbol{\varepsilon}(t) \tag{17.1a}$$

where $\boldsymbol{y}(t)$ is an observed p-variate time series, $\boldsymbol{\eta}(t)$ is a latent q-variate factor series and $\boldsymbol{\varepsilon}(t)$ is a p-variate measurement error series. Because our main interest is not in the constant mean function $\boldsymbol{\mu}$, it is conveniently assumed that $\boldsymbol{\mu} = \mathbf{0}$. Then $\boldsymbol{y}(t)$, $\boldsymbol{\eta}(t)$ and $\boldsymbol{\varepsilon}(t)$, are zero mean weakly stationary series.

The $\boldsymbol{\Lambda}(u)$, $u = 0, 1, \ldots, s$, are (p, q)-dimensional matrices of lagged factor loadings, where $s \geq 0$ is the maximum lag. These lagged factor loadings allow for the possibility that the realization (magnitude or score) of the latent factor series $\boldsymbol{\eta}(t)$ at each time t not only has an instantaneous effect on $\boldsymbol{y}(t)$, but also may have delayed (lead-lag) effects at later time points $t + 1, \ldots, t + s$. The linear combination $\boldsymbol{\Lambda}(0)\boldsymbol{\eta}(t) + \boldsymbol{\Lambda}(1)\boldsymbol{\eta}(t-1) + \ldots + \boldsymbol{\Lambda}(\mathrm{s})\boldsymbol{\eta}(t-s)$ expressing the totality of contemporaneous and delayed effects is called a *convolution*.

For later reference the limiting case of equation (17.1a) is considered in which $s = 0$, that is, the case in which there are no lagged factor loadings:

$$\boldsymbol{y}(t) = \boldsymbol{\Lambda}\boldsymbol{\eta}(t) + \boldsymbol{\varepsilon}(t) \tag{17.1b}$$

where the zero lag matrix of factor loadings $\boldsymbol{\Lambda}(0)$ is written as $\boldsymbol{\Lambda}$. Equation (17.1b) is a special instance of equation (17.1a). It has been assigned several labels, including *state-space* model (e.g., Molenaar, 1985) and *process factor* model (e.g., Browne & Nesselroade, 2005). In what follows equation (17.1b) is referred to as a state-space model. As is explained shortly, equation (17.1b) has a special property not shared by equation (17.1a).

To complete the definition of the dynamic factor model under consideration, the covariance functions of the latent time series occurring on the right-hand sides of (17.1a)–(17.1b) should be specified. The covariance function of the measurement error process $\boldsymbol{\varepsilon}(t)$ is defined as: $\mathrm{cov}[\boldsymbol{\varepsilon}(t), \boldsymbol{\varepsilon}(t-u)'] = \text{diag-}\boldsymbol{\Theta}(u)$; $u = 0, \pm 1, \ldots,$ where diag-$\boldsymbol{\Theta}(u)$ denotes a sequence of (p, p)-dimensional covariance matrices, one for each lag u, which have nonzero elements along the diagonal and zero elements off-diagonal. This implies that each univariate measurement error process $\epsilon_{\mathrm{k}}(t)$ associated with the kth observed univariate series $y_k(t)$, $k \in \{1, \ldots, p\}$, is allowed to have nonzero sequential covariance: $\mathrm{cov}[\epsilon_k(t), \epsilon_k(t-u)] \neq 0$ for $\forall$u. However, measurement error processes $\epsilon_k(t)$ and $\epsilon_m(t)$ associated with different observed univariate series $y_k(t)$ and $y_m(t)$, $k \neq m \in \{1, \ldots, p\}$, are assumed to be uncorrelated at all lags u: $\mathrm{cov}[\epsilon_k(t), \epsilon_m(t-u)] = 0$ for $\forall u$. Finally the covariance function of the q-variate latent factor series $\boldsymbol{\eta}(t)$ is defined as: $\mathrm{cov}[\boldsymbol{\eta}(t), \boldsymbol{\eta}(t-u)'] = \boldsymbol{\Psi}(u)$, $u = 0, \pm 1, \ldots,$ where at each lag u $\boldsymbol{\Psi}(u)$ is a (q, q)-dimensional covariance matrix.

It was proven in Molenaar (1985) that under certain conditions the covariance function $\boldsymbol{\Psi}(u)$, $u = 0, \pm 1, \ldots$ of the latent factor series $\boldsymbol{\eta}(t)$ is not identifiable. That means that under these conditions the variances and sequential covariances in $\boldsymbol{\Psi}(u)$, $u = 0, \pm 1, \ldots,$ cannot be estimated, but have to be fixed a priori. The conditions concerned are twofold. Firstly, the maximum lag s of the matrices of factor loadings $\boldsymbol{\Lambda}(u)$, $u = 0, 1, \ldots, s$, has to be larger than zero: $s > 0$. Secondly, all factor loadings in $\boldsymbol{\Lambda}(u)$, $u = 0, 1, \ldots, s$, should be free parameters (apart from standard minimal constraints to guarantee the distinctness of different component factor series in $\boldsymbol{\eta}(t)$). That is, the dynamic factor model should be *exploratory*, having no a priori restrictive pattern of fixed factor loadings.

If both these conditions obtain (hence we have a general exploratory dynamic factor model) then the covariance function of the latent factor series is not identifiable and therefore has to be fixed a priori. $\boldsymbol{\Psi}(u)$, $u = 0, \pm 1, \ldots,$ then can be fixed at any theoretically feasible stationary covariance function without affecting the goodness of fit of the model. In Molenaar (1985), the simplest covariance function for $\boldsymbol{\eta}(t)$ was chosen: $\boldsymbol{\Psi}(u) = \delta(u)\mathbf{I}_q$, where $\delta(u)$ is the Kronecker delta ($\delta(u) = 1$ if $u = 0$; $\delta(u) = 0$ if $u \neq 0$) and $\mathbf{I}_q$ is the (q, q)-dimensional identity matrix. This particular choice implies that the q-variate latent factor series lacks instantaneous as well as sequential dependencies. Accordingly, $\boldsymbol{\eta}(t)$ can be conceived of as a sequence of random shocks, often referred to in the engineering literature as a white noise sequence. But quite other choices can fruitfully be considered (see Molenaar & Nesselroade, 2001, where special dynamic factor rotation techniques are introduced relating model solutions obtained with different a priori choices for $\boldsymbol{\Psi}(u)$, $u = 0, \pm 1, \ldots$).

If the dynamic factor model is confirmatory, that is, if an a priori restrictive pattern of fixed factor loadings has been specified in $\boldsymbol{\Lambda}(u)$, $u = 0, 1, \ldots, s$, then the covariance function of the latent factor series is identifiable. Also if $s = 0$, that is, if the state-space model equation (17.1b) applies, then the covariance function of the latent factor series is identifiable. In these cases $\boldsymbol{\Psi}(u)$, $u = 0, \pm 1, \ldots,$ can be freely estimated or, alternatively, a parametric weakly stationary time series model for $\boldsymbol{\eta}(t)$ (and hence for its covariance function) can be considered. For instance, the latent factor series $\boldsymbol{\eta}(t)$ can be represented by a vector autoregressive model: $\boldsymbol{\eta}(t) = \mathbf{B}\boldsymbol{\eta}(t-1) + \zeta(t)$, where $\mathbf{B}$ is a (q, q)-dimensional matrix of auto- and cross-regression coefficients and $\boldsymbol{\zeta}(t)$ is q-variate process noise. In this case the complete state-space model is:

$$\mathbf{y}(t) = \boldsymbol{\Lambda}\boldsymbol{\eta}(t) + \boldsymbol{\varepsilon}(t); \boldsymbol{\eta}(t) = \mathbf{B}\boldsymbol{\eta}(t-1) + \zeta(t) \tag{17.1c}$$

In sum, the general dynamic factor model for weakly stationary multivariate time series is defined by equation (17.1a) and the specifications for the covariance functions of the measurement errors, $\text{cov}[\epsilon(t), \epsilon(t-u)'] =$ diag-$\boldsymbol{\Theta}(u)$, and the latent factor series, $\text{cov}[\boldsymbol{\eta}(t), \boldsymbol{\eta}(t-u)'] = \Psi(u)$, $u = 0, \pm 1, \ldots$ The specific dynamic factor model without lagged factor loadings, that is, the state-space model, is defined by equation (17.1c). It is customary to refer to $\boldsymbol{\eta}(t)$ in the general dynamic factor model as the (latent) factor series, whereas $\boldsymbol{\eta}(t)$ in the state-space model usually is referred to as the (latent) state process.

Given that for the state-space model equation (17.1c) the covariance function (or a parametric time series model) of the latent factor series always is identifiable, it would seem rational to restrict attention to this type of model. For exploratory dynamic factor analyses this would preclude the need to have to arbitrarily fix the covariance function of the latent factor series $\boldsymbol{\Psi}(u)$, $u = 0, \pm 1, \ldots,$ which is necessary in such applications of exploratory versions of equation (17.1a). However, it can be shown that for certain types of psychological time series the state-space model equation (17.1c) is too restrictive. In particular when the effect of $\boldsymbol{\eta}(t)$ on $\boldsymbol{y}(t)$ is delayed (existence of lead-lag patterns), then use of the state space model would be inappropriate. For these time series the general dynamic factor model, involving equation (17.1a), in which $s > 0$, is needed.

Such delays occur, for instance, in multidimensional physiological processes. For instance, Molenaar (1985) presents a dynamic factor analysis of a five-variate time series obtained with an 8-day-old newborn who had been assessed at 3-minute intervals during 6.5 hours on the following dimensions: power EEG, heart rate, respiration rate, heart rate variability, and respiration rate variability (Hutt, Lenard, & Prechtl, 1969). It is found that the observed five-variate time series can be satisfactorily described by an instance of the general dynamic factor model with lagged factor loadings, whereas the state-space model equation (17.1c) does not yield an acceptable fit. The dimension of the latent factor series $\eta(t)$ is $q = 1$. The pattern of lagged factor loadings shows that the maximum factor loadings for heart rate and respiration rate occur at lag $u = 2$. In contrast, the maximum factor loadings for heart rate variability, and respiration rate variability occur earlier, namely at lag $u = 1$. This distinct lead-lag pattern suggests an interpretation of the unidimensional latent factor series $\eta(t)$ in terms of arousal in that arousal is known to act as a tuning mechanism that in the first instance increases the response ranges (i.e., variability) of physiological processes. Subsequently these increased response ranges enable the selection of more adaptive levels of response rates. This illustration shows that the pattern of lagged factor loadings can be essential in the proper interpretation of latent factor series.

The statistical analysis of weakly stationary multivariate time series based on the dynamic factor model (the general model with lagged factor loadings as well as the state-space model) can proceed in various ways. Applications pertain to single-subject data as well as data obtained in replicated time series designs using multiple subjects. An overview of different statistical methods to fit the model, together with references to freely obtainable software, is given in Molenaar and Lo (2012). Discussions and illustrations of dynamic factor analysis of (replicated) stationary psychological time series can be found in, for instance, Beltz, Beekman, Molenaar, and Buss (2013), Browne and Nesselroade (2005), Browne and Zhang (2007), Ferrer (2006), Ferrer and Nesselroade (2003), Gayles and Molenaar (2013), Hamaker, Dolan, & Molenaar, 2005, Kim, Zhu, Chang, Bentler, and Ernst (2007), Molenaar, Rovine, and Corneal (1999), Mumma (2004), Nesselroade, McArdle, Aggen, and Meyers (2002), Sbarra and Ferrer (2006), Shifren, Hooker, Wood, and Nesselroade (1997), and Wood and Brown (1994).

DYNAMIC FACTOR ANALYSIS OF NONSTATIONARY PROCESSES

We now turn to the main question, namely how to deal with the statistical analysis of nonstationary processes such as typical developmental processes. The key to the solution is to allow parameters in dynamic models to be time-varying themselves. That is, not only the observed series $\boldsymbol{y}(t)$, the factor series $\boldsymbol{\eta}(t)$ and the error process $\boldsymbol{\varepsilon}(t)$ in the dynamic factor are (randomly) time-varying, but also the (lagged) factor loadings $\boldsymbol{\Lambda}(u)$ and other parameters are allowed to vary in time. The dynamic models incorporating such time-varying parameters belong to a few distinct classes. The main distinction concerns the assumption whether parameters vary abruptly or smoothly in time. Dynamic models assuming that parameters vary abruptly in time are called regime-switching models (Hamaker & Grasman, 2012; Kim & Nelson, 1999). Regime-shifting models are relevant for analyzing stage transitions which are discussed later. Here the focus is on dynamic factor models with smoothly time-varying parameters. To ease the presentation only state-space models equation (17.1c) with time-varying parameters are considered. First a simple example is given, after which the general expression for the (linear Gaussian) state-space model with arbitrary time-varying parameters is presented.

Consider a state-space model in which the dimension of the observed process is $p = 3$ and the dimension of the latent state process is $q = 1$. This simple state-space model with time-varying parameters is described by:$\mathbf{y}(t) = \boldsymbol{\lambda}(t)\eta(t) + \boldsymbol{\varepsilon}(t); \eta(t) = \beta(t)\eta(t-1) + \zeta(t)$. In this model the vector of factor loadings $\boldsymbol{\lambda}(t)' = [\lambda_1(t), \lambda_2(t), \lambda_3(t)]'$ as well as the autoregressive parameter $\beta(t)$ are allowed to vary with time in smooth, but otherwise arbitrary and unknown ways. To obtain a general representation of all state-space models of this kind, the model parameters are collected in an r-variate time-varying parameter vector $\boldsymbol{\theta}(t)$, where in the present example $r = 4$ and $\boldsymbol{\theta}(t)' = [\lambda_1(t), \lambda_2(t), \lambda_3(t), \beta(t)]'$. Then the illustrative model is rewritten as: $\mathbf{y}(t) = \boldsymbol{\lambda}[\boldsymbol{\theta}(t)]\eta(t) + \boldsymbol{\varepsilon}(t); \eta(t) = \beta[\boldsymbol{\theta}(t)]\eta(t-1) + \zeta(t)$.

The general state-space model with time-varying parameters is:

$$\begin{aligned} \mathbf{y}(t) &= \boldsymbol{\Lambda}[\boldsymbol{\theta}(t)]\boldsymbol{\eta}(t) + \boldsymbol{\varepsilon}(t) \\ \boldsymbol{\eta}(t+1) &= \mathbf{B}[\boldsymbol{\theta}(t)]\boldsymbol{\eta}(t) + \boldsymbol{\zeta}(t+1) \qquad (17.2) \\ \boldsymbol{\theta}(t+1) &= \boldsymbol{\theta}(t) + \boldsymbol{\xi}(t+1) \end{aligned}$$

In equation (17.2), $\boldsymbol{y}(t)$ denotes the observed p-variate time series; $\boldsymbol{\eta}(t)$ the q-variate latent factor series (state process). The first expression of equation (17.2) shows that factor loadings in $\boldsymbol{\Lambda}[\boldsymbol{\theta}(t)]$ depend on a time-varying parameter-vector $\boldsymbol{\theta}(t)$ and hence can change in time. The second expression describes the time evolution of the state process $\boldsymbol{\eta}(t)$; the autoregressive weights in $\mathbf{B}[\boldsymbol{\theta}(t)]$ depend upon $\boldsymbol{\theta}(t)$ and therefore can also be arbitrarily time-varying. The third expression in equation (17.2) describes the time-dependent variation of the unknown parameters. The r-variate parameter vector process $\boldsymbol{\theta}(t)$ obeys a so-called random walk with Gaussian process noise $\xi(t)$. Other dynamic models for the parameter vector process $\boldsymbol{\theta}(t)$ are available (e.g., higher-order random walks or autoregressive models).

To fit equation (17.2) to the data, a special and intricate estimation method is required (see Bar-Shalom, Li, & Kirubarajan, 2001). A beta version of the computer program implementing this estimation method can be obtained from the first author. The method yields estimated trajectories of each parameter across the whole observation interval. Because the estimation algorithm has been developed only recently, a limited number of applications of equation (17.2) have been reported until now. A variant of the model was first considered in Molenaar (1994). The first application of equation (17.2) was to father-stepson interactions and is presented in Molenaar, Sinclair, Rovine, Ram, and Corneal (2009). Other applications are reported in Chow, Zu, Shifren, and Zhang (2011), Molenaar, Beltz, Gates, and Wilson (2013), Wang et al. (2014), Zhou et al. (2010).

Molenaar et al. (2009) present an application of this model to a three-variate time series of repeated measures of emotional experiences of a son interacting with his father during 80 consecutive interaction episodes across a period of about 2 months. The measures making up $\boldsymbol{\eta}(t)$ in equation (17.2) are Involvement, Anger, and Anxiety (see Figure 17.3). In the particular instance of equation (17.2) fitted to these data $\boldsymbol{\Lambda}[\boldsymbol{\theta}(t)]$ is fixed at the (3,3) identity matrix and $\boldsymbol{\varepsilon}(t)$ is zero, hence the first expression of equation (17.2) reduces to: $\mathbf{y}(t) = \boldsymbol{\eta}(t)$.

The (3,3)-dimensional matrix $\mathbf{B}[\boldsymbol{\theta}(t)]$ in equation (17.2) contains the possibly time-varying regression coefficients linking $\boldsymbol{\eta}(t+1)$ to $\boldsymbol{\eta}(t)$. Here only the part of the model explaining the Involvement process is considered. This part can be represented as (Inv = Involvement, Ang = Anger, Anx = Anxiety):

$$\begin{aligned} \mathrm{Inv}(t+1) = \beta_{11}(t)^{*}\mathrm{Inv}(t) + \beta_{12}(t)^{*}\mathrm{Ang}(t) + \beta_{13}(t) \\ {}^{*}\mathrm{Anx}(t) + \zeta_1(t+1) \end{aligned}$$

Thus Involvement at time $t + 1$ is a function of Involvement at the previous time point t, Anger at the previous time point t, and Anxiety at the previous time point. Figure 17.4 presents the estimates of $\beta_{11}(t)$, $\beta_{12}(t)$, and $\beta_{13}(t)$ across the 80 interaction episodes.

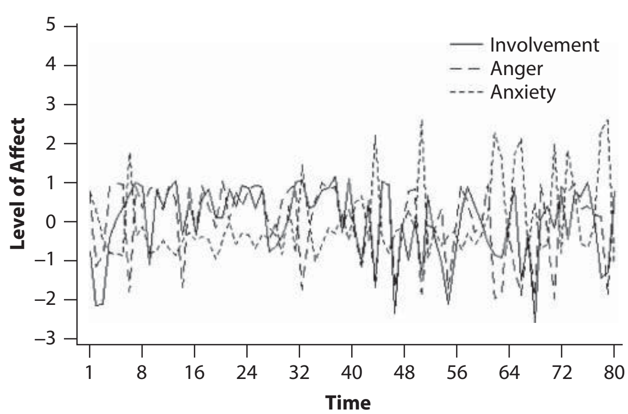

Figure 17.3 Three-variate time series of repeated measures of emotional experiences of a son interacting with his father during 80 consecutive interaction episodes.

Source: Adapted from "Analyzing Developmental Processes on an Individual Level Using Non-Stationary Time Series Modeling," by P. C. M. Molenaar, K. O. Sinclair, M. J. Rovine, N. Ram, and S. E. Corneal, 2009, *Developmental Psychology*, *45*, p. 263.

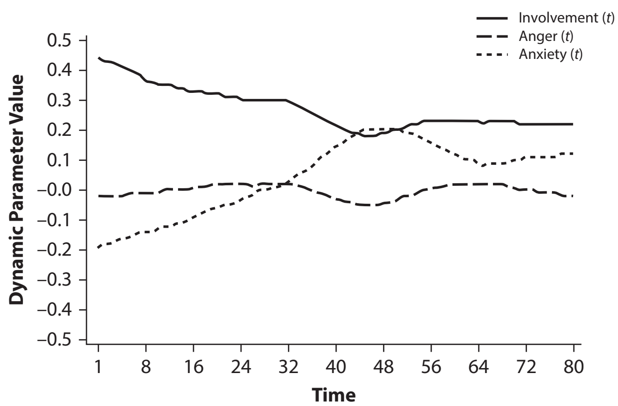

Figure 17.4 Time-varying auto- and cross-lagged regression coefficients of Involvement at $t + 1$ as function of Involvement, Anger and Anxiety at t.

Source: Adapted from "Analyzing Developmental Processes on an Individual Level Using Non-Stationary Time Series Modeling," by P. C. M. Molenaar, K. O. Sinclair, M. J. Rovine, N. Ram, and S. E. Corneal, 2009, *Developmental Psychology*, *45*, p. 266.

$\beta_{11}(t)$, which quantifies the effect of Involvement at time t on Involvement at time $t + 1$ is decreasing across the initial half of the sequence of interaction episodes, after which it stabilizes during the final half. $\beta_{13}(t)$, which quantifies the effect of Anxiety at the previous interaction episode on Involvement at the next interaction episode is increasing across the initial half of the sequence of interaction episodes, after which it stabilizes during the final half. It is noteworthy that $\beta_{13}(t)$ is negative during the initial part of the sequence of interaction episodes, but is positive during the later interaction episodes. Hence increased Anxiety during the initial interaction episodes predicts decreased Involvement at each next interaction episode, whereas this relationship is reversed during the later interaction episodes. Additional details and results can be found in Molenaar et al. (2009).

In closing this section it is noted that the state-space model with time-varying parameters, equation (17.2), consists of subprocesses that evolve at different time scales. The observed process $\mathbf{y}(t)$ and the latent state process $\boldsymbol{\eta}(t)$ both evolve at the fastest time scale. The parameter process $\boldsymbol{\theta}(t)$, however, evolves at a slower time scale. Hence equation (17.2) involves multiple time scales ordered in a multilevel hierarchy. The issue of multiple time scales has been prominent in the literature on dynamic systems applications (e.g., Haken, 1978; Newell et al., 2010; Thelen & Smith, 1994). Equation (17.2) can be extended with a third level by replacing the random walk for $\boldsymbol{\theta}(t)$ by a model with time-varying parameters (for instance, a vector autoregressive model analogous to the model for $\boldsymbol{\eta}(t)$). The third level then describes the evolution of the time-varying parameters in the autoregressive model for $\boldsymbol{\theta}(t)$. The additional process at the third level again evolves at a slower time scale than those at the previous two levels. In principle addition of more levels can proceed in the same way. As indicated in Molenaar et al. (2009), this enables the disentanglement of the effects of short-term processes (e.g., microdevelopment) and long-term processes (e.g., macrodevelopment; see Granott & Parziale, 2002).

Nonergodicity Due to Heterogeneity

The two criteria that a Gaussian process simultaneously has to meet in order to be ergodic are independent of each other. That is, whether a process is stationary is independent from the question of whether the subjects in a population obey the same dynamical model for that process. Here we consider innovative ways to deal with violations of the latter homogeneity across persons criterion. But first some general remarks are in order.

The assumption that a population is homogeneous (or, in mixture modeling, that each of a finite set of subpopulations is homogeneous) is standard in analysis of interindividual variation. For instance in factor analysis of interindividual variation it is assumed that each subject in the population obeys the same factor model in which the number of factors and the values of the factor loadings is invariant across subjects. The derivation of estimators such as the maximum likelihood estimator is heavily dependent on this homogeneity assumption. One therefore would expect that deviations from this homogeneity assumption will lead to severe problems in fitting models to interindividual variation. Yet, surprisingly, this is not the case. If data are simulated according to a scenario in which each person has its own factor model (person-specific number of factors, person-specific values of the factor loadings and/or measurement error variances, etc.) and this maximally heterogeneous data set is subjected to standard factor analysis of interindividual variation, then a nicely fitting factor solution is obtained which in reality does not conform to any of the person-specific models used to generate the data. An overview of the results obtained in such simulation experiments, including analogous results obtained in longitudinal and quantitative genetic factor models, is given in Molenaar (2007). The conclusion is that analysis of interindividual variation is almost blind to large-scale violations of the homogeneity across persons assumption underlying this kind of analysis. This conclusion is corroborated in a formal analysis by Kelderman and Molenaar (2007). The best way to detect heterogeneity across persons is to carry out dedicated analyses of intraindividual variation based on replicated time series data.

Although the existence of large-scale heterogeneity (each person in the population obeying his or her own model) is practically invisible in analyses of interindividual variation, it might be conjectured that such heterogeneity will rarely occur in reality anyway. Strong arguments can be provided, however, that large-scale heterogeneity can be expected to be the rule in human populations, rather than the exception. These arguments are based on the importance of self-organizing nonlinear epigenetic influences during ontogenesis, creating substantial structural variation in the neural networks underlying human information processing. This variation is not caused by genetic and/or environmental influences, but instead it emerges from the dynamic evolution of the developing system itself. In the next section these arguments for the existence of large-scale heterogeneity in human populations are further elaborated.

Nonlinear Self-Organizing Epigenetic Processes

The biological processes within epigenetics often are involved in the alternation of gene expression rather than the underlying DNA sequence. Although there are several epigenetic biological processes, the two most studied are DNA methylation and histone modification. Both processes are different types of chromatin remodeling that involve either addition of methyl groups to DNA (DNA methylation) or posttranslational modification of the amino acids that make up histone proteins (histone modification). A thorough overview of epigenetic processes is given in Jablonka and Lamb (2005). In general, epigenetic processes can promote or inhibit expression of particular genes and may exhibit strong reactivity to environmental influences. These biological processes lead to self-organizing behavior during the development of an organism.

In his contribution to a volume discussing the relevance of D'Arcy Thompson's classic *On Growth and Form* (Thompson, 1917) for modern work on spatiotemporal pattern formation, McLachlan (1999, Chapter 10) presents eight types of influences associated with epigenetics, that is, influences not directly specified by the genome, each inducing individual variation in developmental morphologies. These influences are: physical constraints (such as minimum energy considerations), extra-chromosomal inheritance, environmental influences (such as those determining polarity), self-organizing processes (discussed later), influences of parental genotype, tissue self-assembly, tissue interaction, and specification by use. McLachlan (1999) concludes that due to such influences not directly specified by the genome, the morphology of each individual is different from all other individuals. With respect to the processes underlying these influences he specifies:

> This is more than the interaction of the environment with the genotype, or reaction norm. Such variation comes from the nature of the developmental program, which includes processes of high determinacy, but also some with a high degree of indeterminacy. In consequence, development of the individual is stochastic, and contingent rather than deterministic, and the operation of identical environmental factors on identical developmental programs may lead to different morphologies. (McLachlan, 1999, p. 167)

The influences considered by McLachlan imply the creation of endogenous variation, that is, variation that is neither of genetic, environmental, nor of gene-environment interactive origin. Instead this epigenetic variation is created by what McLachlan calls *stochastic developmental programs*. In mathematical biology a class of very successful models has been developed to explain such stochastic development: the class of nonlinear reaction-diffusion models of biological pattern formation. The first model of this kind was formulated by Turing (1952), followed by the influential model of Gierer and Meinhardt (1972). Deserving special mention are the monograph by Meinhardt (1982), as well as the textbook by Murray (2002) and the overview of experimental work by Harrison (2010). Schöner (2013) discusses these types of models in the context of developmental science.

The mathematical model put forward by Turing (1952) is a so-called system of reaction-diffusion equations. The reaction part consists of two coupled nonlinear partial differential equations describing interactive change in an activator and inhibitor as function of space and time. The reaction part is stable, implying that perturbing it only will lead to transient changes which quickly die out and leave no aftereffect. Hence if the biological system starts up as a homogeneous field then it will stay homogeneous after perturbation.

In a stroke of genius Turing added a diffusion term to each of the equations making up the reactive subsystem (see Figure 17.5). Adding diffusion terms makes biochemical sense but dramatically changes the character of the ensuing reaction-diffusion system in that now an arbitrary small perturbation can lead to a sudden qualitative change in its dynamics. If the biological system initially is a homogeneous field then this homogeneity may become definitively destroyed after perturbing it (so-called symmetry breaking)

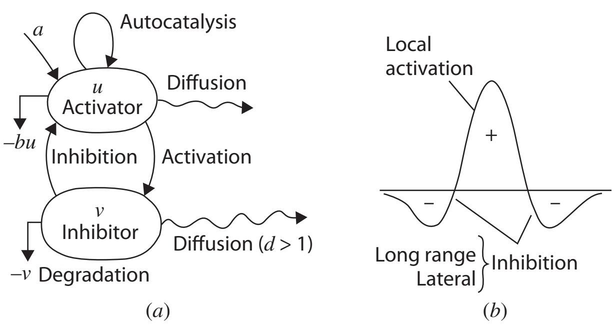

Figure 17.5 (*a*) Schematic representation of a reaction-diffusion system for biological pattern formation. Directed arrows among the activator and inhibitor subprocesses indicate nonlinear functional relationships. (*b*) On-center distribution of activator and off-surround distribution of inhibitor, required for realistic pattern formation.

and new spatial patterns emerge. Symmetry breaking is an example of what is called a phase transition in physics (e.g., the sudden transition of water to ice), a bifurcation or singularity in mathematics, and a stage transition in cognitive developmental psychology (see van der Maas & Molenaar, 1992). In what follows we employ bifurcation as the more neutral and commonly used term. Bifurcation refers to the qualitative change in the equilibrium states of a system which during the transition often split into a new configuration of equilibria. The reader is referred to Grindrod (1991) for an introduction to bifurcation analysis of reaction-diffusion systems.

Only nonlinear dynamic systems can undergo bifurcations. As we saw with the Turing model, a bifurcation can be triggered by a small perturbation, where the nature of the perturbation is immaterial. There are several other scenarios that can trigger bifurcations, for instance, slow continuous change in a system parameter (like the gradual cooling triggering the transition of water into ice). A bifurcation typically is associated with several characteristic features. For instance, one of the most commonly occurring types of bifurcation, the so-called first-order phase transitions, typically are accompanied by a sudden jump in system behavior as well as starkly increased variability of the system's performance (see van der Maas & Molenaar, 1992).

Bifurcations are essential for self-organization emerging from nonlinear epigenetic processes. Because bifurcations are caused by the dynamics of nonlinear processes, it follows that the self-organization associated with nonlinear epigenetic processes also is caused by the dynamics of these processes. With regard to the special characteristics of the symmetry breaking bifurcations occurring in reaction-diffusion models of biological pattern formation there is one characteristic which stands out and which is important for our purposes: Bifurcations in reaction-diffusion models generate structural variation in their results. For instance, Meinhardt (1982) shows that the Gierer-Meinhardt reaction diffusion model (Gierer & Meinhardt, 1972) generates considerable structural variation in computer simulations of growing networks and several other biological structures (see Figure 17.6). In these computer simulations the model is started up several times under identical conditions (identical model parameters, same initial conditions, etc.). Yet after each replication under identical conditions the resulting network structure has a different pattern. The general conclusion is that the bifurcations causing self-organization in reaction-diffusion

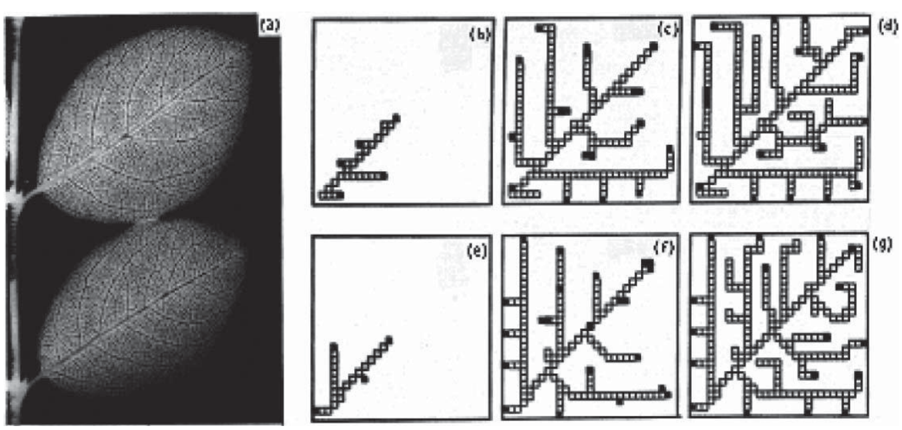

Figure 17.6 Using exactly the same Gierer-Meinhardt reaction-diffusion model with invariant parameters (an instance of the model depicted in Figure 17.5) and identical initial conditions, two leaves of the same tree, (b–d) and (e–g), are generated that vary due to the underlying epigenetic growth process.

Source: From *Models of Biological Pattern Formation*, Figure 15.5, by H. Meinhardt, 1982, London, England: Academic Press. Reprinted with permission. Available at http://www.eb.tuebingen.mpg.de/research/emeriti/hans-meinhardt/82-book/bur82.html models of nonlinear epigenetic processes generate structural variation under identical conditions.

Our discussion of the more formal aspects of reaction-diffusion models of biological pattern formation indicates that the variation generated by bifurcations in self-organizing epigenetic processes is of purely dynamic origin. It can occur under invariant conditions and therefore is logically independent of environmentally and genetically induced variation. Models like the Gierer-Meinhardt reaction-diffusion model (Gierer & Meinhardt, 1972) generate such so-called third source variation (Molenaar, Boomsma, & Dolan, 1993) in growing neural networks, which consequently shows up in observed phenotypic psychological measurements (Kan, Ploeger, Raijmakers, Dolan, & van der Maas, 2010). A concise review of reaction-diffusion modeling in mathematical biology, including applications to explain developmental instability, variability in gene transcription, fingerprint formation, and biological oscillations, is given in Molenaar (2007).

THE DANGERS OF POOLING

To illustrate the confounding effects of treating heterogeneous data as being homogeneous, a simple simulation experiment is carried out. Suppose there are three families, each consisting of four persons (husband, son, wife, and daughter). The degree of rivalry by each person within a family during an ongoing social interaction is measured at $T = 100$ equidistant time points. The data $\mathbf{y}(t)$ for each family are generated according to the following so-called unified structural equation model (Gates, Molenaar, Hillary, Ram, & Rovine, 2010), which can be represented in state space format akin to (17.1c):

$$\mathbf{y}(t) = \boldsymbol{\eta}(t); \boldsymbol{\eta}(t) = \mathbf{A}\boldsymbol{\eta}(t) + \boldsymbol{\Phi}\boldsymbol{\eta}(t-1) + \boldsymbol{\zeta}(t) \qquad (17.3)$$

The first expression of equation (17.3) is an identity, indicating that the four-dimensional observed process equals the “latent” state process. This identity only is used to conform to the general format of state space models. The (4,4)-dimensional matrix $\mathbf{A}$ in the second equation describes contemporaneous relations among the four component series of $\boldsymbol{\eta}(t)$. These contemporaneous relations can be understood as manifesting themselves within the span of the sampling interval. Note that such contemporaneous relations are not explicitly modeled in the state space model, equation (17.1c). Of course the diagonal of $\mathbf{A}$ only can have zero entries, because a process should not be explained by itself at the same moment in time. The (4,4)-dimensional matrix Φ describes the pure lagged relations among the component series of $\boldsymbol{\eta}(t)$. These lagged relations are pure because the contemporaneous relations are explicitly modeled by $\mathbf{A}$. The diagonal of $\boldsymbol{\Phi}$ contains the pure autoregressive relations (regression of each component series of $\boldsymbol{\eta}(t)$ on itself one time step earlier). The four-dimensional process noise $\zeta(t)$ is white noise lacking any contemporaneous and lagged dependencies.

The simulation models for family 1 and family 2 are identical: $a_{13} = .8$, $a_{23} = .7$, $a_{43} = .6$, $\varphi_{11} = \varphi_{22} = \varphi_{33} = \varphi_{44} = .8$, $\varphi_{41} = .6$. The simulation model for Family 3 is identical to the model for Families 1 and 2, save for the cross-lagged regression between Person 4 and 1, which in Family 3 has the reverse direction: $\varphi_{14} = .6$. All other elements of $\mathbf{A}$ and Φ are fixed at zero. This set of simulation models can be characterized as almost homogeneous: Only the third family differs from the other two in a single parameter (relation). The upper row of panels and the left lower panel in Figure 17.7 present the results of separate model fits to each of the families (obtained in three separate single-family analyses). Continuous arrows depict contemporaneous relations and broken arrows depict lagged relations. Broken arrows starting and ending at the same person depict lagged autoregressive relationships. The thickness of each arrow is proportional to the absolute value of its estimated regression weight. The estimation algorithm is completely data-driven and automatically selects without a priori information the best fitting model based on likelihood criteria (see Gates et al., 2010, for all details). It appears that the true (simulation) model for each family is faithfully recovered, showing that Person 3 (the mother) in each family is a kind of organizing center as far as contemporaneous relations are concerned. In particular, the correct direction of the cross-lagged relation between Person 1 and 4 is recovered in each family.

The lower right panel of Figure 17.7 shows the model fit to the average of the covariance matrices across the three families (pooling across replications). It appears that two so-called phantom paths appear in the fitted model which do not pertain to the true model of any of the three families: a contemporaneous relation $a_{42} = .22$ and a cross-lagged relation $\varphi_{42} = .31$. Also the cross-lagged relations between person 1 and 4 are not recovered. Instead negative bidirectional contemporaneous relations between person 1 and 4 appear in the model fitted to the pooled data. This clearly shows the dangers of pooling across data, even when these data are almost homogeneous.

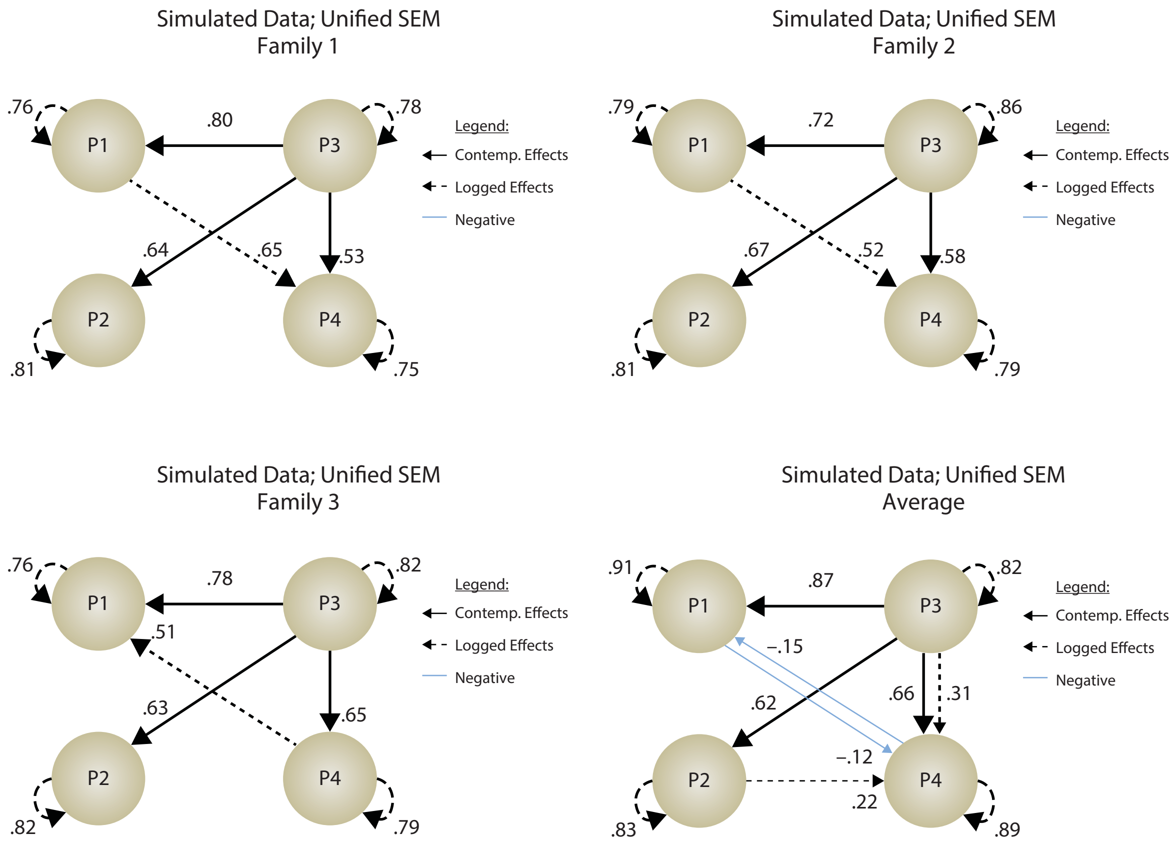

Figure 17.7 Fit of unified SEM to simulated four-variate time series for three families, each consisting of four persons. The upper row and the left panel of the lower row are model fits to individual families. The right panel of the lower row is the model fit to the average sequential covariance structure. See text for further explanation.

AN ALTERNATIVE TO DEAL WITH HETEROGENEITY: IF AND IFACE

A different approach to accommodate a particular form of heterogeneity is the *Idiographic Filter* (IF) proposed by Nesselroade, Gerstorf, Hardy, and Ram (2007). The IF is based on the recognition that the way in which a given factor manifests itself in observed variables can be subject-specific. For instance, stress can manifest itself mainly by gastrointestinal problems in one child and by tremor and perspiration in another child. Or learning potential is optimally manifested in verbal tasks for one child and in arithmetic tasks for another child. The IF therefore allows for subject-specific factor loadings whereas the latent factors are homogeneous. This latter condition allows for the existence of lawful relations among latent variables, the identification of which is not diluted or disguised by idiosyncrasy that can intrude on the measurement of manifest variables and jeopardize their usefulness as indicators of the latent variables. Contrary to proposals to modify the concept of factorial invariance (e.g., configural invariance, partial invariance) or treating factor loadings as random variables, the IF emphasizes measurement properties of the manifest variables (indicators), suggesting that they may not provide a consistent framework across individuals for structuring observations. When manifest variables are not the same variable from one individual to another, it essentially "deconstructs" the data box and naturally leads to an alternative data scheme–replicated time series (multiple P-technique data sets) (Nesselroade, 2010, 2012), which are the linchpin of our proposals in this chapter.

"Deconstructing" the data box provides a useful lead-in to a discussion of the IF. The rationale for the deconstruction begins with the data box portrayed in Panel d of Figure 17.1. The variables axis of the data box is defined over the observable or manifest variables that are measured in order to collect data. The tacit assumption that is seldom if ever questioned is that any such observable variable has the same meaning from one individual to another.

Individuals may differ in the amount of the variable that characterizes them but their scores are commensurate in what those amounts represent. But, we know that many observable variables cannot be relied on to maintain that kind of continuity across individuals. Performance on a paired-associates learning task might reflect sheer memorization ability in one person and reasoning ability (forming strategies) in another person. Answers to questions on a work-values scale might reflect career interests in one person and boredom in another. Once this door is opened, if only a crack, it raises doubts about the integrity of the data box as the cube it is portrayed to be in Figure 17.1.

Doubts about the integrity of the data box created by uncertainty regarding continuity of variables across persons can be eased by decoupling the slices along the persons axis as portrayed in Figure 17.8. However, the decoupling leads to a very different, but not unfamiliar, kind of research design as Figure 17.8 shows. Instead of the familiar data box, we have a collection of variables by occasions data matrices—one matrix for each person. In other words, the data box has been transformed into a collection of P-technique data sets. This is the very research design promoted by Nesselroade and Ford (1985) for the study of behavior emphasizing the individual as the primary unit of analysis (see also Molenaar, 2004, and Nesselroade & Molenaar, 2010). Even more to the point, this is the research design used by Nesselroade et al. (2007) to introduce the IF and illustrate its implementation with empirical data.

The results of fitting an IF model to multiple sets of P-technique data, assuming the fit is acceptable, is a factor loading pattern for each individual and one factor intercorrelation matrix that is the same for all individuals. The implications of this outcome are several. First, person-specific relations between the manifest and the latent variables—the factors—are recognized. These may be marginally different or quite different from one individual to another. In a special case, the loading patterns might not differ at all across individuals resulting in a traditional factorial invariance situation. If the loading patterns do differ substantially across persons, it suggests that the manifest/latent variable relations are quite idiosyncratic and the IF has been usefully employed. Another important implication of a good IF fit is that second-order factors are invariant in the traditional sense across individuals because the primary factor correlations on which they are based are the same from individual to individual. If these second-order factors are obtained and meaningful, it is a simple task to calculate the loadings of the second-order factors directly on the original manifest variables by means of the Cattell-White or Schmid-Leiman transformations (Loehlin, 1987).

An appropriate way to specify the IF is in terms of the following set of linear state space models of the form equation (17.1c) for N different subjects (replications):

$$\mathbf{y}^k(t) = \boldsymbol{\Lambda}^k \eta^k(t) + \epsilon^k(t); \eta^k(t+1) = \mathbf{B}\eta^k(t) + \zeta^k(t+1); k = 1, 2, \ldots, N \qquad (17.4)$$

It is apparent from equation (17.4) that the factor loadings $\boldsymbol{\Lambda}^k$ are person-specific whereas the dynamic model for the latent state process $\eta^k(t)$, in particular the matrix of auto- and cross-regression coefficients $\mathbf{B}$, is invariant across persons. Hence the IF locates homogeneity not at the level of observed variables, but at the level of latent variables. It is shown in Molenaar and Nesselroade (2012)

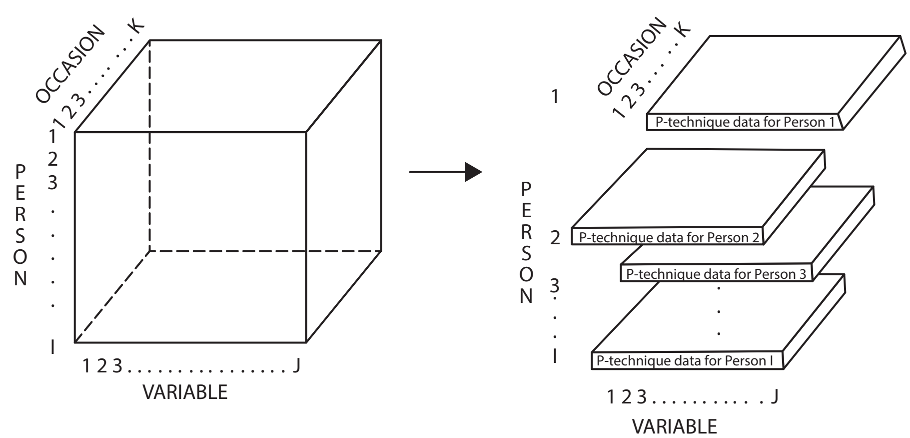

Figure 17.8 Deconstruction of the data box into a set of P-technique data sets for I individuals.

that the IF as represented in equation (17.4) is always testable and constitutes a viable approach to accommodate subject-specific relations between latent and observed developmental processes.

The IF has been generalized to the analysis of multivariate time series obtained with a pair of genetically related subjects. This so-called iFACE (Molenaar, Smit, Boomsma, & Nesselroade, 2012) allows for subject-specific heritabilities and environmental effects. Moreover it estimates the actual additive genetic correlation among the genetically related pair of subjects. This is an important feature because there exists abundant information based on epigenetic and developmental biological studies indicating that the additive genetic correlation among monozygotic twins is not 1.0, but smaller. How much smaller may be subject-specific because of probabilistic epigenetic effects (see Charney, 2012, for an extensive overview)—a first application of the iFACE to multilead EEG obtained with a single DZ twin pair shows clear evidence for considerable subject-specificity of heritable and environmental effects.

ANOTHER ALTERNATIVE TO DEAL WITH HETEROGENEITY: GIMME

Although the IF can accommodate heterogeneity due to person-specific factor loadings, the alternative approach described in this section can accommodate person-specificity of both factor loadings and any other parameters in state space models. It is called *Group Iterative Multiple Model Estimation* (GIMME; Gates & Molenaar, 2012) and is based on the following rationale. Suppose one has p-variate time series obtained with N possibly heterogeneous replications (persons) and, to ease the presentation, it can be assumed that each person obeys a model given by equation (17.3), namely a unified structural equation model. Then GIMME first determines an instance of equation (17.3), which has a common group structure across all N persons. That is, the common instance of equation (17.3) has exactly the same *pattern* of free parameters in $\mathbf{A}$ and Φ across all N replications, although the actual *values* of these parameters are allowed to differ arbitrarily between subjects. In Figure 17.7 these free parameters have been depicted by a network in which the vertices are linked by directed arrows. Hence in the first phase GIMME determines a common network structure for the complete group of N replications, while allowing that the weights associated with each link are person-specific.

GIMME determines the common group model in an automatic data-driven way in which new parameters (directed links) in $\mathbf{A}$ and Φ are freed up sequentially, one by one, starting from a model that in default mode contains no free parameters. It is an option to start the sequential search with a model containing already free parameters in $\mathbf{A}$ and/or Φ, where these parameters have been selected based

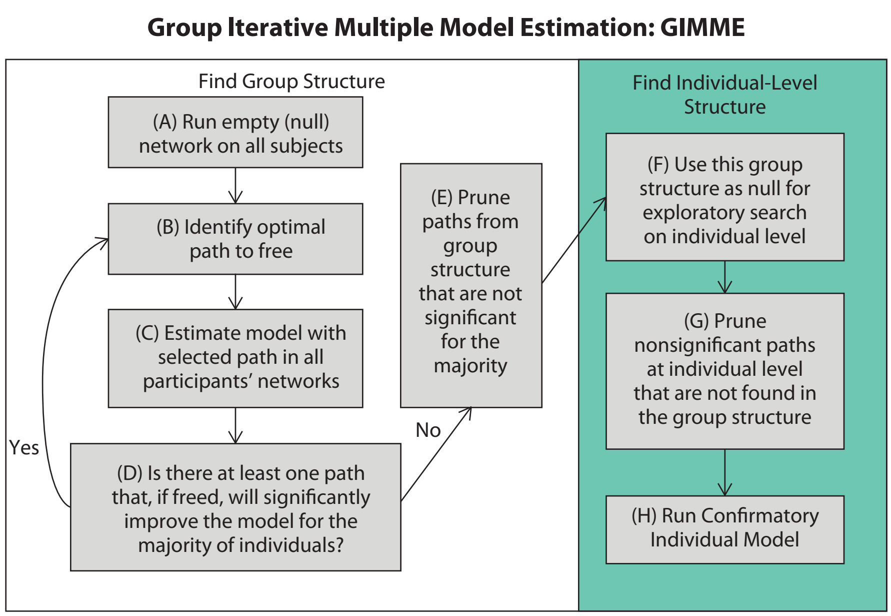

Figure 17.9 Flow diagram of GIMME.

Source: Redrawn from "Group Search Algorithm Recovers Effective Connectivity Maps for Individuals in Homogeneous and Heterogeneous Samples," by K. M. Gates and P. C. M. Molenaar, 2004, *NeuroImage*, *63*, p. 313.

on (theoretical) a priori knowledge. It also is an option to forbid that a subset of selected parameters in $\mathbf{A}$ and/or Φ are freed up during the sequential search, where this subset again is determined based on a priori knowledge. At each step in the sequential model search it is determined which one of the subset of eligible parameters which have not yet been freed up will maximally improve the likelihood across the N subjects. If this improvement of the likelihood is significant for at least a fixed proportion P of the N persons, then this parameter (directed link) is added to the common network structure, the person-specific values of the parameter are estimated and the sequential search moves to the next step. If not, the next phase of GIMME, to be described shortly, starts. Based on extensive simulation studies the proportion P of the N persons for which the increase in the likelihood ratio should be significant has been fixed at 75%.

In the second phase of GIMME the common group network structure determined in the first phase constitutes the starting model in a sequential model search for each individual person separately. In this search, for each person $k \in \{1, 2, \ldots, N\}$ person-specific directed links are added one by one until no additional person-specific directed links can be found that significantly improve the likelihood ratio for this subject. A flow diagram of GIMME is given in Figure 17.9.

GIMME has been validated in extensive simulation studies using data created by S. M. Smith et al. (2011), showing superb performance (Gates & Molenaar, 2012). An application to play behavior in children is presented in Beltz et al. (2013). GIMME is freely accessible at http://www.nitrc.org/projects/gimme/

NONLINEAR DYNAMIC SYSTEMS MODELING OF DEVELOPMENTAL STAGE TRANSITIONS

The previous discussion focused on linear dynamic systems modeling. As explained at the beginning of this chapter, in linear dynamic systems change is a linear function of the component processes, whereas in nonlinear dynamic systems this change is a nonlinear function of the component processes.

Linear dynamic systems models are important for a number of reasons. They constitute strong approximations to complex nonlinear systems operating under local equilibrium conditions. Such local equilibrium conditions imply that the nonlinear systems are in balance, reverting to stable equilibria after perturbation. Moreover, linear dynamic systems models with time-varying parameters can faithfully track the behavior of complex nonlinear developmental processes under a wide range of changing conditions, even far from equilibrium or during bifurcations when the equilibra undergo qualitative changes. But the most important reason is that there is available a mature and powerful statistical theory for stochastic linear dynamic systems (e.g., Brillinger, 1975; Durbin & Koopman, 2012; Ozaki, 2012; Shumway & Stoffer, 2013). This firm statistical basis allows for the direct fit of linear dynamic systems models to observed time series in the same way in which standard parametric statistical models such as structural equation models are commonly used in psychometrics.

In the history of dynamic systems approaches to developmental science the main focus has been on nonlinear dynamic systems, however. One of the earliest applications of nonlinear dynamic systems theory in developmental psychology occurred in Molenaar (1986a, 1986b), in which the then innovative abstract nonlinear dynamic systems theory called *catastrophe theory* (described later) is applied in a criticism of Brainerd's latent Markov model of stage transitions (Molenaar, 1986a) and a criticism of functionalism underlying much of contemporaneous cognitive science (Molenaar, 1986b). Other important early references to nonlinear dynamic systems approaches in developmental science include Thelen and Smith (1994) and van Geert (1993).

Since this early work, nonlinear dynamic systems approaches to developmental science have evolved in various ways. Important contributions have been made using *artificial neural network* (ANN) models (e.g., Hassoun, 1995). In its most basic form, an ANN consists of a hierarchy of several layers of nodes, where each node is a simplified model of a neuron. Usually there are at least three such layers: an input layer, a hidden layer, and an output layer. The configuration of connections within and between layers is called the network architecture. A wide variety of such architectures is possible, including excitatory, inhibitory, and feedback connections. See Figure 17.10 for an example of the so-called exact Adaptive Resonance Theory (ART) network architecture considered in Raijmakers & Molenaar (2004).

The general purpose of an ANN is to learn appropriate representations of the stimuli projected on the input layer. Learning is accomplished by modifying the strengths of connections among nodes (model neurons) as function of the input. The learning rules according to which the connections are modified consist of difference or differential

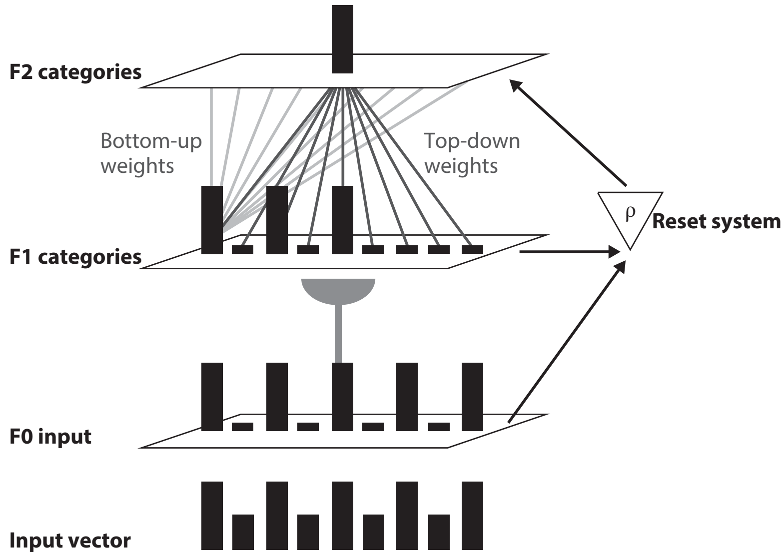

Figure 17.10 Schematic layout of the Exact ART network architecture. Black bars depict activities at the different layers (input, features, categories). Gray lines depict connections between levels. Between F0 and F1 only bottom-up, nonadaptable connections exist. F1 and F2 are mutually, fully connected by bottom-up connections (dark gray) and top-down connections (light gray). Only outgoing connections of one F1 node and one F2 node are shown.

Source: Redrawn from Figure 4 in "Modeling Developmental Transitions in Adaptive Resonance Theory," by M. E. J. Raijmakers and P. C. M. Molenaar, 2004, *Developmental Science*, *7*(2), p. 152.

equations involving the activity of each node as function of its own activity and the activities of other nodes at the same and different layers. The learning rules have to be nonlinear in order to guarantee optimal performance and avoid pathological behavior such as saturation (see Grossberg, 1982). Consequently, the set of learning rules acting on the network architecture comprise a nonlinear dynamic system. Although this perspective, according to which ANNs are conceived of as biologically inspired nonlinear dynamic systems, is not the most prevalent one, it is the theme of an important recent theoretical contribution to developmental science (Spencer, Thomas, & McClelland, 2009).

Typical applications of ANNs in cognitive science, including developmental science, can be summarized as follows: A network architecture and associated set of learning rules are chosen and the connections are randomly assigned initial weights with small absolute amplitude. Next the ANN, almost always implemented on a digital computer, is provided with a (usually very long) sequence of stimuli projected on the input layer, allowing the learning of rules to adaptively update the connection weights. During and after this training the behavior of the ANN (i.e., the activation patterns on the output layer) is recorded and compared with actual human performance in analogous learning tasks. This empirical validation of ANNs is *indirect*, differing from the *direct* fit of parametric dynamic systems models to data, which is the main focus of this chapter.

Due to the complexity of ANNs, often comprising a multitude of free parameters (the connection weights), they cannot be directly fitted to empirical data. The indirect empirical validation of ANNs requires the use of judicious methodological principles such as aptly presented in Shallice and Cooper (2011, especially Chapters 3 and 4). Valuable references addressing the use of ANNs in developmental science include Elman et al. (1997) and Quinlan (2003). A related but distinct important approach is *dynamic field theory* (e.g., Schöner, 2013; Spencer & Schöner, 2003). In contrast to the focus on learning in typical ANN research, in dynamic field theory the notion of stability and the sensorimotor origins of cognition are central to how representational states are conceptualized. Again, empirical validation of dynamic field theory is indirect.

In the remainder of this section we turn to a topic that has been important in developmental scientific applications of nonlinear dynamic system theory, namely the modeling of stage transitions. The focus is on catastrophe modeling of stage transitions in Piaget's theory of cognitive development (Piaget, Brown, & Thampy 1985), but the theoretical considerations to be presented are relevant to a much more general domain.

CATASTROPHE THEORETICAL MODELING OF COGNITIVE DEVELOPMENTAL STAGE TRANSITIONS

During the early history of mathematical nonlinear dynamical systems theory three major approaches arose: *nonequilibrium thermodynamics* (Nicolis & Prigogine, 1977), *synergism* (Haken, 1978) and *catastrophe theory* (Thom, 1975). The common denominator of these approaches is their emphasis on sudden transitions in the behavior of nonlinear dynamic systems (called *phase transitions, bifurcations, singularities*, or *catastrophes*; see Witherington, Chapter 3, this *Handbook*, this volume, for explanation of these concepts) as the hallmark of self-organization. Whereas nonequilibrium thermodynamics and synergism have their origins in physics, the origin of catastrophe theory is in pure mathematics. Here the focus is on catastrophe theory because of its generality and its success in explaining stage-wise development. First a concise characterization of catastrophe theory is given as this is a very abstract mathematical theory that may be unfamiliar to many developmental scientists. Then we summarize the impressive empirical results obtained with applications of catastrophe theory to understand stage transitions in cognitive development.

Catastrophe theory starts with the definition of a nonlinear dynamic system, the behavior of which is described by the p-variate vector $\mathbf{y}(t)$. The first derivative $d\mathbf{y}(t)/dt$ of $\mathbf{y}(t)$ with respect to time is represented as a function of the gradient (partial derivative) $\partial\mathbf{\Phi}[\mathrm{y};\boldsymbol{\theta}]/\partial\mathbf{y}$ of a nonlinear *potential* $\mathbf{\Phi}[\mathbf{y};\boldsymbol{\theta}]$ depending on a q-variate parameter vector $\boldsymbol{\theta}$ that in catastrophe theoretical jargon is called the *control* variable. The potential $\mathbf{\Phi}$ can be best conceived of as a convenient mathematical construct, although in physics it is related to energy. The ensuing nonlinear dynamic system underlying catastrophe theory is schematically expressed as:

$$d\mathbf{y}(t)/dt = \partial\mathbf{\Phi}[\mathbf{y};\boldsymbol{\theta}]/\partial\mathbf{y} \tag{17.5}$$

The dimensions p and q of the behavioral and control variables can be arbitrary large. The mathematical details about the potential $\mathbf{\Phi}$ are not important, only the fact that it is nonlinear is relevant. Equation (17.5) describes a wide range of nonlinear dynamic systems in physics and beyond (the van der Waals theory in thermodynamics which explains phase transitions, such as the sudden change of water into ice if the temperature [an element of the control variable $\boldsymbol{\theta}$] is slowly decreased, is a special instance of equation [17.5]). Gilmore (1981) presents many more examples. When presented with a particular instance of equation (17.5), the most important questions to be answered are: what its equilibria (also called *attractors*; see Witherington, Chapter 3, this *Handbook*, this volume) are and which equilibria are regular (nonsingular) and which are not (singular). For nonsingular equilibria a small change in the control variable $\boldsymbol{\theta}$ induces a small change in the equiibria. In contrast, for singular equilibra, a small change in $\boldsymbol{\theta}$ induces a sudden qualitative change in the types and often also the number of equilibria. These questions are answered by fixing the left-hand side of equation (17.5) at zero and solve for $\boldsymbol{y}$ as function of $\boldsymbol{\theta}$. Let $\{\mathbf{y^k}(\boldsymbol{\theta}),\ k = 1,\ 2,\ \ldots,\ K\}$ denote the set of equilibria for a given value of $\boldsymbol{\theta} = \underline{\boldsymbol{\theta}}$. Then for each of the K equilibrium states $\mathbf{y^k}(\underline{\boldsymbol{\theta}})$ it has to be determined whether it is singular or nonsingular; this is accomplished by determining the condition of the associated matrix of second-order derivatives (called the *stability matrix*). The results thus obtained pertain to the particular instance of equation (17.5) under investigation and have to be computed again for each new instance.

In contrast, catastrophe theory provides answers about the possible equilibria of equation (17.5) in general, that is, irrespective of the mathematical details of the potential $\mathbf{\Phi}$. This is accomplished by transforming the set of all possible potentials to a minimum number of canonical forms. The transformations are diffeomorphisms (i.e., invertible smooth nonlinear mappings, which are extremely powerful, depending on infinitely many degrees of freedom; see Gilmore, 1981, for an in-depth explanation). Toga (1999) presents illustrations of the power of diffeomorphisms, transforming different human faces to the same invariant form or transforming a dot into arbitrary numbers or letters. The unique canonical form of equation (17.5) at, or in the neighborhood of, nonsingular equilibria is a quadratic function, as specified by the Morse lemma (see Gilmore, 1981). But until the work of Thom (1975) it was unknown what the canonical forms of equation (17.5) are if the equilibria are singular.

Thom's classification theorem (see Gilmore, 1981) proves that the canonical forms of equation (17.5) at, or in the neighborhood of, singular equilibria only depend on two numbers after diffeomorphic transformation: the dimension of the system behavior as well as the dimension of the control variable that turn out to be critical for the singularity. Notice that these dimensions of what are called the *critical behavioral and control* subspaces are much smaller than the dimension p of the original behavioral variable $y(t)$ and the dimension q of the control variable $\boldsymbol{\theta}$. This is an extremely powerful result, because it allows for application of catastrophe theory in situations where the mathematical form of the potential function $\boldsymbol{\Phi}$ is unknown. For instance, the dynamic system governing cognitive development is highly complex and nonlinear, in part because the neural network system underlying cognitive information processing is nonlinear (see earlier), which is why its precise mathematical form is entirely unknown. However, to apply catastrophe theory to cognitive development one only needs to know the dimensions of the two critical subspaces along which the developing system is singular. In many applications, in particular in the applications to stage-wise cognitive development described below, these two dimensions turn out to be 1 for the critical behavioral subspace and 2 for the critical control subspace, yielding the canonical form known as the cusp catastrophe (see Figure 17.11).

Figure 17.11 depicts the canonical form of the *equilibrium surface* of the univariate critical dependent behavioral variable as function of the two critical control variables (asymmetry variable A and bifurcation variable B) making up the bottom plane. If the control variables smoothly change from left to right in the bottom control plane then the equilibrium of the system changes, following Path 1 along the broken line in the equilibrium surface, suddenly jumping from the lower sheet to the higher sheet as soon as the control variables leave the cusp region. Before the control variables enter the cusp region in the control plane, there exists a single equilibrium, but as soon as the cusp region is entered there are three equilibria, one of which is unstable. The unstable equilibrium defines the region of inaccessibility for the behavioral variable and will not be observed in real data.

To apply the cusp model to stage transitions in cognitive development, interpretations have to be given to the critical dependent behavioral variable and the critical control variables (the A- and B-axes in Figure 17.11). Based on the above heuristic description of catastrophe theory, these critical variables are in general nonlinear diffeomorphic

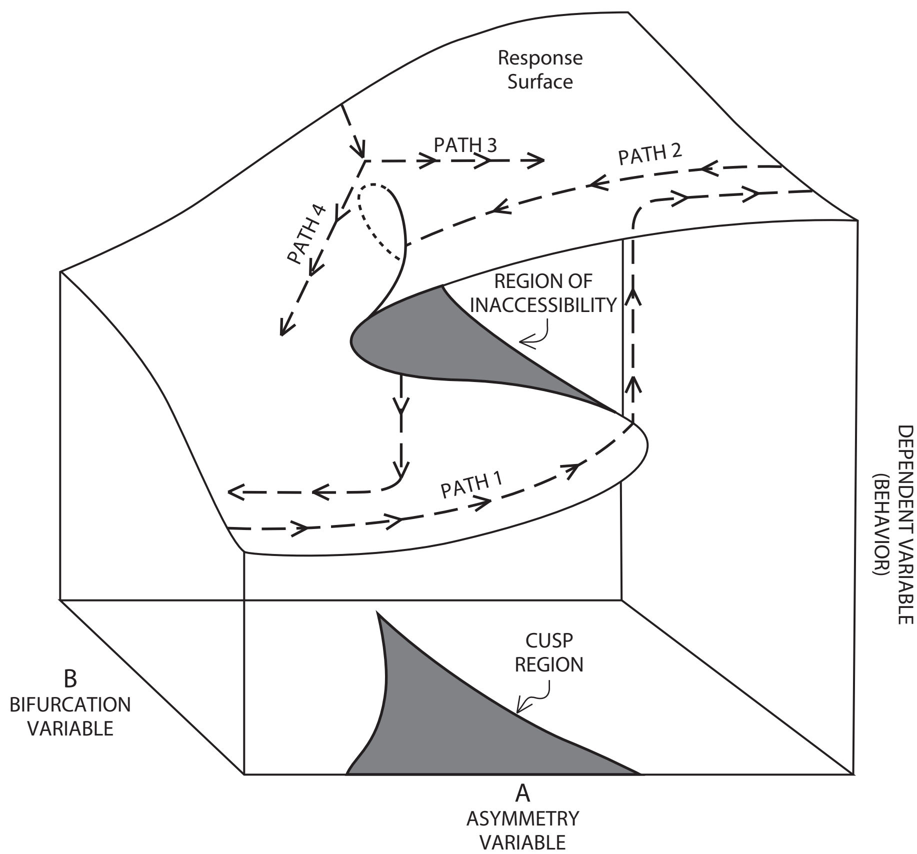

Figure 17.11 The cusp catastrophe. Following first Path 1 and next Path 2 yields a so-called hysteresis loop. In the hysteresis loop the transition from the lower sheet to the higher sheet of the equilibrium response surface of the behavioral variable along Path 1 occurs at a different point than the transition from the higher sheet to the lower sheet along Path 2.

transformations of the original $\boldsymbol{y}$ and $\boldsymbol{\theta}$ variables in equation (17.5) and, therefore, are usually unknown. In applications of the cusp model this complication almost always is overlooked and heuristic interpretations of the critical variables are given. As far as applications in developmental science are concerned, in Saari's (1977) double-cusp model of stage-wise cognitive development the critical dependent behavioral variable is interpreted as cognitive level, while the critical control variables are interpreted as assimilation and accommodation. In van der Maas and Molenaar's (1992) cusp model of the stage transition from the preoperational stage to the concrete operational stage in Piaget's cognitive developmental model, the critical dependent behavioral variable is the probability of giving a correct response to conservation tests, whereas the critical control variables are the availability of nonconserving and conserving rules. In part because of this uncertainty about the identity of the critical variables in catastrophe theory applications in developmental science, researchers often settle for a somewhat less demanding approach involving detection of (cognitive) stage transitions (see later).

The cusp model in Figure 17.11 can be fitted directly to empirical data by means of a stochastic generalization initially developed by Cobb (e.g., Cobb & Zacks, 1985). An improved computer program is freely accessible in R (Grasman, van der Maas, & Wagenmakers, 2009).

CATASTROPHE THEORETICAL DETECTION OF COGNITIVE STAGE TRANSITIONS

To alleviate somewhat the uncertainty about the identities of the critical variables in catastrophe models an indirect approach called catastrophe detection can be used. Catastrophe detection is based on the work of Gilmore (1981), who derives eight catastrophe flags, which typically occur when a catastrophe is present. One of these flags is the occurrence of sudden jumps, whereas others include the presence of anomalous variance and hysteresis (see below). Van der Maas & Molenaar (1992) give a list of all catastrophe flags and relate these to published research on cognitive development. For instance, anomalous variance is associated with oscillations in the responses of transitional subjects as reported in Flavell and Wohlwill (1969) and McCall (1983).

To understand *hysteresis* consider again Figure 17.11, supposing that the critical control variables first proceed from left to right in the control plane so that the equilibrium of the critical dependent behavioral variable follows Path 1. It then is seen that the jump to the upper sheet of the equilibrium surface occurs as soon as the critical control variables cross the right-hand border of the cusp region. If next the control variables return along Path 2 from right to left, the sudden jump to the lower sheet of the equilibrium surface occurs at another point in the control plane, namely as soon as the critical control variables cross the left-hand border of the cusp region. This difference in the location where the sudden jump of the equilibrium of the critical dependent behavioral variable occurs, depending on the direction of the path of the critical control variables in the control plane, is called *hysteresis*. Because the detection of hysteresis requires that the critical control variables follow a path with reverse directions, special experimental techniques are required to observe hysteresis in cognitive development.

The detection of a *catastrophe*, that is, a qualitative change in the behavior of a nonlinear dynamic system signaling self-organization, in principle requires the establishment that all catastrophe flags occur. The hysteresis catastrophe flag is special in that its presence constitutes the strongest evidence for the existence of a catastrophe. The requirement that in principle all eight catastrophe flags should occur implies that the occurrence of only a sudden jump is insufficient to establish the presence of a catastrophe or stage transition. A sudden jump also may be caused by a simple acceleration of a qualitatively invariant developmental process. Van der Maas and his group have carried out a long-standing research program based on the detection of catastrophe flags in cognitive development, especially focusing on the transition between rules that children apply in the balance scale task (see van der Maas & Raijmakers, 2009, for an overview). According to Siegler (1976) the acquisition of an understanding of the principle of torque, as assessed by means of the balance scale task, proceeds in an sequence of transitions between stages that are characterized by the emergence of qualitatively different rules of increasing validity. Van der Maas and his group established the presence of several catastrophe flags in this task, in particular hysteresis. For instance, in two replicated experiments using large samples of children (*N*s of about 300; average age about 8 years), Jansen and van der Maas (2001) systematically varied the distance between weights places on both sides of fulcrum of the balance scale. Starting from an initial configuration of weights placed symmetrically about, and close to the fulcrum, the distance between the weights was systematically increased by placing the weights at the right hand side of the scale at more and more extreme positions. This was an attempt to induce a transition in the use of rules to solve the balance scale task according to Path 1 in Figure 17.11. Consecutively the distance between weights was systematically decreased until the starting configuration was reached again, attempting to induce Path 2 in Figure 17.11 involving the inverse transition in the use of rules. Together these two paths constitute a hysteresis loop. Using a sequence of confirmatory latent class analyses, subgroups of children were identified who indeed displayed a hysteresis loop (see Jansen & van der Maas, 2001, for complete details).

The detection of hysteresis in cognitive development is a unique and powerful result, showing (together with the detection of other flags) that cognitive development in understanding torque as assessed by the balance scale task follows a discontinuous path involving genuine stage transitions.

Additional Comments on Catastrophe Theoretical Modeling of Stage Transitions

Catastrophe detection based on identifying the presence of catastrophe flags also has been instrumental in a broader context. An important application is reported in Raijmakers, van Kooten and Molenaar (1996), who show that artificial neural network models of stage transitions (McClelland and Jenkins, 1991; McClelland, 1995; Shultz, Mareschal, & Schmidt, 1994) do not show any of the catastrophe flags apart from sudden jumps, whereas empirical data do show such additional flags. This result turned out to be a game-changer in ANN-based modeling of stage transitions, showing that contemporary approaches were not valid. Subsequently, Raijmakers and her group presented alternative ANN models of cognitive information processing that do undergo genuine stage transitions, as shown by means of analytical proof (Raijmakers, van der Maas, & Molenaar, 1996; Raijmakers & Molenaar, 2004). Also important in this context is the critical evaluation of connectionistic ANN models of stage-wise cognitive development presented in Quinlan, van der Maas, Jansen, Booij, and Rendell (2007). They consider one of the most promising and powerful types of ANNs that have been proposed for the explanation of stage-wise cognitive development, namely cascade-correlation (CC) networks (Fahlman & Lebiere, 1991). CC networks allow for data-driven increases in the complexity of the network architecture, in particular by adding nodes to hidden levels. These CC networks are used by Quinlan et al. (2007) in a large-scale simulation experiment of the stage-wise development of understanding torque as assessed by the balance scale task. The performance of the networks then is compared with relevant empirical data. The conclusions of Quinlan et al. (2007) are: (a) the CC networks frequently recover rules never previously seen in children; (b) the networks fail to recover some of the rules that have been established with children; and (c) there is no evidence that any of the networks acquires the principle of torque, while normal children do so.

Notwithstanding the considerable success of catastrophe theoretical modeling of stage transitions in developmental science, there is a fundamental shortcoming in its foundations as far as applications in the behavioral and social sciences are concerned. Empirical processes in the latter sciences almost always are intrinsically stochastic, whereas equation (17.5) is deterministic. This could be accommodated by supposing that observed developmental processes are corrupted by additive measurement error, but that would imply the implausible assumption that the true underlying developmental processes still are deterministic. A rigorous foundation adequate for the intrinsically stochastic processes observed in developmental science is to extend equation (17.5) with a random term, transforming it into a system of nonlinear stochastic differential equations. It then turns out, however, that carrying out the diffeomorphic transformations underlying standard catastrophe (see earlier) cause a collapse of Thom's (1975) classification program because the transformation rules for stochastic differential equations differ substantially from those for deterministic differential equations. To restore the classification theorem for stochastic differential equations it is necessary to construct an alternative approach. This has been accomplished in a long-standing research project at the University of Amsterdam, involving the research groups of Molenaar and van der Maas (Wagenmakers, Molenaar, Grasman, Hartelman, & van der Maas, 2005). Important preliminary solutions were developed by Hartelman (1997). Hartelman, van der Maas, and Molenaar (1998) showed how the diffeomorphic transformation rules for stochastic differential equations always enable transformation of the bimodal probability distribution associated with the stochastic cusp catastrophe into an equivalent unimodal probability distribution. This transformation from bimodal to unimodal probability distribution implies the disappearance of the stochastic cusp catastrophe. Hartelman (1997) proved how this collapse of the stochastic cusp catastrophe can be circumvented by considering a different bimodal function of the stochastic cusp catastrophe that stays invariant under diffeomorphic transformations for stochastic differential equations.

The complete mathematical derivation of this alternative bimodal function is presented in Wagenmakers et al. (2005).

In closing this section, we want to concisely address the controversies that have surrounded the initial phase of catastrophe theory. Partly these controversies were due to the personality of Thom, who aroused discontent of such mathematical luminaries as Smale in the United States and Arnold in the USSR. But perhaps the main source of discontent was Thom's main treatise (Thom, 1975). Gilmore (2004) comments:

> This book was an enigma in both form and substance. It was largely inaccessible to the mathematics community because it was written in the language of biologists, and inaccessible to the biological community due to its presentation of mathematical concepts which seemed to be deep and mysterious. (p. 116)

Some applications of catastrophe theory in the social and behavioral sciences also had their own controversies. This concerned in particular the work of Guastello (e.g., 1988), who fitted catastrophe models to data by means of nonlinear regression analysis. Not only is this regression approach invalid because it neglects the existence of inaccessible regions (see Figure 17.11), but it also has been severely criticized because of other statistical flaws in a paper by Alexander, Herbert, DeShon, and Hanges (1992). The reply of Guastello to this devastating critique (Guastello, 1992) provides for interesting reading in the sociology of science, as it boils down to word salad without real content.

Another controversial issue in the application of catastrophe theory in developmental science concerns Kelso's (1995) critique of van der Maas & Molenaar (1992). Kelso takes issue with the potential in equation (17.5), stating: "Given this totally unrealistic constraint, one wonders what gave the authors (never mind their reviewers) pause" (Kelso, 1995, p. 181). Again, this is an instructive example in the sociology of science. It so happens that Kelso's own published work at the time in which he wrote this verdict on the use of potentials in nonlinear dynamic systems modeling is itself replete with the use of the very same potentials (see, e.g., the many figures of potentials in Haken, Kelso, & Bunz, 1985, and Jirsa, Friedrich, Haken, & Kelso, 1994). Apart from this, it should be recognized that catastrophe theory is a local theory of stage transitions, that is, it applies in the neighborhood of a single transition and has to be reapplied in the neighborhood of a different transition. In this sense it substantially transcends the constraint to which Kelso refers and provides a powerful local approximation to a wide range of singularities in nonlinear dynamic systems that globally may not obey a potential (see Huseyin, 1986).

It is pertinent to close this discussion on these initial controversies about catastrophe theory with the wise words of Gilmore (2004):

> The result was a multiyear public dialogue on the merits of this subject of discontinuities using arguments now long forgotten and best left unearthed, a dialogue of which the public eventually tired. The appearance of the monographs of Poston and Steward (1978) and Gilmore (1981) made it clear that this was a subject of substance, which had to be taken seriously, one capable of providing a useful language for the description of discontinuities at both a qualitative and a quantitative level. (p. 117)

Optimal Guidance of Developmental Processes

When a parametric dynamic systems model has been successfully fitted to a developmental process, and the systems model includes the effects of measured external input, then this model can be employed to optimally guide the process to desired levels if the external input can be manipulated. This is an important extra payoff of analysis of intraindividual variation, which comes at no extra cost in experimental efforts but only requires dedicated computation. Such optimal guidance is related to the concepts of homeostasis, feedback, and control that have played a long-standing role in psychology (e.g., Carver, 2004). This role, however, has thus far been mainly confined to the theoretical level. If one of the dynamic systems models considered in this chapter has been fitted to a developmental process then one can use this model to actually optimally guide the process as it unfolds in real time by means of powerful mathematical techniques developed in optimal control theory. Here we present an elementary introduction to optimal control as a computational technique in order to guide developmental processes to desired levels. Our sole aim is to provide a first glimpse of the straightforward and appealing rationale underlying optimal control theory. In doing so we hope that its powerful potential will be picked up in dynamic systems modeling approaches to developmental science.

Consider the following simple developmental process model in discrete time:

$$y(t+1) = \beta y(t) + \phi u(t) + \epsilon(t+1)$$

Here $y(t)$ denotes an observed univariate developmental process, $u(t)$ is a univariate external input, and $\epsilon(t)$ is process noise. It is assumed that $u(t)$ can be manipulated, that is, the value of $u(t)$ at each time t can be chosen at will (e.g., parental effort, medication, reinforcement, instruction). Also it is assumed that the desired level of the developmental process is a priori given by y^*.

Given this simple dynamic model and y^*, the computational feedback problem is defined by introducing a so-called cost function. For the present simple illustration the cost function is defined as follows. Let $E[y(t+1|t)]$ denote the expected value of $y(t+1)$ based on all information up to time t. A simple cost function $C(t)$ then is: $C(t) = E[y(t+1|t) - y^*]^2$. The external input $u(t)$ has to be chosen in such a way that $C(t)$ is minimized for all times t. Because $E[y(t+1|t)] = \beta y(t) + \phi u(t)$, substitution of this expectation in the cost function yields the optimal solution $u^*(t)$ given by:

$$u^*(t) = [-\beta y(t) + y^*]/\phi$$

This is a feedback function according to which the optimal $u^*(t)$, which is used to optimally guide the value $y(t+1)$, depends on $y(t)$.

Figure 17.12 depicts a simulated univariate developmental process $y(t)$, $t = 1, \ldots, 50$ (labeled Y), where $y(t)$ has been simulated according to the simple model with $\beta = 0.7$ and $\phi = 0.9$. If the desired level y^* is chosen to be zero, $y^* = 0$, application of the above feedback function yields $u^*(t) = [-0.7y(t) + 0]/0.9$, which yields the sequence of values labeled UO in Figure 17.12. Application of $u^*(t)$ in the original dynamic model yields the optimally guided developmental process which is labeled YO in Figure 17.12. It is evident from Figure 17.12 that the deviation of the optimally guided process YO from $y^* = 0$ is much smaller than the analogous deviation of the process without control Y.

This example of optimal feedback guidance is elementary in a number of respects. For instance, the developmental process to be guided is univariate, as is the external input. Often one or both are multivariate. Also, the dynamic systems model is a simple linear model, which is assumed to be known, whereas in general the model is one of the much more complex dynamic factor models considered in this chapter, the parameters of which are unknown and have to be estimated. In this example, the cost function is a quadratic function that does not penalize the costs of exercising control actions (i.e., the costs of manipulating $u(t)$), whereas in general both the deviations of the developmental process and the manipulation of the external input are penalized according to cost functions, which can have much more intricate forms. However, this example serves to illustrate that optimal guidance of development can be quantified and applied in real time, thus allowing for much more precise and efficient modification of ongoing developmental processes.

In general, well-developed mathematical theories exist for optimal feedback control in each of the types of dynamic factor models considered here. Kwon and Han (2005) present an in-depth description of optimal control

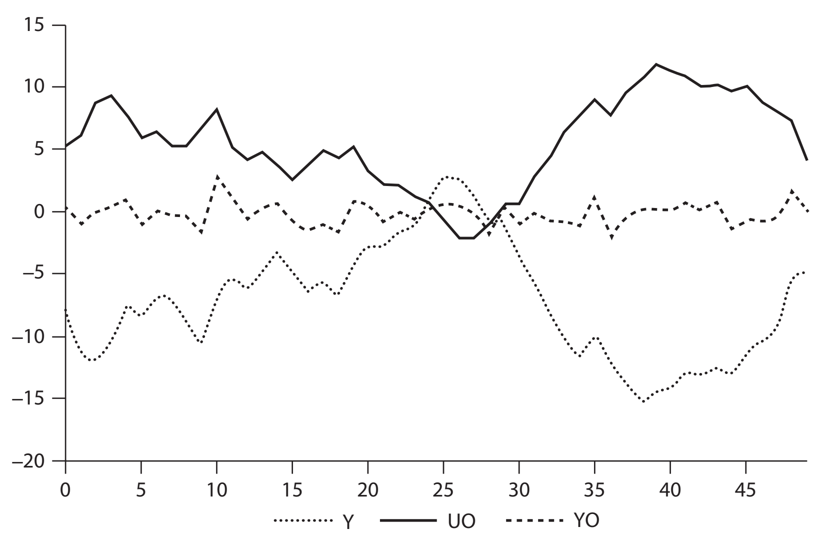

Figure 17.12 Simple optimal feedback control. Y: Developmental process without guidance. YO: Optimally guided developmental process. UO: Optimal external input.

in linear dynamic factor models (see also Molenaar, 2010). Elliott, Aggoun, and Moore (1995) is the classic source for optimal control in hidden Markov models (i.e., dynamic factor models for categorical processes; see later). Presently we are not aware of any applications of optimal control theory in developmental science, but we expect that this will change soon. An application to optimal treatment of diabetes Type 1 patients is reported in Zhou et al. (2010; see also Wang et al., 2014).

CONCLUSIONS

The future of the dynamic systems approaches discussed in this chapter is challenging because of the *necessity* to focus on the structure on intraindividual variation in the study of nonergodic developmental psychological processes. This necessity follows directly from the classical ergodic theorems. In case subjects are heterogeneous, that is, in case person-specific dynamics describe the intraindividual variation of particular developmental processes, one can only obtain valid information about such nonergodic processes by means of replicated time series analysis. In a similar vein, in case psychological processes are nonstationary, as are almost all developmental and learning processes, but also many clinical and biomedical processes, one also can only obtain valid information about such nonergodic processes by means of nonstationary time series analysis.

The future of dynamic systems approaches in developmental science also is exciting because a wealth of statistical dynamic modeling tools have become available, enabling the direct fit of parametric dynamic models inspired by relational developmental systems to appropriate empirical time series data. This opens up the possibility to focus investigation on themes that are especially emphasized by relational developmental systems, such as the context-dependent unfolding of multiple interacting influences on development as well as the self-organization driven by nonlinear epigenetic processes. As far as context-dependent unfolding of multiple interacting influences on development is concerned, these influences can be expected to occur at a hierarchy of time scales. Some will be fast-acting whereas others take much more time to materialize. The state space model with time-varying parameters given by equation (17.2) is well-equipped to accommodate different time scales and, as explained, can be extended with a hierarchy of system equations describing evolution at increasingly slow time scales. Empirical applications of such extensions of equation (17.2) will require the availability of high-dimensional developmental processes $y(t)$, which have been intensively measured at high sampling rates over long periods. But in principle it is possible by means of this approach to empirically investigate the ways in which microdevelopmental processes (Granott & Parziale, 2002) contribute to macrodevelopmental change.

It was shown how one can deal with violations of the two jointly necessary and sufficient criteria for Gaussian ergodicity, namely nonstationarity and person-specificity (heterogeneity). The general state space model with arbitrarily time-varying parameters given by equation (17.2) was proposed to accommodate violations of stationarity. Viable alternative ways exist to accommodate (local) nonstationarity, for instance regime-switching dynamic models (e.g., Hamaker & Grasman, 2012). Also the current implementation of GIMME can handle violations of stationarity as function of external input. That is, the GIMME model has been extended in ways that enable it to accommodate nonstationarity as a function of external input by adding bilinear components describing time-varying interactions between input and the strength of auto- and cross-lagged relationships.

Special emphasis has been given in this chapter to alternative ways to accommodate subject-specificity (heterogeneity). The success of GIMME to handle heterogeneous data, as determined in large-scale simulation experiments, appears to be impressive. GIMME can be extended in several ways in addition to the extensions mentioned earlier. In its present form GIMME identifies a single common group model in the first phase of the data-driven model search. We are currently developing an extension of GIMME in which during the first phase a finite set of common group models is identified, similar to mixture modeling.

The IF not only constitutes a viable approach to accommodate subject-specificity of the way in which latent processes manifest themselves in observed time series, but it also involves an alternative definition of measurement equivalence. It is the conviction of the authors of this chapter that developmental science requires such alternative definitions of measurement equivalence because the currently standard operationalization in terms of invariant factor loadings is too static and based on a conception of psychological constructs as trait-like. In addition to this standard definition developmental science needs alternative definitions aimed at dynamic measurement equivalence. Instead of addressing the question whether the same trait is measured across repeated measurement occasions, the alternative definitions should address the question whether it is the same dynamic process which is measured across different occasions. In the IF this dynamic measurement equivalence is operationalized in terms of the constraint that the latent state process has to be invariant across subjects (whereas the factor loadings are allowed to be person-specific). Reasoning further along these lines, it would seem feasible to consider definitions of dynamic measurement invariance in terms of sufficiently smooth time-dependent variations of the parameters in a state space model. Such definitions would certainly be of potential interest for developmental science.

An extended heuristic description was given of catastrophe theory as a powerful nonlinear dynamical systems approach to model stage transitions. A number of successful applications of catastrophe theory in stage-wise cognitive development as assessed by the balance scale task were described. It is expected that these applications will be generalized to other domains of developmental science, as appropriate tools to do so now are publicly available. This will enable direct applications of nonlinear dynamic systems models to developmental processes that complement the indirect and graphical methods that often have not been used.

Special emphasis also was given to not overlooking the importance of linear dynamic systems modeling, as so many powerful statistical approaches to apply these models now exist. Moreover, linear dynamic systems models can provide excellent local approximations to nonlinear dynamical systems. We concentrated on Gaussian linear dynamical systems, mainly to ease the presentation. But there exist several additional types of dynamical systems that are of importance for the same reasons. Take the linear Gaussian state space model given by equation (17.1c) as starting point. In this model the observed process $\mathbf{y}(t)$ and the latent state process $\boldsymbol{\eta}(t)$ are real-valued. Yet if both $\mathbf{y}(t)$ and $\boldsymbol{\eta}(t)$ are categorical then one obtains the hidden Markov model (e.g., Visser, Raijmakers, & Molenaar, 2002). Hidden Markov models have for instance successfully been applied to the analysis of mother-infant interaction sequences (Rovine, Sinclair, & Stifter, 2010). Another interesting type is the so-called hybrid state space model (e.g., Simon, 2006) in which the observed process $\boldsymbol{y}(t)$ occurs in discrete time, but the latent process $\boldsymbol{\eta}(t)$ evolves in continuous time. This hybrid state space model is important for the analysis of ecological momentary assessment (EMA) data, which often are obtained at irregular sampling intervals. A beta version of a computer program to fit hybrid state space models to empirical time series data can be obtained from the first author.

The future of dynamic systems approaches in developmental science is challenging and exciting for the reasons mentioned in this section. The integration of advanced theoretical models, new intensive measurement techniques and sophisticated statistical process modeling will further establish dynamic systems models inspired by Relational-Developmental-Systems as the dominant methodological paradigm in developmental science.

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CHAPTER 18

Neuroscientific Methods With Children

MICHELLE DE HAAN

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The human adult neocortex contains approximately 20 billion neurons, each connected to about 1,000 other neurons, resulting in networks involving trillions of connections. For the most part, these neurons have already been created and traveled to their correct positions by the time of full-term birth. They will, however, continue to differentiate and refine their patterns of connection over a prolonged period stretching into late adolescence. Neuroscientific methods can be used to capture the structural and functional changes happening in the human nervous system as it develops throughout infancy, childhood, adolescence, and across the life span. These methods allow researchers to investigate the normal development of brain ←→ behavior relationships, as well as how factors such as brain injury, neurodevelopmental disorder, or atypical environments affect these relationships. Contemporary relational developmental systems models of human development (see Lerner & Benson, 2013; Overton, 2013, Chapter 2, this *Handbook*, this volume) are very useful in framing the study of these relations, as the brain is one part of a whole coacting system, wherein brain ←→ behavior relations are reciprocally influential (e.g., see Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume; Marshall, Chapter 7, this *Handbook*, this volume) and development proceeds according to the principle of probabilistic epigenesis (Gottlieb, 2007). Numerous neuroscientific methods are now available to study brain structure and function, and doubtless many more will be developed by the inventive researchers in the field. This chapter provides an introductory overview of the noninvasive neuroscientific methods used in developmental research involving humans. It covers measurement of both the central and the autonomic nervous systems, considers the relative strengths and weaknesses of the methods, and provides examples illustrating their use. Although behavioral and molecular genetics are important methods within developmental neuroscience, they are not covered in this chapter. The chapter begins by describing general issues in measurement, then focuses on methods for measuring brain structure and function, followed by sections focused on methods for measuring the autonomic nervous system. It concludes with a discussion of challenges neuroscientific methods with children need to address and the role they will play in future research.

METHODS EMPLOYED IN THE STUDY OF BRAIN STRUCTURES AND FUNCTIONS

The brain, together with the spinal cord, makes up the central nervous system. A number of methods, including magnetic resonance imaging (MRI) and its variants, ultrasound, electroencephalography (EEG), magnetoencephalography (MEG), and near infrared spectroscopy (NIRS) can be used to measure the structure and function of the human brain. These methods differ from one another in fundamental ways, such as the actual signal they are detecting, but they also share some common factors influencing the quality of information they can provide. This section first discusses some of these general similarities and differences, before the specifics of each method are described in the sections that follow.

What Do Brain Imaging Methods Measure?

Neuroimaging methods measure the structure of the brain (details of its appearance that are relatively stable), and/or the function of the brain (task-related, transient spatial, and temporal changes in activation). Neuroscientific methods differ in the information they use to inform us about brain structure and function. EEG and MEG both measure currents produced by the electrical activity of brain neurons; in particular the postsynaptic potentials of parallel dendrites in cortical columns. However, they do so by capturing different aspects of the brain signal. EEG measures the electrical fields produced by the sum of many currents as they reach the scalp surface, whereas MEG measures the magnetic field produced by the primary currents at the scalp surface (see Figure 18.1). This difference affects the nature of brain signal each technique can detect: EEG reflects mainly activity produced by brain sources oriented radially (toward or away from the scalp, as in cortical gyri) and to some extent those oriented tangentially (parallel to the scalp, as in cortical sulci), whereas MEG reflects primarily activity produced by brain sources oriented tangentially and is relatively insensitive to radial sources (see Figure 18.1). In contrast to both these methods, functional magnetic resonance imaging (fMRI) and NIRS do not measure brain activity. They index brain activity indirectly, by measuring blood flow and blood oxygenation. This relies on the assumption that blood flow in a region increases when neurons become active (see Figure 18.2).

Understanding differences among methods has implications for developmental studies. The assumption that local increases in blood oxygenation reflect increases in neuronal activity has been investigated and supported mainly by studies in adult humans and nonhuman primates (e.g., Logothetis, Pauls, Augath, Trinath, & Oeltermann, 2001). Much less research has been carried out to confirm this assumption in the developing brain, even though developmental differences in neurovasculature and autoregulatory systems mean that the *blood oxygen level dependent* (BOLD) response measured in fMRI likely differs in the immature compared to the mature brain (Kozberg, Chen, DeLeo, Bouchard, & Hillman, 2013). This is important to understand because conclusions about differences in brain activity between groups (e.g., children and adults) based on the BOLD response could, in principle, be confounded by differences between groups in hemodynamic responsiveness (ability to deliver blood to the neural tissue).

Although EEG does provide a direct measure of brain activity, it does so via sensor electrodes placed on the scalp, distant from the physical surface of the brain. The path that electrical activity travels from its brain source to the recording electrodes is not straightforward, and can be influenced by a number of factors including the characteristics of the tissue (cerebral spinal fluid, skull, etc.) that the electrical signal must pass through to arrive at the scalp (Reynolds & Richards, 2009). This makes it challenging to identify the location of the brain sources of the scalp-recorded activity. Algorithms for identifying sources rely on accurate knowledge about conductance of the tissues that the signal must pass through. Measurements suggest that adults and children have similar skull anatomy and conduction. However, measurements are not readily available for young infants and are likely to differ as infants' skulls are thinner, less dense, and have openings (fontanels). Thus, applying algorithms developed for adults to young infants without modification could confound changes in tissue properties over development with changes in brain activation over development (see Reynolds & Richards, 2009, for further discussion and potential solutions to this problem). In summary, different brain-imaging methods measure different signals and acquisition and analysis of these signals make various assumptions that are often based on knowledge of adult brains. These assumptions must be evaluated when applying brain-imaging methods to the developing brain so that appropriate modifications can be made.

Temporal and Spatial Resolution

Brain imaging methods can be characterized by their spatial and temporal resolution. *Spatial resolution* refers to how well the method can discriminate between nearby

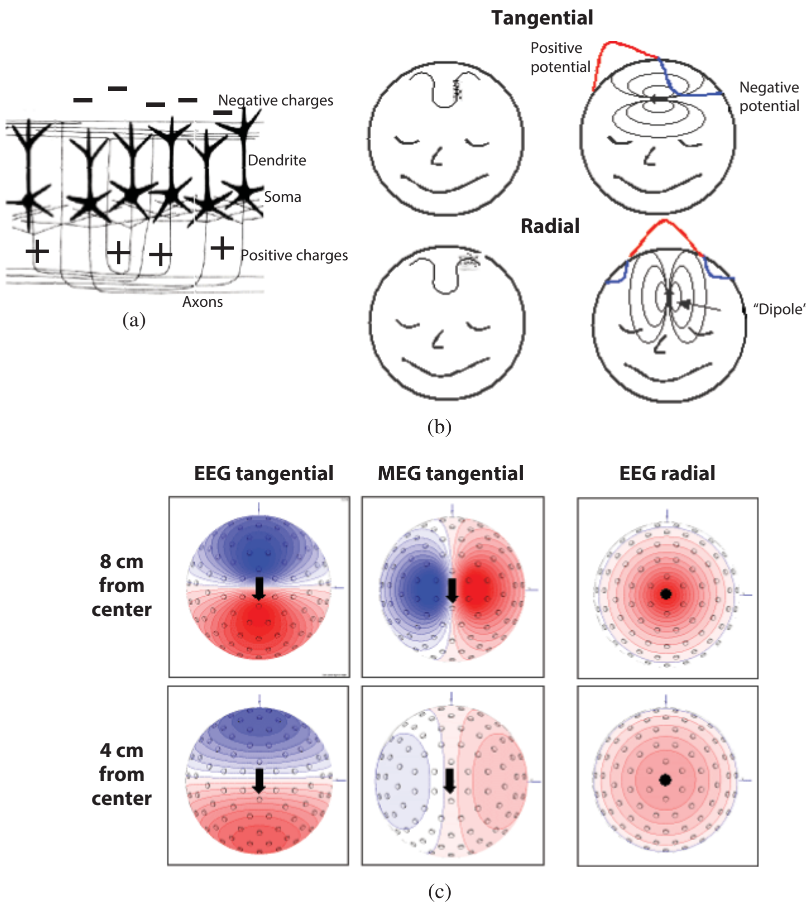

Figure 18.1 Illustration of the physiological basis of the EEG. (a) The main generators of the EEG (and MEG) signals are voltage gradients along dendrites in upper cortical layers. This causes a current flow in the conducting medium surrounding it. Several thousands of parallel-oriented neighboring dendrites have to be active synchronously to produce a measurable signal. (b) The summed activity within a small area of cortex can be described by a so-called dipole. This dipole describes the strength and direction of the current flow within this area. A "tangential dipole" is oriented parallel to the scalp surface, whereas a "radial dipole" points toward or away from it. Each dipole produces a positive scalp potential in the direction it points to, and a negative potential in the opposite direction. Each current also produces a magnetic field. The magnetic field of a tangential dipole is roughly perpendicular to its potential distribution (not illustrated, but see item (c)). (c) Simulation of the scalp potential (EEG) and magnetic field (MEG) distributions for dipoles with different orientations and different distances from the center of the head.

regions within the brain; *temporal resolution* refers to the smallest time period of neural activity that can be reliably separated. An ideal brain imaging method would possess high spatial resolution as well as high temporal resolution, allowing precise pinpointing of brain changes with at least millimeter spatial precision and millisecond timing precision. Table 18.1 lists common brain imaging methods with a ranking of several basic characteristics, including their relative spatial and temporal resolutions. As can be seen, no single method is ranked top for both spatial and temporal resolution. Although fMRI has high spatial resolution, it does not have the highest temporal resolution as it relies on measuring blood flow, a response that is slower than brain electrical activity; in contrast, EEG has high temporal resolution, but relatively low spatial resolution as it measures brain activity at the scalp after it has passed through tissue that smears the spatial information. This is one of the reasons why researchers sometimes combine methodologies, or select particular methods depending on whether their hypothesis is more focused on the timing or the location of brain events.

Artifacts and Signal-to-Noise Ratios

Noise or *artifact* refers to changes to the brain signal that are unwanted because they do not originate in brain and/or

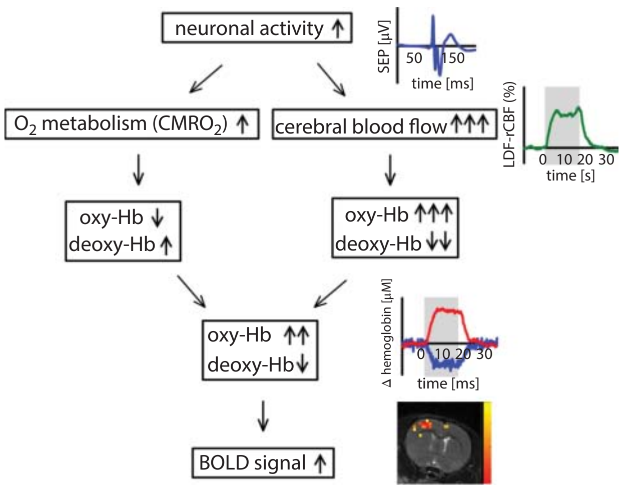

Figure 18.2 Physiology of the hemodynamic response during increased neuronal activity. Hb-hemoglobin; BOLD-Blood oxygen level dependent.

Source: From "Pathophysiological Interference with Neurovascular Coupling—When Imaging Based on Hemoglobin Might Go Blind," by U. Lindauer et al., 2010, *Frontiers in Neurogenetics*, *2*, p. 25.

are not of interest to the researcher. Minimizing noise in an experiment is advantageous because it means that smaller differences between conditions can be detected and/or that reliable data can be obtained within shorter recording sessions. One common source of noise is body or eye movement that occurs while measurements are being taken. MRI/fMRI and MEG measurements are taken with millimeter precision, thus even small movement cause blurring of the images. In using EEG, movements of the body or eyes can create electrical signals that are much larger than those generated by the brain's processing of the experimental activity, obscuring these signals (see Figure 18.3). Younger children are typically less able to sit still and quietly than older children or adults, or be comfortable with apparatus (e.g., chin rest, head restraint) designed to keep the head in position, making it more challenging to get "good" data free from artifact. Although algorithms exist for the various neuroimaging methods to correct the data for the influence of movement artifacts, these algorithms are not foolproof and minimizing the occurrence of movement at the time of recording remains a priority.

A common way of describing the amount of noise is the *signal-to-noise ratio*. This refers to the size of the brain signal being measured relative to the amount of noise. A higher signal-to-noise ratio means that the recorded signal contains a higher proportion of true brain signal and a lower proportion of noise; something researchers aim to achieve. Signal-to-noise ratios can often vary by age. Compared to older children or adults, younger children typically have shorter attention spans and find it more difficult to keep still. This means that younger children, or those with developmental delay, may provide less data containing more artifact. This means signal-to-noise ratios may differ across age in developmental studies and/or between study groups (e.g., patients versus controls). Potentially, differences in brain measures could be obtained, or fail to be obtained, due differences in the amount of noise in the measurement over age or between groups rather than true differences in the brain processes under study.

One way to increase the signal-to-noise ratio, used in ERP and fMRI, is signal averaging. For example, the ERP response is typically as small as 1 to 10 microvolts and must be extracted from the ongoing EEG, which can reach values as large as 100 microvolts. By averaging the EEG across repeated presentations of the stimulus, signal that is unrelated to the processing of the stimulus (noise) should

TABLE 18.1 Qualitative approximate rankings on distinguishing characteristics are provided for the methods of diffusion tensor imaging (DTI), electroencephalography (EEG), event-related potentials (ERP), functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), magnetic resonance imaging (MRI), magnetic resonance spectroscopy (MRS), near infrared spectroscopy/optimal imaging (NIRS), pharmacologic magnetic resonance imaging (phMRI), positron emission tomography (PET), and single photon emission computed tomography (SPECT)

Characteristics	**Less** ————	————	————	————	→ **More**
Ability to measure both cortical and deep structures	NIRS		MEG ERP, EEG	SPECT	PET, MRS, fMRI, phMRI, DTI
Temporal resolution	MRI DTI MRS	phMRI	PET SPECT	fMRI NIRS	EEG, ERP MEG
Spatial resolution	ERP EEG	MEG	SPECT	PET	NIRS, fMRI, DTI MRI, phMRI
Invasiveness of method		ERP EEG NIRS MEG	fMRI MRI DTI MRS	phMRI	PET SPECT
Expense of method		EEG ERP NIRS	fMRI DTI MRI MRS	phMRI	PET SPECT MEG
Ease of use with developmental populations	PET SPECT	phMRI	fMRI	MRI DTI MRS	

Source: From "Introduction: New Methods in Development Science," by B. J. Casey and M. de Haan, 2002, *Developmental Science*, *5*, pp. 265–267.

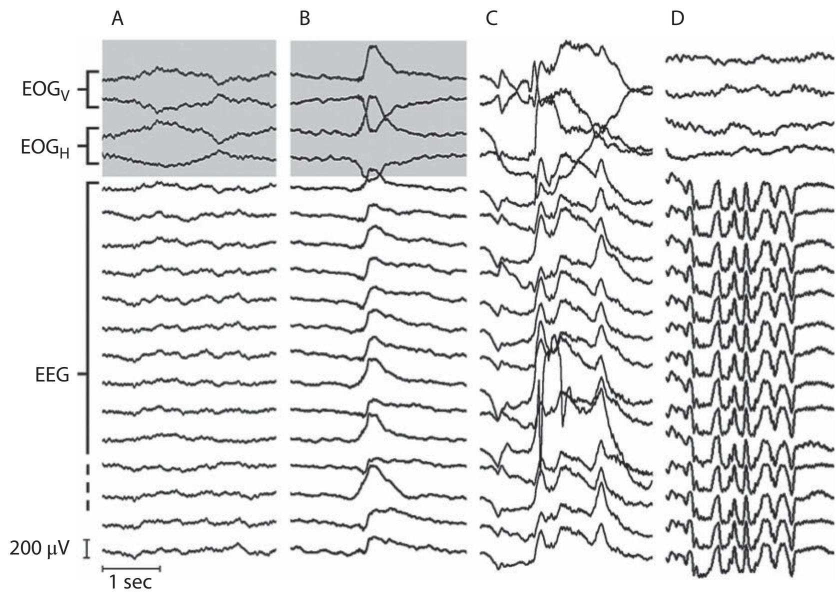

Figure 18.3 Sequences of infant electrooculogram (EOG) and electroencephalogram (EEG) data containing typical artifacts. Panel A: Eye movement. Panel B: Blink. Panel C: Head/body movement. Panel D: Pacifier artifact (rhythmic sucking). EEG data were referenced to the linked mastoids, EOG were recorded bipolarly. Note that the effects of eye movements and blinks also affect the EEG.

Source: From "Recording Infant ERP Data for Cognitive Research," by S. Hoehl and S. Wahl, 2012, *Developmental Neuropsychology*, *37*, pp. 187–209.

average out to zero as it will occur randomly relative to the stimulus onset. By contrast, activity related in time to the onset of the stimulus (and thus related to the processing of the stimulus), called the *event-related potential*, will remain. The greater the number of trials contributing to the average, typically the greater the signal-to-noise ratio—in other words, the more clearly the brain response of interest can be characterized against the background activity (see Figure 18.4). This aspect of ERP and some fMRI designs has implications for the types of questions that can be asked using these methods. To obtain a reliable response through signal averaging, it must be possible to present the stimulus condition of interest repeatedly within a confined period of time. Events that are difficult to repeat or are naturally prolonged, such as the experience of emotional states, may be better studied using other methods (e.g., the ongoing EEG rather than time locked event-related activity).

Baselines

Neuroscientific measures of brain activation are often measured against some baseline or comparison condition. This baseline might be a period of low stimulation or "rest" so the change in brain response when the stimulus is presented can be measured, or it might be relative to another stimulus, such as comparing activity elicited by an emotional face to a neutral face baseline to isolate the processing related to emotion per se from the general processing of the face. It is important to consider the baseline when designing a study or interpreting results from an existing study, because differences in the baseline will contribute to differences in the pattern of brain activation obtained to the experimental condition of interest. For example, the pattern of brain activity to a happy face will likely include more brain areas if it is compared to brain activity to a fixation point baseline than if it is compared to brain activity to a neutral face. This is because the areas of brain activation for a happy face and a neutral face would likely overlap more than that for a happy face and a fixation point, and thus more common activation would be "subtracted out" in the former than the latter circumstances.

Baselines involving periods of low-stimulation can be more difficult to obtain in younger children, as they may find these boring or distressing and be more likely to move or fuss. For example, in event-related potential studies it is usual to have a short "baseline" period prior to the presentation of each stimulus, against which to measure the change in brain activity elicited by presentation of the stimulus. This baseline usually involves a short period where the stimulus presentation screen is blank or contains only a small fixation point, and no sound is presented. In studies with infants and young children, this can be challenging because infants and young children are more likely to, for example, look away from the screen during

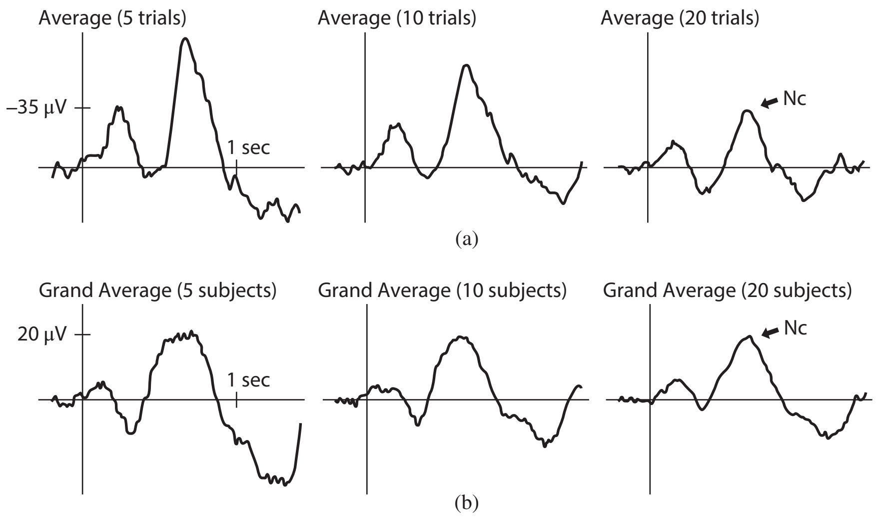

Figure 18.4 Examples of event-related potential (ERP) averages including differing numbers of trials within one subject (Panel a) and examples of grand averages including differing numbers of subjects (Panel b). Data from the Fz electrode in response to a visual stimulus are shown and negativity is plotted upward. Note that high-frequency noise is averaged out with an increasing number of trials and subjects, and amplitude is reduced. The depicted Negative central (Nc) component is a large deflection in infants' ERPs and its morphology is visible even when only a small number of trials and subjects are included. However, its peak gets more clearly defined with an increasing sample size.

Source: From "Recording Infant ERP Data for Cognitive Research," by S. Hoehl and S. Wahl, 2012, *Developmental Neuropsychology*, *37*, pp. 187–209.

such periods, creating artifacts in the brain signal due to eye movements. When working with very young children or infants, researchers often present "distractor" stimuli (such as a colorful moving image and/or sound) in between the experimental stimuli of interest to help maintain the participants in a quiet, attentive state, looking at the screen. Although this is useful for ensuring optimal participation, if such distracters are present during the baseline measurements, they may contribute to the ultimate result—at best introducing unwanted noise, and at worst introducing a systematic difference that confounds the study's comparison of interest. This specific example from ERPs illustrates the importance of ensuring equivalent baseline recordings across age, so that differences in baselines do not confound results when, for example, comparing findings from younger children with those from older children or adults.

Correlation and Causation

Studies of task-related brain activation show which areas are active while participants carry out the task, but do not tell us whether those brain areas are necessary for carrying out the task. Most studies using neuroscientific measures in children are correlational in nature. For example, a researcher might measure a brain structure in children at different ages or with different psychiatric diagnoses, and find that a change in the size of the structure maps on to differences in behavior across age or between groups. However, it is not appropriate to conclude that the change in brain structure caused the change in behavior, nor that the change in behavior caused the change in brain structure. The direction of the effect cannot be conclusively identified in this type of study. Even in cases where an intervention or training paradigm is used, the possible direction of relations is not necessarily clear—did an intervention affect the brain, which in turn enabled a change in behavior, or did the intervention alter the behavior, which in turn caused a change in the brain?

Interpretations about causality are also an issue when studying brain networks. Researchers often want to understand causal relations within brain networks—that is, to determine the influence of one brain region on another. This type of analysis is called *effective connectivity analysis*. In principle, this analysis could take advantage of temporal information when identifying the influence of one region on another within brain networks, as causes must precede effects. However, this is not as straightforward as it sounds. For example brain tissues can differ in how quickly the hemodynamic response reacts to the change in neural activity, and this time variation among tissues may not be known. Thus, synchronization of fMRI measurements from the distinct brain regions involved in the hypothesized brain network may not reflect the true sequence of the underlying neural activities (see Ramsey et al., 2010, for further discussion)

Technological Advances

The speed of technological advancement can be an advantage to neuroscientific research if it allows easier and more accurate brain measurements; however, it can be challenging for studies carried out over a large time span, such as longitudinal studies or studies involving rare or difficult-to-recruit participants. Parameters used in data collection (e.g., number of gradient directions in diffusion tensor imaging), the hardware used for data collection (e.g., the type or layout of EEG electrodes), and/or analysis method established at beginning of a study may be considered outdated by the end. These factors can make it difficult to compare data over the time frame of the study and/or require time-consuming reworking of data sets.

Summary

Neuroimaging can provide reliable measurements of brain structure or activation, but methods differ in the way they obtain these measurements and in their spatial and temporal resolution. Developmental researchers must take care to consider how factors such as choice of method, presence of noise, and use of baseline affect measurements of developmental change brain structure or activation, as well as the types of interpretations applied to neuroscientific results.

The following sections provide overviews of specific neuroimaging methods, starting with methods aimed at measuring brain structure and going on to methods aimed at measuring brain functional activation.

BRAIN STRUCTURE

Measuring brain structure is useful to developmental cognitive and social neuroscientists for understanding how the development of brain structure relates to emergence of skills, how behaviors or environments may influence brain structure, and for quantifying the effects of brain injury or disease. Three tools that can be used to this end are structural magnetic resonance imaging, diffusion tensor imaging, and ultrasound.

Structural Magnetic Resonance Imaging

MRI is a noninvasive method that can provide high spatial resolution structural images of the brain. It uses static and dynamic magnetic fields and radiofrequency pulses to receive and localize signals from hydrogen nuclei (protons) from the brain or other part of the body, including microscopic movements of the protons. A more detailed overview of the basic principles of MRI for human developmental research can be found in Kennedy, Markis, Herbert, Takahashi, and Caviness (2002).

To obtain an MRI scan, a participant must lie in a scanner while the images are being obtained (see Figure 18.5). The MRI scanner is a hollow machine with a tube running horizontally through its middle. During the scan, a special device called a head coil is placed around the person's head. The head coil does not touch the participant, and the participant can see through large gaps in the coil. As it collects the images, the scanner usually makes a continuous knocking sound, which can be quite loud. The participant must lie as still as possible, because even small movement can cause blur in the images, much as a photo taken by a camera

Figure 18.5 Pictures of various MR simulators. The top panel shows a scanner simulator that includes a replica of the head coil and stimulus display device just above. The bottom panels show a 10-year-old male in the scanner simulator, wearing headphones and looking at the video display where, during the simulation, a movie is playing or, during a study, the experimental stimuli are projected.

Source: From "Special Considerations for Functional Magnetic Resonance Imaging of Pediatric Populations," by E. Kotsoni, D. Byrd, and B. J. Casey, 2006, *Journal of Magnetic Resonance Imaging*, *23*, pp. 877–886.

is blurry if someone moves while taking it. MRIs used in research and clinical practice with humans typically have field strengths of 1.5 to 3 Tesla. The higher field strength of 3T MRI results in an increase in signal-to-noise ratio, spatial resolution, and speed, all of which may provide substantial benefits.

A number of different MRI techniques can be used to provide detail about the brain structure. The techniques most commonly used in research are described below, and an overview including additional techniques is provided in Table 18.2.

T1- and T2-Weighted Images

MRI primarily images the signal coming from hydrogen nuclei, as hydrogen is part of both water and fat, which together make up the majority of the human body. Hydrogen nuclei possess a property called *spin*, which can be thought of as a small magnetic field that produces a measurable signal. When an ambient magnetic field is present, the spinning nuclei tend to become aligned along the main axis of that field. Images are made by applying a series of brief energy pulses (radiofrequency pulses), through the field. The time between pulses is called the *repetition time* or TR. Each pulse acts to momentarily tilt the hydrogen nuclei in a particular plane. This causes their energy state to change, and measuring this change allows an image of the tissue to be created. For example, a measure called *T1 relaxation* is based on the time taken for energy to be released as the pulsed nuclei relax back to their initial, aligned position. Different tissue types show different relaxation times. T1-weighted images are obtained using a short TR, so that not all tissues' nuclei have had time to return to their initial positions. This gives contrast, or differentiation, among the tissue types—in T1-weighted images this means white matter is darker than gray matter (see Figure 18.6 for an example). T1-weighted images are often called "anatomy scans," and are those most often used by cognitive scientists to measure basic brain structure.

TABLE 18.2 Common MRI Techniques and Their Applications

Technique	Appearance	Use
T1	White matter is darker than gray matter; fluid dark, water-based tissue midgray, and fat-based tissue bright.	"Anatomy scans" because boundaries between tissues seen.
T2	White matter is brighter than gray matter; fluids bright, water and fat tissue midgray.	Tissue edema (water and fluid are bright)
T2*		
FLAIR	Fluid attenuated inversion recovery is a type of contrast that is heavily weighted to T2 and suppress the cerebrospinal fluid signal.	Good for multiple sclerosis or lesions close to ventricles
Diffusion-weighted	Measures the diffusion of water into tissues, and allows the detection of areas where diffusion has become restricted, such as within a white matter projection.	Stroke; demyelination/ myelination
Susceptibility-weighted imaging	A type of image contrast based on the differences in susceptibility between tissues with respect to the degree they become magnetized in response to the applied magnetic field.	Venous blood, hemorrhage, iron storage

MRI contrasts different types of brain tissue—to have a good view of the details, some of the brain contents should respond differently than others. The type of image obtained during an MRI depends on the contrast applied, which depends on a number of parameters, including the TR and other variables. With a longer TR, the T1 signal is eliminated because all tissues will have come to a similar response (returned to their initial, aligned position) given enough time. It is then possible to obtain another type of contrast, a T2-weighted image. T2 relaxation is based on the time taken for the nuclei to gradually fall out of alignment and no longer show uniform motion. In T2-weighted scans white matter is brighter than gray matter (see Figure 18.6, for an example). These types of images are considered particularly useful for differentiation of normal from pathological brain tissue.

Because MRI signals come from the hydrogen nuclei in the brain's water, it is important to consider that the water content of the human brain decreases over the first years of life, from approximately 92% to 95% at term birth to adult-like levels of 80% to 85% by 2 years of age. The higher water content of the neonatal brain affects the pulse sequences used when acquiring images, as it leads to longer relaxation times (Counsell & Rutherford, 2002).

Diffuse Tensor Imaging

A widely used variant of conventional MRI is diffusion tensor imaging (DTI), a method that allows more detailed study of brain white matter. It is called a *diffusion* technique because it relies on detection of microscopic movement of water within tissue. In white matter, tissue water does not diffuse freely, but rather in an anisotropic, or directional, manner along the axis of the fiber bundle.

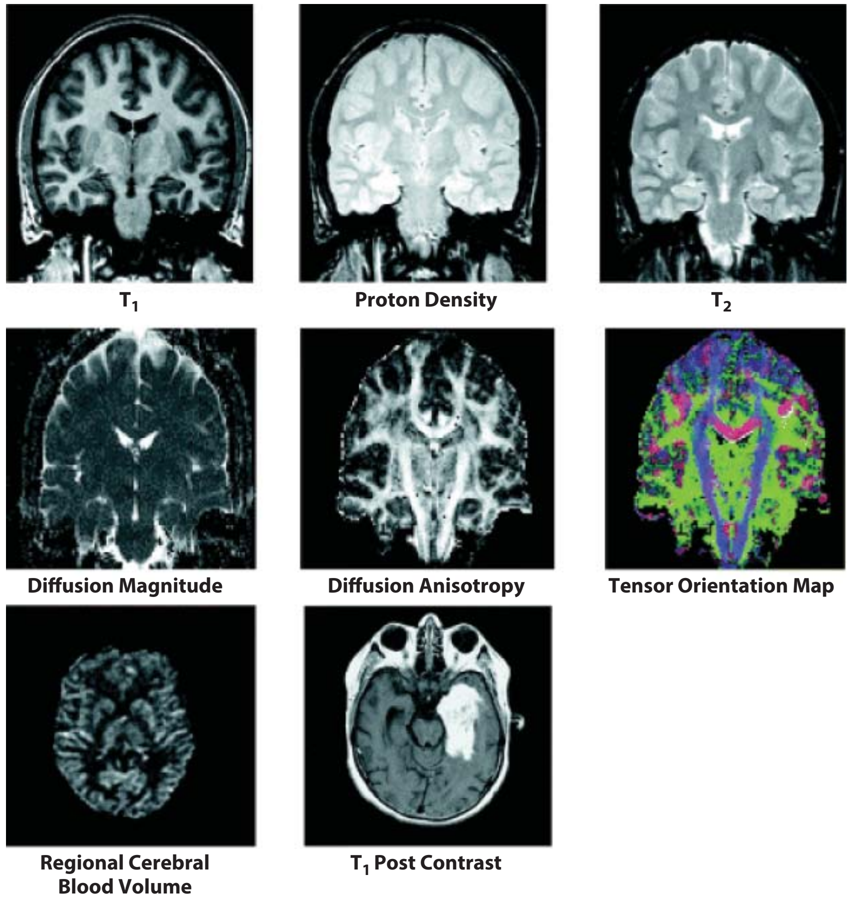

Figure 18.6 MRI images produced with different kinds of acquisition: includes T1, T2, proton density “conventional” images; echo-planar-based images of diffusion magnitude, anisotropy, and tensor orientation. Also shown are examples of regional cerebral blood volume map (rCBV), and a postcontrast T1-weighted scan in a tumor patient.

Source: From “Basic Principles of MRI and Morphometry Studies of Human Brain Development,” By D. N. Kennedy, N. Markis, M. R. Herbert, T. Takahashi, and V. S. Caviness, Jr., 2002, *Developmental Science*, *5*, pp. 268–278.

DTI uses this property to identify and characterize white matter pathways, typically by calculating the overall amount of diffusion, the speed and the direction of diffusion (see Figure 18.6, second row for examples of diffusion-weighted images). Diffusion anisotropy is quantified within white matter tracts using measures such as fractional anisotropy (FA), apparent diffusion coefficient, mean diffusivity, axial diffusivity or radial diffusivity. Changes in diffusion or anisotropy measured by DTI are thought to be associated with microstructural alteration including changes in myelin. Thus, DTI can be used to gain insights into normal brain anatomy, into alterations of white matter pathways in disease or for identifying the presence of qualitatively different pathways in congenital disorders or following recovery from acquired brain injury.

When obtaining diffusion tensor images, one parameter affecting the quality of information obtained is the number of directions measured. The signal can be increased by collecting more directions (e.g., 32 instead of 16) or increasing the number of times each direction is sampled (e.g., measuring 12 directions twice, and computing the average). More directions or samples gives better images but takes longer to acquire and is more likely to be influenced by noise. The minimum number of directions/gradients required to calculate the tensor is 6 with 15 to 20 directions being typical.

Analysis of the MR Signal

Signals from the MRI are digitized into images consisting of voxels. *Voxels* are three-dimensional cuboids that are typically 1 to 5 mm. Smaller voxels allow better spatial resolution, but have smaller signal and take longer to scan. Once digitized images are obtained, they need to be evaluated. There are a number of different methods available for analysis of MRI images, including visual inspection, volumetrics, voxel-based morphometry, tractography, and tract-based spatial statistics.

Visual Inspection. Using this method, a trained clinician inspects the image by eye to identify regions of abnormality. Visual inspection allows a relatively quick classification of brain scans as normal or abnormal, and is a commonly available measure in some clinical populations (e.g., epilepsy) as it would be part of routine clinical care. Potential disadvantages of the visual inspection approach for researchers are that it does not provide quantitative information, it may be insensitive to subtle variations among brain scans, and visual inspection needs to be carried out by a highly trained medical professional such as a neuroradiologist.

Manual Tracing and Automated Procedures for Identifying Regions of Interest. These approaches provide quantitative techniques in which a region of interest (e.g., the hippocampus), is identified, either by manually tracing around the structure on the slices in which it is visible or by using an algorithm that semiautomatically identifies the boundaries of the structure. This method can provide a quantitative measure of the volume of the target structure, measurements such as cortical thickness or cortical folding, or it can be used to define regions of interest for extraction of FA values from diffusion tensor images. Manually tracing can be time consuming and subjective; this problem has driven the development of semiautomated programs for obtaining volumetric measures. Several such semiautomated programs are freely available (e.g., Free Surfer, FSL, SPM8), and they also allow linking of data from other neuroimaging modalities to MRIs.

A study examining the neural correlates of socioeconomic status in the developing brain illustrates the application of this approach (Noble, Houston, Kan, & Sowell, 2012). T1-weighted images were obtained from 60 participants age 5 to 17 years. Cortical and subcortical gray matter regions were defined using Free Surfer automated brain segmentation procedures, and regional volumes of interest were calculated using Free Surfer's automated quantification of cortical and subcortical structures, which assigns a neuroanatomical label to each MRI voxel based on probabilistic information estimated from a manually labeled training set. Analyses then focused on examining the relation of SES to regional volumes, adjusting for age and total cortical volume. Adjusting for total cortical volume removes overall "brain size" effects, so that differences in regions of interest reflect effects specific to that area rather than general to the whole brain. Results showed SES differences in the hippocampus and amygdala (see Figure 18.7) across age, as well as increasing SES differences with age in the left superior temporal gyrus and left inferior frontal gyrus. This pattern was interpreted as consistent with the reported relation of SES to skills thought to rely on those brain regions, including memory, language, and social skills.

The brain regions of interest in a study do not always have easily identifiable boundaries, creating a challenge for both manual and semiautomated methods. Automated methods are often less accurate in regions that are hard to model (e.g., mesial temporal lobe) or that have large

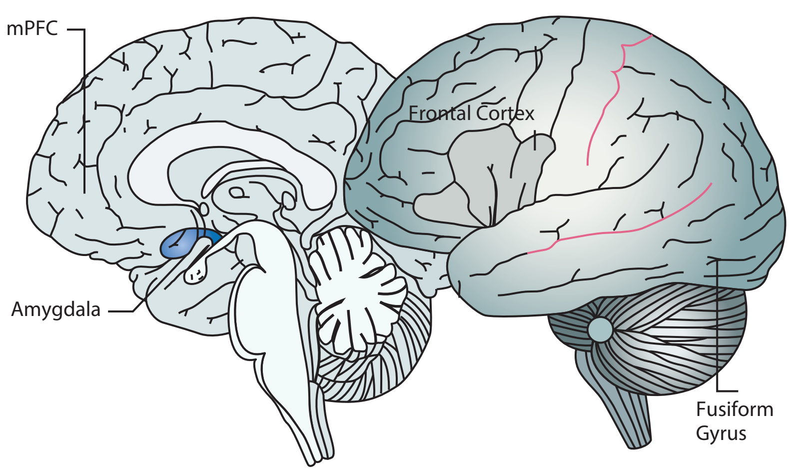

Figure 18.7 A drawing showing the medial (left) and lateral (right) view of the cerebral hemispheres, illustrating the position of structures mentioned in the chapter text including the frontal cortex, the medial prefrontal cortex (mPFC) the amygdala, and the fusiform gyrus.

Source: Adapted from "The Social Brain in Adolescence: Evidence from Functional Magnetic Resonance Imaging and Behavioural Studies," by S. Burnett, C. Sebastian, K. Cohen Kadosh, and S. J. Blakemore, 2011, *Neuroscience & Biobehavioral Reviews*, 35, pp. 1654–1664.

lesions or pathology that are difficult for the software to accurately distinguish. Both semiautomated and manual methods are often less accurate in differentiating between grey and white matter in infants and young children compared to older children or adults. This is because changes in white matter over the first postnatal years secondary to myelination can lead to nonuniform signal intensity, making the differentiation between gray and white matter less clear (see Figure 18.8). Neonatal brain MRI in particular exhibits lower image contrast due to incomplete myelination, lower signal-to-noise ratio as a result of shorter scan times, and lower spatial resolution due to smaller head size (Yu et al., 2010).

Voxel-Based Morphometry (VBM). VBM is a quantitative method that allows comparison of the local concentrations of gray and white matter at the level of the voxel (see Ashburner & Friston, 2000). Before the images can be statistically compared, several steps of preprocessing are needed to handle differences between images in gross anatomy and positioning. This preprocessing involves first spatially normalizing images from all subjects into a common template (ideally an average of a large number of individual structural images, though standard templates such as Talairach are also used), then segmenting the tissue into gray matter, white matter, and cerebrospinal fluid, and then smoothing the images. After this preprocessing, statistical tests compare groups or conditions voxel-by-voxel with correction for multiple comparisons, resulting in the statistical parametric map. Voxel-based morphometry is useful as a fairly quick and straightforward method for analyzing MRI images that requires less neuroanatomical expertise than visual inspection or volumetrics. In addition, it allows a detailed analysis of the whole brain, rather than just a targeted region of interest. Several free software packages are available that include voxel-based comparisons and other tools, including FMRIB Software Library (www.fmrib.ox.ac.uk/fsl) and SPM (http://www.fil.ion.ucl.ac.uk/spm/software/). Disadvantages of VBM include its sensitivity to factors such as image quality, and susceptibility to errors during segmentation and normalization. These are important factors to consider in developmental studies, where images may be noisier, and in studies of atypical populations, where, for example, abnormal neuroanatomy may result in misregistration during the normalization process.

VBM has advantages over the manual and semi-automated tracing techniques described earlier as it does not require a priori identification of structure boundaries, it allows the whole brain to be analyzed and it can potentially detect more subtle differences in brain signal. For example, work with children with episodic memory impairments known as *developmental amnesia* initially used manual tracing to demonstrate reduced hippocampal volumes within this population (Vargha-Khadem et al., 1997). However, this left open the possibility that other brain structures were also affected; in particular, the integrity of the temporal cortex surrounding the hippocampus was of interest, as theories differed according to the role given to this region of cortex in episodic memory function. However, the relevant subregions of temporal cortex do not have clear boundaries, making it difficult to use a

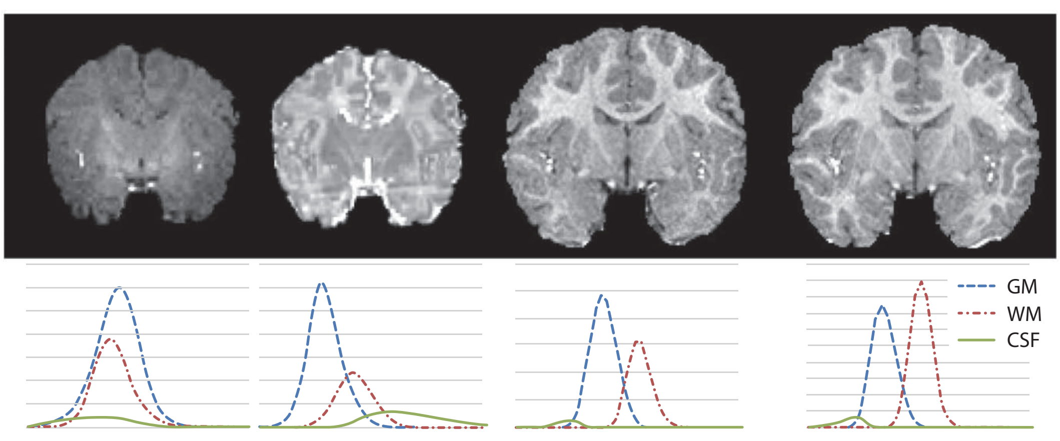

Figure 18.8 Representative longitudinal MR images and corresponding tissue intensity distributions of a subject. (a) T1 image at neonate; (b) T2 image of a neonate; (c) T1 image of a 1-year-old; and (d) T1 image of a 2-year-old. Note that in neonates the gray and white matter distribution are completely overlapping in the T1 image.

Source: From "Neonatal Brain Segmentation in Longitudinal MRI Studies," by F. Shi, Y. Fan, S. Tang, J. H. Gilmore, and D. Shen, 2010, *Neuroimage*, *49*, pp. 391–400.

region-of-interest volumetric approach. VBM enabled examination of the whole brain, and showed no evidence of temporal cortical injury, while confirming reduced gray matter in the hippocampus (Gadian et al., 2000). The only additional brain abnormality identified was gray matter reduction in the basal ganglia and thalamus, a pattern consistent with the perinatal hypoxic-ischemic injuries sustained by the patients.

Tractography

Tractography is a semiautomated method for tracing fiber bundles in DTI scans. It allows extraction of tract-specific white matter measures without the need for defining a region of interest a priori. Tracing the white matter pathways in the brain using this method does still have challenges because of the difficulty in accurately showing tracts if they cross each other (crossing problem) and difficulty in accurately showing the start and endpoints of fiber tracts (termination problem). Researchers have developed solutions to these problems. For example, High-Density Fiber Tractography (HDFT) can track white matter fiber tracts from their origin, through complex fiber crossings, to their termination point, with resolution of 1 millimeter or less using a combination of imaging processing, reconstruction, and tractography methods (Fernandez-Miranda et al., 2012).

A study used tractography to test the hypothesis that interhemispheric connections play an important role in language development (Northam et al., 2012). They examined the relation of interhemispheric white matter tracts to language skill in 50 adolescents who had been born preterm and 30 term-born adolescents. Diffusion images were analyzed using MRtrix, a freely available tractography software package that provides a solution to the fiber crossing problem (Tournier, Calamante, & Connelly, 2012; http://www.brain.org.au/software/mrtrix/). Tractography identified interhemispheric language pathways (corpus callosum and anterior commissure) and intrahemispheric pathways (arcuate fasiculus and uncinate fasciculus/extreme capsule) and volumes for these were computed. Results showed that only callosal fibers connecting the temporal lobes, and not those connecting other regions, were reduced in preterms. This reduction was only associated with language impairment if the anterior commissure (a second temporal lobe commissural pathway) was also small. The results were interpreted as supporting theories emphasizing the importance of interhemispheric connections for language, particularly in the developing brain.

Tract-Based Spatial Statistics (TBSS). TBSS allows the automated analysis of microstructural integrity of brain white matter (Smith et al., 2007). FA images from DTI data are spatially normalized, and then subject-specific measurements are projected onto a "skeleton" of the common white matter structures to allow comparison between subjects. This approach allows a more objective way to quantify DTI and compare such images between participants, allowing voxel-wise comparison using VBM (see earlier). A potential disadvantage of this approach is that, by restricting analysis to the central skeleton, some white matter may be excluded from analysis.

Advantages and Disadvantages of Structural MRI and DTI Methods

The main advantage of structural MRI and DTI methods is that they are noninvasive and so can be used with children to acquire detailed images of the living human brain. A limitation of structural MRI in developmental studies is the nature of the environment in which the images are typically acquired: Participants must stay motionless in a small, noisy space for prolonged periods. These requirements make it difficult to study children younger than about 7 years, unless they are asleep or sedated. This means that most normative studies focus on children 7 years and older, or very young infants in the first months of life who can tolerate the scanner when swaddled and sleeping. Even for older children, the environment is unusual and can be frightening, and so familiarization with the scanner environment prior to data collection is considered important to maximize cooperation (see Kotsoni, Byrd, & Casey, 2006, and Raschle et al., 2012, for discussion). Techniques to help optimize successful data collection include exposure to a mock scanner prior to testing (see Figure 18.5), allowing parents to be present in the scanning room, and allowing the child to view a film during the scan. Additional challenges related to use of MRI in developmental studies are discussed later in the section on functional MRI.

DTI provides useful information about the development of brain white matter, beyond that provided by regular MRI images. Although these measures are interpreted as reflecting white matter integrity and are believed to be influenced by microstructural changes, such as myelination, there is still quite limited knowledge about the neural bases underlying the different DTI measures that can be obtained. This makes the meaning and functional impact of changes in these measures with development unclear, and can make it difficult to know which of the measures is best to use in a particular study. From a practical point of view, obtaining DTI images adds to the scan timing and acquisition is particularly sensitive to movement, so may not always be feasible depending on the population under study. The time course of DTI-related developmental changes has yet to be definitively established, highlighting the need for more normative studies.

Ultrasound

Cranial ultrasound uses reflected sound waves to produce pictures of the brain and the ventricles through which cerebrospinal fluid (CSF) flows. Ultrasound waves cannot pass through bones, so this technique is largely limited to use with babies, before the bones of the skull have grown together (up to about 18 months old). The ultrasound takes a “slice” through the structure, resulting in a 2D image of a 3D structure. Although there are methods for creating reconstructed 3D ultrasound images, most clinical and research use is with 2D images.

Cranial ultrasound can be carried out quickly, safely, and repeatedly, even in very sick infants. For these reasons, it has been very useful as a screening tool in sick infants. Cranial ultrasound is often part of routine screening in babies born preterm or with complicated births. It can detect common patterns of brain injury in these infants, such as brain swelling, bleeding in the brain (intraventricular hemorrhage), and white matter injury (periventricular leukomalacia or PVL). Neonatal cranial ultrasound diagnosis can predict school-aged motor and cognitive outcomes in preterm infants (Vollmer et al., 2003). Cranial ultrasound also has potential use as a screening tool for early detection of those at risk for later adverse outcomes, as it is less expensive and more readily available than alternatives such as MRI. For example, one study prospectively examined whether ultrasound measures obtained in more than 700 infants at 6 weeks of age could predict attention deficit hyperactivity disorder (ADHD) or impaired executive functions at preschool age (Ghassabian et al., 2013; see Figure 18.9). This type of large-scale study that includes typical infants would not easily be feasible using MRI. Results of the work showed that smaller corpus callosum length, but not basal ganglia/thalamus diameter or ventricular volume, predicted poorer executive function at 4 years, though none of the measures predicted ADHD.

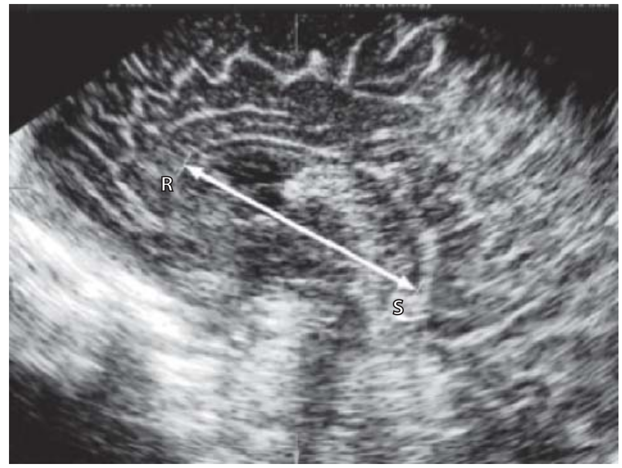

Figure 18.9 Ultrasound imaging showing the corpus callosum, from rostum (R) to splenium (S). The corpus callosum is the semicircle tract above the double-arrowed line.

Source: From “Infant Brain Structures, Executive Function, and Attention Deficit/Hyperactivity Problems at Preschool Age: A Prospective Study,” by A. Ghassabian et al., 2013, *Journal of Child Psychology and Psychiatry*, *54*, pp. 96–104.

Summary of Brain Structure Methods

MRI provides a noninvasive tool for studying brain structure in developing humans. For studying typical development, it is most useful in children aged about 7 years and above or very young sleeping infants, as they most easily tolerate the constraints of the scanning environment; patient groups may be studied at other ages if the clinical benefits of the scan outweigh the risks of sedation. However, scans obtained for clinical purposes may make use of different parameters during MRI acquisition than do scans obtained for purely research purposes, so there may be some limits in the information obtained from clinical scans. For example, DTI may not be standardly part of a clinical scan, or in hospitals with multiple scanners clinical scans may be carried out on different scanners whose results cannot be easily combined for quantitative analyses. Advances in software will help make some aspects of analysis more automated, and allow more detailed quantification of DTI and other measures.

Ultrasound provides a quick, easy, portable, and economical approach to obtaining information about brain structure. Although it lacks the spatial resolution of MRI, it is a useful option for large-scale studies, clinical studies where such information would be routinely collected, and studies in environments (e.g., remote locations) where MRI technology is not readily available.

BRAIN FUNCTION

Although knowing whether a brain structure looks mature is one indication of its development, this information does not necessarily indicate whether the structure is functionally mature. That is, is the structure activated within the same neural network, under the same circumstances, and so on, as in adults? Several tools have been used to assess brain activation during development in order to understand the functional development of brain areas involved in social, cognitive, and perceptual functions. In the next section, four of the more commonly used methods, functional MRI, Near Infrared Spectroscopy (NIRS), EEG/Event-Related Potentials, and Magnetoencepholgraphy (MEG) are described. At the end of the section, the use of electromyography (EMG) as an indirect index of central nervous system function is also described.

Functional Magnetic Resonance Imaging

Functional magnetic resonance imaging (fMRI) is an indirect measure of brain activity. It measures changes in blood oxygenation, called the *blood oxygen level dependent* or BOLD response (see Figure 18.2). This is accomplished by capitalizing on magnetic differences between oxygenated and deoxygenated blood. Deoxygenated hemoglobin in blood becomes strongly paramagnetic, so it can be used as a naturally occurring contrast agent, with highly oxygenated brain regions producing a larger MR signal than less oxygenated areas. The methods assumes that the local increase in blood oxygenation reflect increase in neuronal activity, an assumption that has been supported by studies in adult humans and nonhuman primates (e.g., Logothetis et al., 2001). The change in the MR signal from neuronal activity is called the *hemodynamic* response. This response lags the neuronal events triggering it by 1 to 2 seconds, because it takes that long for the vascular system to respond to the brain's need for glucose. From this point the *hemodynamic* response typically rises to a peak at about 5 seconds after the stimulus onset. If the neurons keep firing, as might happen if there is a continuous stimulus, the peak spreads to a flat plateau because the neurons stay active. After activity stops, the BOLD (blood oxygen level dependent) signal falls below the original level and then eventually the signal returns to the baseline level.

The fMRI data acquisition environment is similar to that described above for structural MRI (see Figure 18.5). An additional element is that the participant must typically perform some task in the scanner, which requires equipment for stimulus presentation and for recording responses. Because of the strength of the magnets used in MRI, the equipment used must be suitable for use within this environment. It is also advisable to familiarize the child with the task outside of the scanner, so that optimal performance can be obtained during the scan (see the section on advantages and disadvantages later for further discussion).

When embarking on an fMRI study, decisions must be taken about the overall study design, and the method in which stimuli will be presented. These decisions should be guided by the research questions, as they are related to details such as whether one wishes to identify brain regions that differ or are in common among experimental conditions, whether one wishes to measure activity related to each trial or activity sustained across a whole trial block, and so on. In the next sections, the common approaches to study design and stimulus presentation are described.

Study Designs

There are four basic designs that are typically used in fMRI to identify brain activity related to a particular function (Amaro & Barker, 2006):

1. In a *comparison design*, images from a control or baseline condition are subtracted from the experimental condition of interest. For example, one study with 6 to 16-year-olds compared activity during a spatial working memory task to a control condition with similar motor and attentional demands, but without memory demands, to show activation in the intraparietal sulcus (Dumontheil & Klingberg, 2012).
2. A *factorial design* builds on the comparison design by allowing examination of interactions. To achieve this, conditions of interest are presented alone or in combination. For example, a visual working memory task, an auditory working memory task, and an auditory-visual working memory task might be presented so that interactions between visual and auditory working memory can be examined.
3. A *parametric design* involves increasing the cognitive demands associated with a particularly task while leaving the basic nature of the task unchanged. The increase in the BOLD effect associated with increase in cognitive demand would imply an association of that area with this processing. For example, Kucian, Loenneker, Martin, and von Aster (2011) used a parametric design to examine number processing in children with developmental dyscalculia. They studied the "numerical distance effect," which is characterized by an inverse relation of reaction time to the distance between numbers in a magnitude comparison: The larger the numerical disparity, the faster and more accurate are the judgments. The ratio between sets of items was

systematically increased, and, based on prior studies, the authors looked for a "negative parametric effect," whereby brain regions decrease in activity with increasing ratios. Children with developmental dyscalculia and controls displayed similar behavioral performance, but those with developmental dyscalculia showed stronger activation in the supplementary motor area and the right fusiform gyrus. (see Figure 18.7). Dyscalculic children engaged brain areas involved in response selection more than control children, suggesting they may have found the task more challenging, possibly due to a deficient development of a spatial number representation in developmental dyscalculia.

4. A *conjunction design* is similar to a factorial design in that cognitive components of interest are shared in some conditions. However, this analysis relies on detecting the common activation across the varying conditions. Identifying the common activity among the conditions then allows distinguishing basic processes involved across them. For example, in a study of auditory, visual, and auditory-visual working memory the analysis would focus on identifying activity common to the different conditions, to identify modality-independent brain regions supporting working memory.

In addition to considering the general task design as outlined above, researchers must take decisions regarding how to present stimuli in an fMRI task. The main methods are:

- *Block design*, where stimuli of the same condition are presented one after the other before moving onto a contrasting condition. Here, activity over the block gives a measure of the overall pattern of activity.
- *Event-related design*, where each stimulus' hemodynamic response function is detected and analyzed in detail. It allows analyses relating a brain response to on a particular trial to a behavioral response on the same trial, for example, examining error-related brain activity.
- *Mixed design*, which combines having closely presented events with an intermingled with a control condition. This allows an event-related analysis of transient responses on trials as well as a cognitive state analysis of more sustained responses (Petersen & Dubis, 2012).

Church et al. (2009) used a mixed design to examine adaptive control and task maintenance in adolescents with Tourette Syndrome. This required a mixed design because adaptive control is a trial-by-trial operation, whereas task maintenance is the ability to sustain performance over time. Participants performed a living/nonliving decision task with pictures and words and the mixed blocked/event-related design that allowed separation of responses to start cues (adaptive control), and sustained activity across the blocks (task maintenance). The authors found that adolescents with Tourette Syndrome showed anomalous start-cue activity that was not similar to any activity observed in typical development, suggesting that adaptive control is abnormal. They also observed increased sustained activity in frontal cortex, (see Figure 18.7), similar to that seen in younger typical children, suggesting immature, but not abnormal, brain correlates of task maintenance.

Sustained and transient signals may show different patterns of development. One study used a mixed design to compare sustained and transient signals in 7- to 8-year-old children and adults performing the same cognitive task (Burgund, Lugar, Miezin, Schlaggar, & Petersen, 2006). Results showed that several regions, including a region in the right lateral inferior frontal gyrus, show decreased sustained signals and increase transient signals with age. Importantly, reanalysis of the data assuming "blocked" and "event-related" designs, as opposed to a mixed design, produced different results. These results illustrate the potential value of separately measuring both sustained and transient signals in developmental fMRI studies.

Resting-State MRI

This is a procedure for studying whole-brain neural networks. The fMRI signal is measured while participants are in a task-free state (e.g., eyes closed in quiet environment). Because brain activity occurs even in the absence of any task, brain regions will have spontaneous fluctuations in BOLD signal and the connectivity among brain regions can be measured. *Structural connectivity* refers to connectivity of brain regions that are physically connected; *functional connectivity* refers to links between brain areas whose functional activity is correlated. Connectivity measures can be obtained during task performance as well as during resting state, and can be derived from all functional imaging data such as fMRI, EEG, MEG, and near-infrared spectroscopy (NIRS), though the current developmental literature is mostly based on findings from fMRI.

Analysis

The main aims of fMRI data analysis usually involve localizing the brain regions activated by a task and/or describing the distributed brain networks that underlie brain function in typical or clinical populations (for a detailed overview of analysis, see Lindquist, 2008). For developmental scientists, documenting how these results change over age is often an additional goal.

Local differences in the BOLD response between experimental conditions or groups of subjects are often quantified using the voxel-based morphometry method described earlier in the section on structural MRI. Differences in brain activation in contrasting conditions, commonalities in brain activation across conditions, and relations of brain activation with behavioral performance can all be examined.

The results of fMRI studies are usually summarized in a *statistical parametric map* (SPM). These maps describe brain activation by color-coding voxels whose statistical test values exceed a certain statistical threshold for significance. The implication is that these voxels are activated by the experimental task. When constructing such a map it is important to carefully consider the appropriate threshold to use when declaring a voxel active. In a typical experiment up to 100,000 hypothesis tests (one for each voxel) are performed simultaneously, and it is crucial to correct for multiple comparisons.

Describing the distributed brain networks that underlie brain function in typical or clinical populations can be achieved through connectivity analyses. Functional and structural connectivity of brain networks (see Figure 18.10) has been analyzed in a number of ways from computing correlations among regions to more complex approaches. One method that is increasingly being used is *graph theory*, a branch of mathematics that deals with the formal description and analysis of graphs. It provides a quantitative framework for analyzing complex networks (Bullmore & Sporns, 2009). The brain's structural and functional systems have features of complex networks—such as small-world topology, highly connected hubs, and modularity—both at the whole-brain scale of human neuroimaging and at a cellular scale in nonhuman animals (Bullmore & Sporns 2009, 2012). The graph theory approach can be used not only with fMRI, but also research using other imaging modalities where the question is aimed at characterizing brain networks (e.g., see Bathelt,

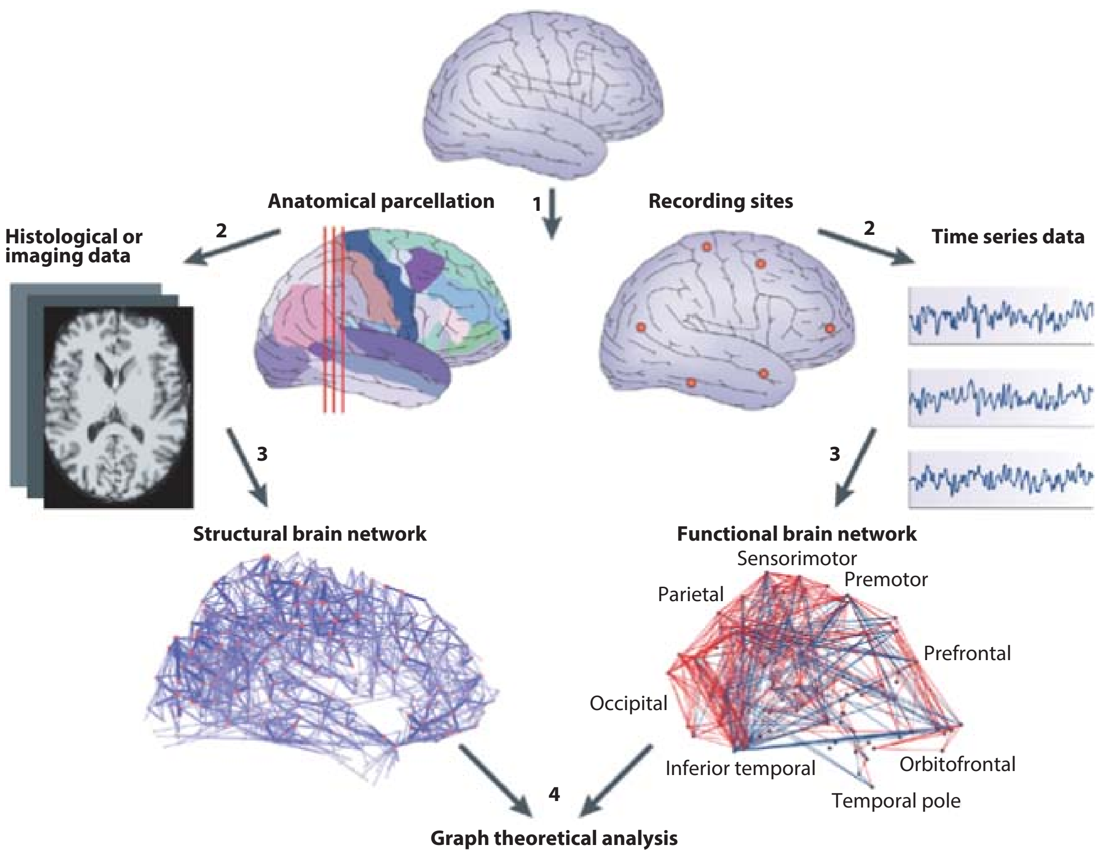

Figure 18.10 An overview of steps in identifying brain networks and calculating parameters of the network.

Source: From "The Economy of Brain Network Organization," by E. Bullmore and O. Sporns, 2012, *Nature Reviews Neuroscience*, 13, pp. 336–349.

O'Reilly, Clayden, Cross, & de Haan, in press, for use with EEG).

A consistent finding in the functional connectivity MRI literature is the presence of an interconnected network consisting of the medial prefrontal cortex, the posterior cingulate, the inferior parietal lobe, the lateral temporal cortex, and the hippocampal formation during the resting state (see Figure 18.7; Cherkassky, Kana, Keller, & Just, 2006; Fox & Raichle, 2007; Shulman et al., 1997). This network is called the *default mode network* (DMN; see Figure 18.11) and it is thought to be one of three major reciprocally regulated brain networks (Menon, 2011). The DMN is less active during executive tasks than at rest and is implicated in Theory of Mind, episodic memory, and other self-reflective processes (Menon, 2011). The DMN can be investigated even if the participant is not engaged in a task, which is particularly useful in groups with limited cooperative ability, such as children or developmentally delayed patients.

Functional connectivity analysis of fMRI data has shown that interhemispheric connections between homotopic brain regions are relatively adult-like in 7- to 9-year-old children. In contrast, anterior-posterior connections differ in children and adults. The mPFC and posterior cingulate and parietal regions are highly interconnected in adults but show little functional connectivity in children. (Fair et al., 2008; Supekar & Menon, 2012; see Figure 18.11). Another developmental difference is in *cortical hubs*, which are disproportionally connected brain regions that act as information convergence zones. Cortical hubs are thought to capture key aspects of how

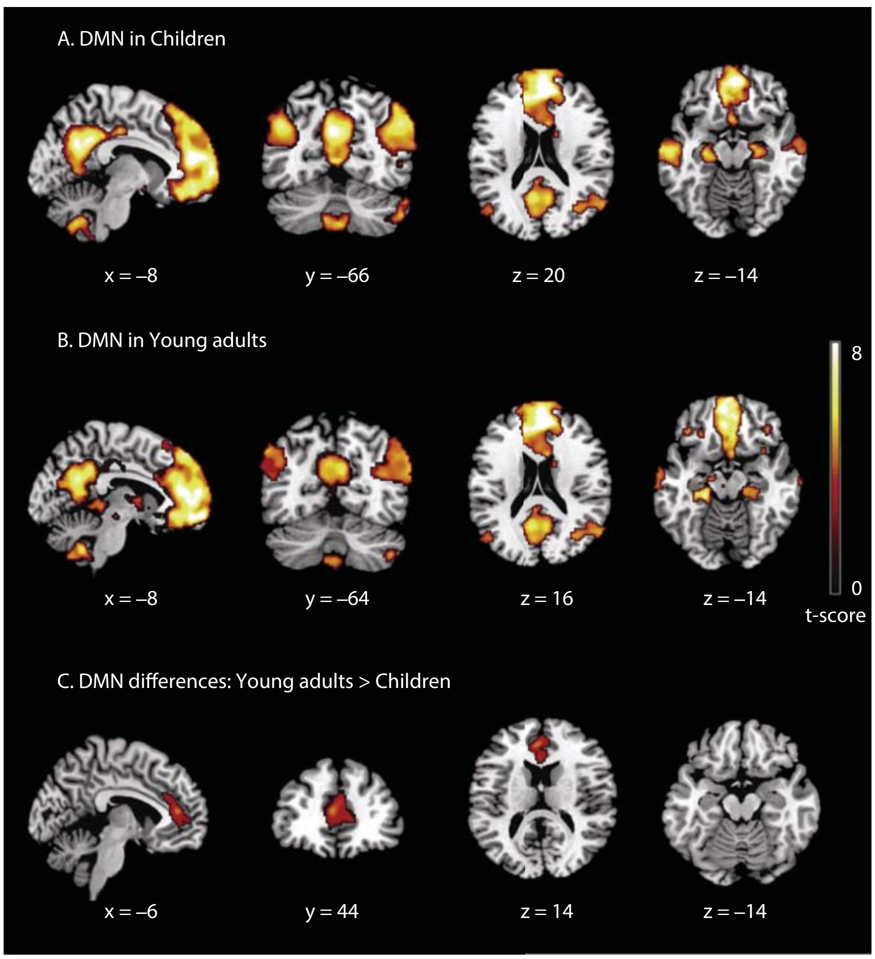

Figure 18.11 Weaker DMN activity in children. Default mode network (DMN) in (A) children, and (B) young adults. (C) shows results of a two-sample *t* test contrasting the DMN in young adults versus children. Both groups show activity in posterior cingulate cortex (PCC), medial prefrontal cortex (mPFC), medial temporal lobe (MTL), and angular gyrus (AG). Compared to young adults, children showed reduced activity in the mPFC. Compared to young adults, children did not show greater DMN activity in any brain region.

Source: From "Developmental Maturation of Dynamic Causal Control Signals in Higher-Order Cognition: A Neurocognitive Network Model," by K. Supekar and V. Menon, 2012, *PLoS Computational Biology*, 8, e1002374. doi:10.1371/journal.pcbi.1002374 the brain's architecture supports human behavior and is affected by disease. In adults, the majority of cortical hubs and related networks are located in multimodal association cortex, but findings indicate that they are largely confined to primary sensory and motor brain regions in the infant brain. The functional network architecture in infants may be linked to support tasks that are of a perception-action nature (Fransson, Aden, Blennow, & Lagercrantz, 2011).

Advantages and Disadvantages of fMRI

fMRI provides a measure of brain functional activation with spatial resolution on the order of millimeters, but temporal resolution only on the order of seconds. It is the main source of information about development of the location of brain areas active while children perform tasks.

As described earlier in the section on structural MRI, MRI studies in very young children are difficult because of the nature of the scanning environment. Functional MRI studies present an additional challenge, because, apart from resting-state studies, they typically rely on some sort of active response from the participant. This raises issues for task compliance and movement so most fMRI studies have not tested children younger than school-age (but see, e.g., Dehaene-Lambertz, Dehaene, & Hertz-Pannier, 2002, for exceptions). Even for older children, preparation prior to scanning is important, so that children are accustomed to the task itself. For these reasons, fMRI has a limited scope in providing a full profile across the age span of functional brain development. A challenge for pediatric imaging studies is that performance differences between groups make it difficult to determine if differences in brain activation reflect biological differences (e.g., biological maturation) or individual differences in ability. Increased difficulty or practice may alter both the magnitude of blood flow and the regional pattern of activation. Using parametric designs that vary task difficulty, equating task performance through training prescanning, equating task performance by matching post-hoc, or covarying age and behavioral performance are all approaches that have been used to address this issue (Kotsoni et al., 2006).

There are also numerous other considerations for developmental fMRI studies including developmental differences in anatomy and physiology that can affect the BOLD response and issues related to processing and analysis of pediatric data, all of which can potentially confound results. These problems are often magnified when dealing with atypically developing populations who may have atypical brains and/or be of lower ability level. For example, age-related structural differences might influence the ability to localize brain activity in a common stereotactic space as that used with adults. Studies that have examined this issue suggest that, at least in children 7 to 8 years and above, anatomical differences between children and adults are small relative to the resolution of fMRI suggesting that direct comparison in a common stereotactic space is reasonable (Kang, Burgund, Lugar, Petersen, & Schlaggar, 2003). This conclusion does not necessarily hold for younger children or clinical populations with atypical brain structure.

Near Infrared Spectroscopy

Functionalear infrared spectroscopy (fNIRS) uses specific, calibrated wavelengths of near infrared light to noninvasively illuminate the tissue below a sensor placed on the scalp (see Ferrari & Quaresima, 2012, for a review of the technique). These wavelengths of light scatter in the tissue and are absorbed differently dependent on the amount of oxygen attached to hemoglobin in the microcirculation. Light that is not absorbed is returned as an optical signal, detected, and analyzed to produce a ratio of oxygenated hemoglobin to total hemoglobin, expressed as percent StO_2. fNIRS is thus like fMRI, in that it provides an indirect measure of neural activity that relies on the assumption that blood oxygenation relates to brain activation via local metabolic demand.

Typical developmental fNIRS studies measure activity with a limited number of sensors, over a region of interest rather than whole-brain coverage, though commercial systems are available that record as many as 52 channels simultaneously. The spatial resolution of NIRS is about 1 cm, and it is mainly useful for measuring activity in the cortical surface as interrogating deeper structures would require laser-light intensities that could damage tissue. Figure 18.12 shows an example of stimuli and recording device in an infant NIRS experiment. A useful discussion of the use of NIRS in developmental perceptual-cognitive research can be found in Aslin (2012).

Data Analysis

Analysis of fNIRS data requires conversion of the raw data to obtain Hb and HbO2 measures, and data filtering. Analyses of fNIRS data are often adapted from established fMRI techniques, but specific software for fNIRS is also available, such as the NIRS Analysis Package toolbox in MATLAB (Fekete, Rubin, Carlson, & Mujica-Parodi, 2011).

Several studies have used fNIRS to investigate brain responses to faces in infants. For example, one study

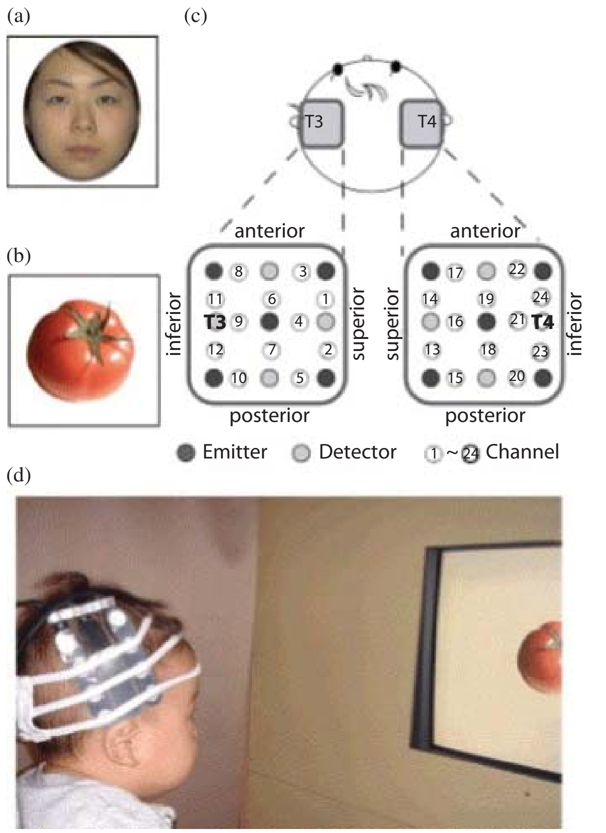

Figure 18.12 (a and b) Examples of the face and object stimuli used in the experiment. (c) Location of the optical fibers placed on the lateral areas in both hemispheres. (d) An infant wearing the NIRS sensor probes.

Source: From "Neural Activation to Upright and Inverted Faces in Infants Measured by Near Infrared Spectroscopy," by Y. Otsuka et al., 2007, *Neuroimage*, *34*, pp. 399–406.

recorded changes of oxy-Hb, deoxy-Hb, and total-Hb in 7- to 8-month-old infants' and adults' brains in response to faces with the features typically arranged and scrambled faces (Honda et al., 2010). Infants showed a greater Total-Hb in response to the typical face than the scrambled face in the right, but not the left, hemisphere over the superior temporal region. Adults showed a similar hemispheric asymmetry, with responses increasing for the typical face compared to baseline only over the right hemisphere. One limitation of NIRS for studying face processing is that it is not sensitive to the fusiform gyrus, a region thought to be key for the encoding of faces, as it lies deep on the ventral surface of the brain.

Advantages and Disadvantages

A strength of fNIRS is that it provides a tool for measuring brain functional activation that can be used even with young infants. For infant studies, it provides better spatial resolution than the main alternative, EEG. Disadvantages are that high-density systems (whole-scalp coverage) are not commonly used in developmental studies, and it is not always clear which of the NIRS-derived measures is the best to use for a particular study or how to interpret differences among the measures. fNIRS is also not sensitive to deep brain sources, so it may not target the area of interest in particular studies; conversely, it may provide a cleaner measure of the areas that it can detecte, as they will be uncontaminated by co-occurring activity from the deep sources. There is also as yet limited normative developmental data using fNIRS.

Electroencephalography/Event-Related Potentials

Functional MRI and NIRS are tools with relatively good spatial resolution for identifying developmental differences in brain activation. However, because fMRI is not easily applied to infants and very young children, it cannot provide a full picture of functional brain development. Event-related potentials, in spite of their more limited spatial resolution, provide an important additional tool because they can be applied across a wide span of age and ability level (for a review of the technique, see DeBoer, Scott, & Nelson, 2007).

The electroencephalogram (EEG) is the ongoing electrical activity of the brain, whereas the event-related potential (ERP) is the subset of this activity that reflects processing of specific stimuli or response preparation and execution. For brain electrical signals to be measurable from the scalp, they require that the activity of large numbers of neurons be summed together. When many neurons are activated simultaneously they summate and the activity propagates to the surface. It is believed that postsynaptic potentials likely provide the current that is detected by ERPs, as their time course is most compatible with that needed to provide sufficient summation of the signal (Allison, Wood, & McCarthy, 1986). The activity recorded at the surface is thought to be primarily from pyramidal cells of the cortex, as these cells tend to be aligned parallel to one another (which helps summation of activity) and oriented more or less perpendicular to the scalp (which helps propagation of activity to the surface).

ERP/EEGs are recorded from electrodes held in place on the scalp (see Figure 18.13). In research, it is common to use electrode caps or electrode nets which include a large number of electrodes, though typically not more than 256. Usually, a set of nets is needed to accommodate different head sizes across age. The circumference of

(a) (b) (c) (d)

Figure 18.13 Methods for recording EEG/ERP in infants, including (a) attaching individual electrodes with electrode paste, foam pads, and cloth headband; (b) attaching individual disposable electrodes; (c) an Electro-Cap with electrodes sewn in; and (d) and a sensor net, with electrodes held together with elastic thread.

Source: From "Methods for Acquiring and Analyzing Infant Event-Related Potentials," by T. DeBoer, L. S. Scott, and C. A. Nelson, in *Infant EEG and Event-Related Potentials*, M. de Haan (Ed.) (pp. 5–37), 2007, New York, NY: Psychology Press.

the participant's head usually provides the guide as to which size net to use for that individual. A good net fit is important for keeping the electrodes in place snug on the scalp, to ensure a good recording. Electrodes need preparation in some way prior to application in order to make a good contact with the scalp. This might involve soaking the electrode nets in electrolyte (salty water), or inserting a conductive gel around the electrode-scalp interface. The signal impedance at each electrode is typically measured before beginning the experiment, to ensure that each electrode will obtain a clear signal. For high-density recordings, this process can take some time as electrodes with high impedances may need to be repositioned or more electrolyte added. To help children tolerate this procedure without becoming bored or fidgety, they are often allowed to watch videos or play hand-held games. In the case of infants, a second experimenter is often useful to engage the baby with toys or other entertainment such as blowing bubbles.

Before recording ERP signals, researchers need to make decisions about the sampling rate, band-pass, and reference electrode. The *sampling rate* refers to how often the continuous EEG signal is sampled and digitized during the recording. This is often expressed in Hz, where, for example, sampling every 2 ms would equate to a sampling rate of 500 Hz. To accurately characterize the waveform, the sampling rate must be at least double the highest frequency of interest in the EEG signal. The *band-pass* refers to the range of frequencies being recorded, and is set by the low-frequency and high frequency filters applied to the signal. Typically, ERPs occur between .1 and 30 Hz, but researchers interested in other aspects of the EEG, such as gamma-band activity, will want to include higher frequencies. EEG can be digitally refiltered after recording to further exclude unwanted frequencies, but obviously frequencies excluded at the time of recording cannot be later recreated. Activity recorded at each electrode reflects the activity at that electrode relative to a *reference electrode*. The choice of reference electrode can be a matter of debate, as there is not a single standard and each choice has strengths and weaknesses. With high density arrays, the average reference (average activity across the whole electrode array) is common. The choice of reference is further discussed in DeBoer et al. (2007).

ERP Components

ERPs can be recorded from all of the primary sensory modalities (visual, auditory, somatosensory, and gustatory) and from motor events (e.g., a button press). However, precisely defining the time of stimulus onset is more difficult in some modalities (e.g, touch, taste) than others (e.g., visual). The ERP waveform itself typically consists of a series of peaks and troughs called *components*. Components are usually characterized by considering their eliciting conditions, polarity at particular recording sites (positive or negative), timing (latency), and scalp distribution (topography). Typically components are labeled according to their polarity (P for positive, N for negative) and either their order of occurrence (e.g., P1, P2) or mean latency from stimulus onset (e.g., N170, P300) although there are exceptions (e.g., the ERN, or error-related negativity is not labeled by its order of occurrence or latency but rather by its eliciting conditions). Sometimes, the ERP waveform also contains broad, sustained deviations from baseline called *slow waves*. These are often observed in younger individuals and/or in situations with a prolonged recording after stimulus onset. Components with latencies up to about 250 milliseconds are classically thought to reflect sensory and early perceptual processes, whereas those after 250 milliseconds or so are thought to reflect higher-level cognitive processes (e.g., memory and language; Rugg & Coles, 1996). Generally, latencies of components become shorter with age, though amplitudes may increase or decrease depending on the specific component (for further review of developmental changes in ERP components, see de Haan, 2007; Taylor & Baldeweg, 2002).

ERP Analysis

The basic preprocessing of the ERP signal is aimed at obtaining, for each participant, a clear artifact-free waveform for each electrode and each stimulus condition, which is the average of the responses over trials within a condition. This usually involves several steps:

1. *Segmentation:* During data acquisition, EEG is usually recorded in one long continuous block across the whole session, together with a set of event markers that define precisely when key events occurred, such as presentation of the stimulus or a button press response. Segmentation is the process through which the continuous EEG recording is divided into multiple shorter segments. Usually the segment includes a brief period before stimulus presentation (the baseline, usually 200 ms long) and a period after stimulus onset whose length depends on the particular experiment but is usually not more than 2 seconds.
2. *Filtering:* As described earlier, data are filtered at the time of recording, but additional filters are often applied afterwards. Filtering is the process in which activity at unwanted frequencies is removed. For example, a recording may be acquired at a bandpass of .1 to 100 Hz, and later a high-frequency filter of 30 Hz applied. Mains noise, which occurs at 60 Hz in North America and 50 Hz in Europe, can also be removed with notch filters that target specific frequencies.
3. *Artifact rejection:* Eye and body movements, movements the electrodes, and other factors can cause large signals that obscure event-related activity. During artifact rejection, trials containing artifacts such as movement are removed or marked to be corrected. This procedure can be done manually, through visual inspection and marking of trials, or it can be automated by setting criteria (e.g., all trials with activity greater than a certain microvolt value rejected). In developmental studies, particularly those with infants involving viewing visual stimuli, participants are video recorded during the ERP session, so that fixations can be monitored and any trials where participants were not looking at the screen are discarded. Sometimes, particularly when high-density recording arrays are used, researchers interpolate the resulting missing data if it is below a certain amount (e.g., on trials with no more than 10% excluded electrodes, data from those electrodes interpolated based on nearest neighboring electrodes).
4. *Signal averaging:* Because EEG signals are typically of much larger amplitude than ERPs, the ERP signal must be extracted from the EEG. Typically this is accomplished by averaging the ERP signal over repeated presentations of a particular stimulus or stimulus condition. In this way, the part of the EEG that is random with respect to the timing of the event (and presumably unrelated to event processing) averages out to zero, whereas the part of the EEG that is time-locked to the stimulus (and presumably specifically relates to its processing) is retained. Thus, in signal averaging, all the artifact free trials in a particular condition are averaged together. Typically, researchers require a minimum number of trials to contribute to an average for the average to be considered acceptable; if data from a participant does not meet this standard, they are discarded from further analysis. Note that the averaging process assumes that the brain response is invariant and has invariant latency across trials. Woody filtering is an attempt to deal with "latency jitter," which refers to conditions when this assumption of latency variation is violated.
5. *Baseline correction:* Average activity during baseline is subtracted from each subsequent time point of the waveform to help remove the influence of any global drifts.
6. *Rereferencing:* This is an optional step in which the data are mathematically referenced to a different reference electrode than the one used during recording. For high-density recordings, this is often the "average reference" or average of the activity across the electrode array.
7. *Grand averaging:* This is an optional step, where the individual participants' averages are themselves combined to make a mean waveform. This is the type of waveform typically used in published figures.

The statistical analysis of ERP data is as yet not fully standardized, and the strategies employed can vary considerably depending on the hypothesis and purpose underlying the experiment. Typically, commercial EEG/ERP systems come with software that can be used for analysis, or the data can be exported for analysis in other systems such as MATLAB or SPM. The classic approach is to quantify components of interest by measuring their peak amplitudes and the latency at which the peak occurs at electrodes of interest, or to use principal component analysis to extract summary waveforms. An approach is independent component analysis, which assumes that the scalp recorded EEG is a linear mixture of activity in underlying sources, and decomposes the scalp-recorded signal into these sources (Makeig, Bell, Jung, & Sejnowski, 1996). This type of analysis can be used to obtain event-related activity, as well as for identifying and removing the influence of artifacts such as eye blinks.

A challenge for researchers is that the timing and location on the scalp of components thought to be functionally equivalent can vary across development, so care must be taken when identifying the time windows and electrodes for extracting peak amplitudes and latencies. For example, the face-sensitive N170 component occurs approximately 170 ms after stimulus onset over posterior, lateral electrodes in adults, but the infant equivalent, the N290, occurs at about 290 ms after stimulus and has a more medial distribution (de Haan, Johnson, & Halit, 2003).

EEG Analysis

EEG is not time-locked to an event in a precise fashion, but is typically recorded in ongoing, more prolonged conditions. For example, EEG might be recorded while expressing an emotion or when a certain mood is induced. The resulting electrical activity is traditionally analyzed by decomposing the EEG signal into its constituent frequencies, by a method such as Fournier analysis, and quantifying the power in particular frequency bands. Different bands have been related to different states of consciousness or types of brain function. For example, power in the alpha band (~8–12 Hz in adults) over posterior regions is typically interpreted as being inversely related to brain activation, with high power in this band linked to low activation (see Stroganova & Orekhova, 2007, for further discussion of development of different bandwidths and their functional correlates). Investigators studying children have also been interested in studying event-related oscillations, which are somewhat intermediate between EEG and ERP measures. Event-related oscillations (EROs) are bursts of EEG at particular frequencies that are approximately time-locked to task or stimulus presentation events. There is a growing literature on EROs in adults, particularly with respect to high-frequency (gamma-band) bursts, and this approach has begun to be applied to infants (see Csibra & Johnson, 2007, for review).

Source Analysis

Another important type of analysis that can be applied to EEG and ERP data is source analysis, which attempts to identify the location of the brain sources of the scalp-recorded activity. One challenge for EEG/ERP source analysis is the inherently low spatial resolution of these measurements. The other main challenge is known as the *inverse problem*: There is not one unique solution that gives rise to a particular pattern of brain activity, but rather many different solutions are possible. For this reason, converging data from studies using other techniques such as MEG and fMRI are important to help constrain solutions.

There are two main types of approaches to source localization (Michel et al., 2004). In *dipole models*, the number of small pieces of activated cortex (dipoles) is assumed to be known, and an initial guess about their location and orientation is made. These parameters are then adjusted step-by-step until the predicted electric potential or magnetic field resembles the measured one within certain limits. In *distributed source models*, which constitute the other main type of approach, an assumption about the number of sources is not required. Analysis is based on reconstruction of the brain electric activity in each point of a 3D grid of solution points, the number of points being much larger than the number of measurement points on the surface. Each solution point is considered as a possible location of a current source, so there is no a priori assumption about the number of dipoles in the brain. Analyses aim to find a unique configuration of activity at these solution points that explains the surface measurements. A challenge in this approach is that there is not a single overall solution, and thus additional constraints are needed to identify the optimal solution. Developmental studies face additional issues, as most commercially available software packages for source localization are based on adult head models, and do not take into account differences in size and shape, volume conduction of signal, and so on that can occur with development (see Johnson et al., 2001; Reynolds & Richards, 2009, for further discussion of source analysis in developmental studies).

EEG source localization can be aided by supplementary information that helps to optimize results for individuals. For example, digitizing electrode positions helps to take away noise from inaccuracies in electrode positions; individual MRIs can be used to help better localize sources. In cases where individual MRIs are not available, there are age-specific templates that can be used (see, for example, http://jerlab.psych.sc.edu/neurodevelopmentalmridatabase; Sanchez, Richards, & Almli, 2012).

Advantages and Disadvantages

One key advantage of EEG/ERP measures for developmental study is that they can be recorded even in passive tasks, when participants are simply looking at or listening to the stimuli. Also, the environment is less restrictive than MRI or MEG (see later) and not as sensitive to movement artifact. For these reasons, EEG and ERP have been used across a wider range of age and ability level than fMRI. Another advantage is that ERP provides much better information about the timing of brain events than can fMRI, with the former providing temporal resolution on the order of milliseconds and the latter on the order of seconds.

A main disadvantage of EEG and ERP is their limited spatial resolution, which is inferior to fMRI and many other methods, and their relative insensitivity to subcortical sources. Although the data acquisition environment of EEG/ERP is often considered more child-friendly than the MRI scanner, it still requires some thought and effort to ensure cooperation of young children. Although electrode nets and caps are made as comfortable as possible, some children may not enjoy wearing them, leading to fussing or refusal. ERP also involves repeating stimuli multiple times across the session, so signal averaging can be used to extract the waveform. Young children can typically tolerate only a limited period of on-task time thus the number of experimental conditions that can be tested is small compared to what is possible in adults. This is particularly true of visual tasks, where active attention is needed; auditory tasks can be somewhat easier, as it is possible to obtain reliable auditory ERPs in sleeping infants (e.g., Suppiej et al., 2010).

A resulting further disadvantage of ERP studies, particularly those involving infants and young children, is the high attrition rates—it is not uncommon for 30% to 50% of participants to be excluded (see de Haan, 2007, Chapter 4, Table 1, for summary of attrition rates across studies). This is typically due to a combination of not tolerating the procedure (e.g., refusal to wear electrode cap) and/or noisy data (due to movement, etc.). This raises questions about the representativeness of the retained sample, and causes clear difficulties for longitudinal studies and those based on difficult-to-recruit or rare clinical samples.

Magnetoencephalography (MEG)

MEG detects magnetic fields created by electrical currents in the brain, and allows estimation of their brain sources. EEG and MEG detect the same currents—a moving electric charge is always associated with an electric field and a concomitant magnetic field surrounding the axis of movement. However, the two signals differ. Only tangential currents parallel to the head surface give rise to extra cranial magnetic fields. Thus, MEG signals arise mainly from tissue walls and are relatively insensitive to radial or deep sources, whereas EEG signals are dominated by radial currents (see Figure 18.1). Inhomogeneous tissue conductivity spreads EEG signal, which contributes to source localization difficulties, but it does not change magnetic fields, a benefit to source localization with MEG.

To record MEG, the subject sits or lies with the head inside a sensor helmet, as close to sensors as possible (see Figure 18.14). Head movement is minimized by allowing the participant to watch videos, or with restraints such as neck collars, head fixing devices, or bite bars. Head position within helmet can be determined by coils placed around the head, whose position is sensed with a 3D digitizer within an individual head coordinate system.

Data Analysis

MEG traces are similar to EEG signals, and the analysis involved for MEG data is similar to that involved in ERP data, in terms of processing and quantifying waveforms and source localization.

Advantages and Disadvantages

The testing environment of MEG is not particularly child-friendly. The MEG sensors are rigid in the helmet and the head has to be kept still relative to the helmet. Techniques such as preexposure to the equipment can help ensure better cooperation. The MEG signal fades off proportionally to the second power of the distance from the source. This creates problems for different-sized heads, within the same size helmet. For infant or small head sizes, special designed baby helmets, or adjustable devices must be used. MEG systems are relatively costly, and so are not as widely used as alternatives such as EEG.

Figure 18.14 A child viewing a movie during a demonstration of magnetoencephalography (MEG).

Source: Joseph Kaczmarek/AP in Encyclopædia Britannica. Retrieved from http://www.britannica.com/EBchecked/media/155985/

Electromyography (EMG)

EMG detects the change in electrical potential generated by muscle cells when the muscle contracts. It can measure involuntary responses believed to reflect activation of specific pathways in the central nervous system. One such reflex is the startle response. Startles—components of the defensive motivational system—are responses to sudden unexpected stimuli such as a flash of light or a loud noise. They include involuntary contractions of muscles in the legs, arms, and around the eye (i.e., blink reflex). Startle responses figure in social and affective neuroscience because they are modulated by emotion-evoking stimuli that produce different motivational states (Lang, Bradley, & Cuthbert, 1998). Emotion-modulation of the startle response involves pathways from the amygdala and bed nucleus to brainstem nuclei that generate startle responses (Davis, Walker, & Lee, 1997).

It is common to measure startle by placing electrodes over the *obicicularis oculi*, a muscle group that is just below the eye, and then measuring the EMG intensity of blink in response to a startle (often acoustic) probe. The motivational or emotional state of the participant can be manipulated by conditioning them to threat-predicting versus safety-predicting cues (Lissek et al., 2005), or by showing them static photos or movie clips rated to evoke different emotional/motivational states (see Lang et al., 1998). Photos of people displaying different emotional expressions also modulate the startle reflex, with increases in response to threatening facial expressions and decreases to positive facial expressions (Hess, Sabourin, & Kleck, 2007).

In contrast to the typical pattern, in which exposure to negative stimuli increases startle and exposure to positive stimuli decreases startle, individuals with autism spectrum disorder show startle potentiation to both positive and negative stimuli (Wilbarger, McIntosh, & Winkielman, 2009; see also Dichter, Benning, Holtzclaw, & Bodfish, 2010). This difference occurred even though implicit valence appraisals, as measured by facial EMG responses, and appropriate overt appraisals, as measured by self-reported ratings of the stimuli, did not differ between those with and without autism. The results suggest a disruption in basic affective processes in ASD at an early stage of motivational processing.

Another measure using the startle reflex is *prepulse inhibition* (PPI). In this paradigm, the reflexive startle eyeblink response to an abrupt, and intense noise burst (pulse) is inhibited when a weak (e.g., 60 to 85 dB) acoustic stimulus (prepulse) precedes the startle stimulus at a short (e.g., 60 to 300 ms) stimulus onset asynchrony. PPI is already present in human neonates and children (Anday, Cohen, Kelley, & Hoffman, 1988; Ornitz, Guthrie, Sadeghpour, & Sugiyama, 1991) and typically increases with age until about 10 years (Gebhardt, Schul-Juergensen, & Eggert, 2011). A study used PPI to investigate the potential negative effects of maternal stress on the neuromaturation of information processing. Results showed a different development of PPI in infants whose mothers reported enhanced stress levels due to social isolation and reduced social recognition, suggesting altered development of brain inhibitory systems (Huggenberger, Suter, Blumenhtal, & Schachinger, 2013).

AUTONOMIC NERVOUS SYSTEM

In addition to the techniques aimed at assessing the central nervous system described above, researchers have also benefited from measuring activity of the peripheral nervous system as this system is involved in our every day experience. Measures of peripheral activation, such as heart rate, muscle activity, and electrodermic responses, can be easier to obtain than many of the measures described above, yet still provide important insight into neural bases of behavior. Cardiac and electrodermal measures have been used to assess activity of the autonomic nervous system.

The *autonomic nervous system* (ANS) is both responsive to information processed by the central nervous system and provides feedback that affects central activity (Porges, 1995). The two arms of the autonomic nervous system, *sympathetic* (SNS) and *parasympathetic* (PNS), are regulated through different neural pathways and, although often opposing one another, function separately (Berntson, Cacioppo, Quigley, & Fabro, 1994). Because many target organs are innervated by both arms of the ANS, simple measurements of the organ's activity reflect both SNS and PNS contributions. For example, although an increase in heart rate might be interpreted as a sympathetic response, this is inaccurate as heart rate increases can reflect increased sympathetic input, decreased parasympathetic input or some combination. Different psychological states (e.g., fear versus positive excitement) produce heart rate accelerations through different patterns of sympathetic activation and parasympathetic withdrawal (Berntson, Cacioppo, Binkley, et al., 1994). One challenge for researchers has been to develop pure measures of each arm of the ANS. Below, the commonly used procedures to measure the ANS is described, beginning with those used to assess sympathetic activity.

Sympathetic Activity

The sympathetic nervous system uses acetylcholine as its preganglionic neurotransmitter and norepinephrine (NE: predominantly in most tissues) and epinephrine (E: predominantly from the adrenal medulla) as its postganglion neurotransmitters. E and NE produce their effects via alpha (higher affinity for NE than E) and beta (higher affinity for E than NE) adrenergic receptors. Although the sympathetic nervous system is capable of mass discharge, as in intense fight/flight responses, the differential sensitivity of alpha and beta receptors to E and NE, and the fact that most E is produced by the adrenal medulla rather than the nerve endings of most postganglionic sympathetic fibers, mean that assessing sympathetic input to different organs provides information about different aspects of sympathetic functioning.

Cardiac Activity—Pre-Ejection Period

The *pre-ejection period* (PEP) is often used to index sympathetic activity. It is the time from the onset of ventricular depolarization, as indexed by the QRS complex (the series of deflections in an electrocardiogram that represent electrical activity generated by ventricular depolarization prior to contraction of the ventricles), until the beginning of left ventricular ejection (Berntson, Quigley, & Lozano, 2007). In other words, it is the time when the left ventricle of the heart is contracting against the closed aortic valve or the time between when the heart signals pump and the valve is opened to allow the left ventricle to pump the blood to the right ventricle. Beta-adrenergic receptors responsive to E (particularly) regulate PEP duration, with increases in beta adrenergic activity *shortening* the pre-ejection period.

To measure PEP, the researcher needs to know both when the QRS complex occurs (i.e., when the heart signals pump) and when the blood is released from the left to right ventricle (i.e., when the aortic valve opens). The QRS complex can be identified in the electrocardiogram, but to obtain information on when the aortic valve opens impedance cardiography is used. Electrodes are placed on the neck and thorax and a low-grade electrical current (2 to 4 mA) is sent through the heart. Impedance is the resistance to the flow of an electrical current and, because blood is a better conductor than tissue, when the left ventricle is full of blood, impedance is lower than when it is empty. The increase in impedance when the ventricle empties (and thus the aortic valve has opened) is indexed by a particular waveform (dZ/dt where Z is bioimpedance, a measure of the way biological tissues conduct alternating current activity). Thus, to measure PEP one identifies the time difference between the QRS signal in the electrocardiogram and the dZ/dt complex in the impedance cardiogram (see also Lozano et al., 2007). PEP is measured with each heart beat and typically averaged. Because sympathetic activation of the heart may be very brief in response to many psychological challenges imposed in the laboratory, the issue for the researcher is to identify the smallest number of heart beats to average to capture a sympathetic response while still averaging out errors in measurement. Two-minute periods are often preferred (e.g., Demaree et al., 2006). Developmentally, although PEP has been measured in infants, children, and adults, there is evidence that this measure may be less responsive to stimulation in children (Quigley & Stifter, 2006).

Electrodermal Measures—Galvanic Skin Response

The *galvanic skin response* (GSR), also called the *skin conductance response* (SCR) or *electrodermal response* (EDR), is a method of measuring the electrical resistance of the skin. This resistance is decreased with sweating as electrical signals flow more readily through fluid than tissue. Sweat is produced by eccrine glands that are under sympathetic regulation. Thus GSR provides a measure of sympathetic activity. GSR is conducted by attaching electrodes to the skin, usually on the fingers. There are a variety of automated systems for GSR collection.

One study used GSR to examine fear-extinction learning across development in mice and humans to test the hypothesis that immature functional connectivity between the ventromedial prefrontal cortex and amygdala in adolescents affects emotion regulation (Pattwell et al., 2012). Parallel behavioral studies using the GSR measure in humans and freezing behavior in mice revealed attenuated extinction learning during adolescence. Probing neural circuitry in mice revealed altered synaptic plasticity of prefrontal cortical regions implicated in suppression of fear responses across development. The results suggest a lack of synaptic plasticity in the prefrontal regions during adolescence is associated with blunted regulation of fear extinction.

Parasympathetic Activity

The parasympathetic arm of the ANS complements sympathetic activity in the organs and tissues they jointly innervate. Sympathetic activity typically accelerates working over organs and tissues and parasympathetic activity typically provides the brakes (Berntson et al., 2007). The parasympathetic nervous system uses only acetylcholine (Ach) as its neurotransmitter operating through muscarinic and nicotinic cholinergic receptors. Typically, parasympathetic ganglia are close to their areas of innervation, allowing the parasympathetic system to operate in a highly nuanced fashion. Interest in social neuroscience has been directed to the portion of the parasympathetic system associated with the 10th cranial or vagus nerve arising from cell groups in the brainstem at the level of the inferior olivary complex. Two cell groups in this complex regulate different aspects of vagal activity: The nucleus ambiguous provides vagal innervation to the heart, while the motor nucleus primarily regulates activity at the level of the gut. This differentiation of vagal regulation is the basis for Porges' (1995) *polyvagal theory*, which argues that cardiac measures of vagal activity are closely orchestrated with neural activity innervating facial muscles, and thus with the capacity of humans and other higher primates to engage in complex social interchanges that involve controlling emotional expressions and with speech, which requires coordination of breathing, tongue, and larynx. Because of vagal feedback to the nucleus tractus soliarius in the midbrain, which sends afferents to the hypothalamus, amygdala, and cingulate gyrus, activity of this segment of the PNS may also help play a role in inhibiting or regulating central emotional reactivity. From an individual differences standpoint, considerable attention has been paid to differences in vagal regulation as it relates to social and emotional competence (e.g., Bornstein & Suess, 2000; Moore, 2010).

Respiratory Sinus Arrhythmia or Vagal Tone

Vagal input to the heart slows heart rate by reducing the conduction velocity of the sinatrial (SA) node. During expiration (breathing out) vagal input increases, slowing the heart, whereas during inspiration (breathing in) vagal input decreases, allowing the heart to beat faster. Variations in heart rate associated with breathing index the degree of vagal input to cardiac control, hence the terms *respiratory sinus arrhythmia* (RSA) or *vagal tone* (VT). Average heart rate variability provides a rough index of vagal regulation, but because only some beat-to-beat variability reflects breathing, heart rate variability (HRV) is not a reliable index of vagal activity. All techniques for measuring RSA or VT depend on isolating the beat-to-beat variability dependent on breathing. This can be done somewhat directly by simultaneously collecting respiration data and then isolating co-occurring variability in interbeat intervals (IBI), or through examining variation in the spectral frequency that is typically associated with breathing. Both methods provide fairly similar results in healthy children and adults under most laboratory conditions of psychosocial measurement (Berntson et al., 2007). RSA or VT tends to decrease when individuals actively process social information and when they speak. Developmentally, baseline RSA or VT increases over the first years of life (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996), although changes in RSA or VT to social and emotional stimuli are observed in both children and adults (Quigley & Stifter, 2006).

CONCLUSIONS

This chapter has overviewed the diverse neuroscientific methods that are used to study the central and autonomic nervous system during human development. The range of methods available is powerful as these methods provide the opportunity to understand brain ←→ behavior relations at many different levels of analysis.

What use are these diverse approaches to researchers interested in studying development? A main importance for developmental neuroscientists is, of course, the usefulness of these methods for understanding the development of the human brain as its own point of study. However, these methods can be useful in a number of further ways. First, they can complement measures of behavioral development in a number of ways. Behavioral measures tend to inform about the outcome of cognitive, emotional, and motivational processes, and neuroscientific measures, particularly those with good temporal resolution, can inform about biological processes associated with these outcomes. They may also provide useful indexes of developmental change in populations with limited response repertoires, such as young infants and those with developmental delay. Evidence of processing and discriminating information may, for example, be apparent in brain measures even if they are not yet evident in behaviors. Secondly, building from the last point, neuroscientific measures have potential use as markers for developmental trajectories. A change in neural activity may precede the emergence of new skills, or a developmental set back, and thus can be useful from educational or clinical points of view. For example, one study found that working memory related activation in the left intraparietal sulcus predicted arithmetical outcome independently of behavioral measures (Dumontheil & Klingberg, 2012). A logistic model including both behavioral and imaging data showed improved sensitivity by correctly classifying more than twice as many children as poor arithmetical performers after 2 years than a model with behavioral measures only. These results demonstrate that neuroimaging data can provide useful information in addition to behavioral assessments and be used to improve the identification of individuals at risk of future low academic performance.

Combining neuroscientific methods can potentially provide a more comprehensive picture of the development of brain function, by providing good temporal and spatial information on brain activation, and how it affects peripheral systems. This represents a technological and statistical challenge, but it may be possible to combine measures from different modalities into a single brain index reflecting the different aspects of information.

One impediment to using some neuroimaging methods, such as MRI, can be there relatively high cost. One potential value of using multiple methods within the same study, in addition to the benefit of multiple levels of analysis, is that it may provide useful links between tasks for further study. For example, many methods for studying the autonomic nervous system are relative inexpensive and easy to obtain, yet they are still thought to tap into central nervous system processes. A better understanding of these relations during development may allow better exploitation of these inexpensive, easier methods as ways of marking central nervous system function.

From a developmental perspective, one challenge is that it is not always possible to use the same techniques across development, from infancy to adolescence and beyond. For example, MRI brain imaging techniques have been used mainly with children older than 7 years, at least for studies of normative development, because of issues of cooperation in the scanning environment. This can make it difficult to document a comprehensive developmental trajectory of structural and functional brain development. Techniques such as EEG/ERP, which can be applied to participants across a wide range of age and ability levels, can provide important information in this regard. However, there are few to date which have actually applied these techniques using the same paradigm across a wide age span. Comparisons across age are themselves not always easy even when the same tool can be applied. For example, physical changes in respiratory systems or skull thickness can influence MRI or EEG measurements, respectively, and one must be informed so as not to misinterpret changes related to nonneural factors as changes in brain function or structure. Changes in behavioral performance across age are, on the one hand, a point of interest for study. However, distinguishing changes in brain activity related to age and changes in brain activity related to performance is not always straightforward.

A general limitation of many methods described in this chapter is that they require obtaining nervous system measurements under circumstances seemingly very different from everyday life. Although this is true across the life span, the atypical environment of the MRI scanner or MEG machine may be particularly influential on results obtained with younger children. Can results obtained in these circumstances really inform about how the brain operates in everyday life? One approach to tackling this issue is with task-development. Employing more real-life tasks may make results more applicable to daily life and possibly even more engaging for participants. For example, one study examined neural processes that were evoked naturalistically, during educational television viewing. Children and adults all watched the same *Sesame Street* video during functional magnetic resonance imaging (fMRI), and analyses computed measures of neural maturity for different brain regions. Neural maturity in the intraparietal sulcus (IPS), a region with a known role in basic numerical cognition, predicted children's formal mathematics abilities. In contrast, neural maturity in Broca's area correlated with children's verbal abilities, consistent with prior language research. These data show that children's neural responses while watching complex real-world stimuli predict their cognitive abilities in a content-specific manner (Cantlon & Li, 2013). Technological advances may also assist researchers in obtaining brain measurements under more everyday circumstances. Open field MRI scanners already exist, though are not common; wireless EEG/ERP and NIRS systems have also been commercially developed, though are not yet commonly used in scientific research.

Theoretical and metatheoretical models such as Relational-Developmental-Systems (see Marshall, Chapter 7, this *Handbook*, this volume; Overton, Chapter 2, this *Handbook*, this volume) must guide research using neuroscientific methods. Often, psychological researchers may feel forced to adapt their research questions to fit in with the available neuroscientific technology; however, the reverse pathway should also operate. For example, theories of human functional brain development such as the interactive specialization theory have implications for use of neuroscientific tools. In the interactive specialization view, development is in part characterized by an increased localization and specialization of the brain's activation in a particular task or while carrying out a particular function (Johnson, Grossmann, & Cohen Kadosh, 2009). This theory highlights the importance of whole-brain approaches, and connectivity-based approach as it makes predictions about how the pattern of activation and connectivity across the whole brain changes, not only in isolated regions.

A standard neuroimaging study gives rise to massive amounts of noisy data with a complicated spatiotemporal correlation structure. Statistics plays a crucial role in understanding the nature of the data and obtaining relevant results that can be used and interpreted by neuroscientists. Advances in analysis need to keep up with the increasingly vast amounts of data made available through advances in acquisition techniques, to make the best use of these data. Modeling of change across time in such vast data sets is a major challenge. Another challenge from a data processing point of view is characterizing individuals. To interpret results from neuroscientific methods at the level of the individual, reliable methods and solid normative data are required. This is particularly challenging for a number of reasons, including data loss from artifact (e.g., infant ERP, where many data are lost due to artifacts), and the difficulty in establishing normative databases that keep up with rapid changes in technology.

Ultimately, many of the challenges of methods described in this chapter related to the fact that studying development involves studying a relational, developing, changing system, with methods that themselves rapidly change with technological advances. Moving forward, further strong interdisciplinary work and collaboration to build strong methods and resources such as normative databases will be very valuable.

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CHAPTER 19

Mixed Methods in Developmental Science

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A review of the theoretical and methodological chapters in prior editions of this *Handbook* reveals a multistage progression from a focus on understanding typical developmental and variable relations, to describing the organization of the development of individuals across time and place (see Elder, Shanahan, & Jennings, Chapter 2, this *Handbook*, Volume 4). To explain more complex, contextual, and interrelated aspects of development, this progression has led to a focus on characterizing the relational developmental systems interdependencies that constitute the fundamental processes of human development (Lerner & Benson, 2013; Overton, 2013, Chapter 2, this *Handbook*, this volume). Accompanying this progress has been increasing attention to metatheory, issues of paradigm and epistemology, and the explicit acknowledgment that any given study or set of studies provides a limited, partial understanding of developmental processes (Overton, 2006, 2013, 2014, Chapter 2, this *Handbook*, this volume). Co-occurring with this history, there has been progress in analytic interests and related methodologies that facilitate sophisticated alliances of methods with theory, the incorporation of Relational-Developmental-Systems and transactional models into statistical and qualitative analytic models, a greater recognition of the limits of any given method of analysis, and a recognition of the necessity of providing explicit justifications for the choice of any analytic tool (Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2003, 2010; Ram & Grimm, Chapter 20, this *Handbook,* this volume; von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume). Overall, these advances, along with the increasing appreciation for the contextual, interrelated, and dynamic nature of human development, point to the value of coordinated use of multiple methods.

This chapter focuses on the reemergence of an appreciation of the value of multiple methods, or more specifically *mixed methods*, that is, the coordinated use of more than one method, including quantitative methods and analytic techniques (e.g., dynamic factor analysis, structural equation modeling, or configural frequency analysis) and qualitative methods and analytic techniques (e.g., interviews, focus groups, discourse analysis, or narrative analysis) in advancing understanding of developmental processes (Tashakkori & Teddlie, 2003). Although the term *mixed methods* most commonly refers to the juxtaposition of qualitative and quantitative methods, in this chapter the term is used to refer to *systematic application of more than one quantitative and/or more than one qualitative method*. Mixed methods, either within or across quantitative and qualitative methodologies, offer advantages for reducing uncertainty and providing frameworks for elaborating understandings that cannot be gained through reliance on a single method. Furthermore, multiple methods can reveal important limitations of understandings gained from a single method, expanding the types of knowledge generated and contextualizing prevalent measurement and methods not subjected to prior juxtaposition-based scrutiny (Tashakkori & Teddlie, 2003). This perspective is based on the view that the use of mixed methods enriches the sophistication and utility of description and explanation in the developmental sciences and, thus, ultimately enriches developmental science as a whole.

The value of mixed methods can be traced to increasingly sophisticated attempts to address two central challenges for developmental science. The first challenge entails understanding and reconciling three conflicting truisms:

1. There are fundamental universal developmental processes and benchmarks.
2. There are meaningful variations by subgroups that are not reducible to simple derivations from the universal processes.
3. Each organism's development is a unique entwining of individual and context and this relational system functions in a reciprocal bidirectional manner (←→) (Lerner & Benson, 2013; Overton, 2013, Chapter 2, this *Handbook*, this volume).

The second challenge for developmental science concerns the need to characterize state and change simultaneously and dynamically, while recognizing that in their interdependence one does not simply determine the other (Thelen & Smith, 2006). To understand human development, then, requires that metatheory, theory, and research capture the dynamic stability of developmental processes as a rapid cascading multi-influence developmental stream that is contextually—sensitive with patterns occurring at multiple levels on multiple timescales through fluctuations and transitions (Cummings & Valentino, Chapter 15, this *Handbook*, this volume; Lerner, 2006; Masten & Cicchetti, 2010; Overton, 2013). Such understanding may exceed the capability of any given specific theory or method.

These challenges concerning progress in accumulating substantive knowledge could be viewed as precluding the possibility of gaining a scientifically based systematic accumulation of lawful knowledge of development. However, these challenges can be, and for the most part have been, more usefully viewed as evidence of the complexity of phenomena that are of interest to developmental science. Although still pointing to the importance of unifying and integrating analyses, addressing these challenges is central to a relational developmental systems approach that is oriented toward programmatic scientific knowledge building (Overton, 2006, Chapter 2, this *Handbook*, this volume; Tashakkori & Teddlie, 2003). This knowledge building—as argued elsewhere (Boker, Molenaar, & Nesslroade, 2009) and demonstrated in previous editions of this *Handbook*—requires the careful articulation of explicitly detailed theory within the relational epistemological framework. Further, the knowledge building necessitates careful attention to how the methods of specific research studies are consistent with the theory so articulated. This latter requirement entails an explicit acknowledgement of the assumptions made and constraints imposed by any given method (Bates & Novosad, 2008). In this context the systematic application of more than one method can add to the quality of understanding that can be gained from a given study. Additional methods can increase confidence of the validity of the results and provide better understanding of how a given study relates to the larger field (Campbell & Fiske, 1959). Additional methods can also provide an understanding of the specific implications and limitations of a given set of findings and how those relate to methods of inquiry and analyses that is difficult to otherwise demonstrate.

It seems evident then that there are important advantages in the often-lauded use of multiple methods. Yet, this important hedge against bias, unknown generalizability, reliability of findings, contextual insensitivity, and undue realism in interpretation of results is rarely implemented (Podsakoff, MacKenzie, & Podsakoff, 2012). For example, a review of six areas of psychological research found that in 76% of studies only a single measurement method was utilized and approximately half of those were self-report (Bodner, 2006). Even multiple measures of constructs are still unusual, despite recognition that multiple measures increase the internal validity of a study (Grissmer, Subotnik, & Orland, 2009). Moreover, in most studies there is a notable lack of explanation concerning how the study's measures are based in a theory of measurement and how that is tied to the substantive formulations of the subject matter, including how the measures are theory-based. This situation can be problematic, as it promotes the faulty assumption that measures are free of theoretical entailments and that they are "objective" representations of constructs. Without operational definitions of such constructs that are tightly tied to their measurement and the needed coverage of the domain of interest, important theoretical implications and constraints of a given measure are treated as trivial.

Two such examples can be found in the cases of *social class*, a broad construct utilized in some way across many developmental studies, and *parental monitoring*, a specific construct that has had much attention and is focused on the role of parenting practices in child outcomes. Social class is a construct that is measured in multiple ways in developmental science, yet investigators seldom describe in much detail their choice of measures as grounded in theoretical or empirical implications that come with using different markers for social class (e.g., parental education versus household income versus free/reduced lunch status versus neighborhood average income; Deutsch, Lawrence, & Henneberger, 2013). Moreover, there has been limited attention given to the reason social class is included in a given study (e.g., is it treated almost automatically as a qualitative difference for the very poor versus the rest of society or as some easily measured linear unidimensional developmental influence?). Social class is treated as an "address" or without much explanation of the basis for and why this conceptualization is preferable (Oakes & Rossi, 2003).

The second example is parental monitoring. There has been widely held consensus that this concept reflects parental attention to and care for the safety, behavior, and interactions of the child (Tolan, Dodge, & Rutter, 2013). Yet, many if not most studies have relied on measures with a large portion of item content actually reflecting adolescent disclosure and parental-adolescent communication (Stattin & Kerr, 2000). The disjuncture between measure content and construct could mean that communication back and forth is the critical parent-child construct or that monitoring is important but has just been poorly measured. Thus, although there is conceptual consensus and even shared measures that predominate, the lack of correspondence of the measure content and the construct conception raises uncertainty and skepticism about a large body of findings. Both examples show that measurement decisions have theoretical and empirical impact that if unstated could easily misdirect understanding of findings. In both examples the constructs as measured represent complex and dynamic constructs that should be defined specifically in relation to theoretical interest and measurement issues. Unfortunately, too often the theoretical basis and appropriateness of measurement used in a given study are detached from application.

Simply increasing the use of multiple measures and assuring that measurement is closely and thoughtfully tied to the specific framework and theoretical formulation guiding a given study can substantially improve the construction of valid knowledge. Employing multiple measures would increase focus on how variations in methods affect results and impact on relations among studies. Further, as a basic version of multiple methods, multiple measures can help close the often present and considerable gap between the metatheoretical framework guiding developmental science, the theory guiding a specific study, and actual methods as an expression of theory within a metatheoretical framework. Most basically, the increase in information gained by use of multiple measures, even within a given theory and frame, leads to substantially improved specificity and understanding of the generalizability of a given study. When this approach is elevated to use of multiple methods, uncertainty concerning the meaning of the results of studies is even further reduced, by a comparatively larger extent. Furthermore, the potential explanatory power of a given body of studies is increased.

DEFINING A MIXED METHODS FRAMEWORK

As noted earlier, the term *mixed methods* most commonly refers to the coordinated combination of methods in a study or series of studies and may be comprised of quantitative and qualitative methods, whether across these two categories or within each (Tashakkori & Teddlie, 2003). However, much of the writing about the value and challenges of the use of mixed methods has been about the juxtaposition of quantitative and qualitative methods, which differ in the type of data recorded (numerical codes versus textual/descriptive renderings) and usually in reliance on numerical analysis (although numerical analysis can be used with qualitative data and as part of qualitative methods; Creswell & Clark, 2007).

Although mixed methods were first used in psychology in the early 20th century (Teddlie & Tashakkori, 2003), in the field of human development, developmental scientists have historically conducted their studies primarily, and often solely, within a quantitative methods framework. This may stem from developmental science's origins in psychology as a lab-based science and following John Stuart Mill's (1858) *System of Logic* (Guba & Lincoln, 1994). Mill positioned the social sciences in relation to the physical sciences, with identical aims of attaining explanation and prediction through the discovery of timeless universal laws. This view of the social sciences, including developmental science, has its roots in the methodologies of positivism, neopositivism, and postpositivism, all of which asserted the ontological assumption that there is a bedrock objective mind-independent reality, and the epistemological assumption that this reality can be objectively isolated, measured (either in whole or in part), and either verified (positivism and neopositivism) or falsified (conventionalism, instrumentalism, postpositivism; Lincoln & Guba, 2003; Overton, 2006). As a result, Mill positioned the social sciences as methodologically identical to the physical sciences in having the aim of reducing the world of common sense observation to a bedrock "objective" reality that could be captured through the discovery of timeless, unchanging universal laws. However, it was quickly recognized, at least theoretically, that human development is not well mapped through reduction to simple universal lawful cause-effect relations. Central to this misfit are the aforementioned conflicting truisms of universal, group specific, and individual uniqueness in developmental phenomena and challenges in characterizing interdependent states and transitions. Similarly, people's beliefs and understandings of their own needs, relationships, and settings and the saliency of the situational context can all vary among persons otherwise thought to be the same (e.g., people sharing group characteristics, such as ethnicity, circumstances, such as neighborhood residency, or disposition, such as personality traits). The difficulty in social science of approximating the isolation and control of potential causes/influences aspired to in the physical sciences such as chemistry and physics quickly brought into stark relief the limits of neopositivism. This has resulted in researchers questioning social science's reliance on neopositivism's methodological strictures as the dominant or even preferable research methodology. The limitations of relying on quantifying all phenomena against a universal standard emerged quickly after the field formed. These limitations were further recognized through the difficulty researchers had in teasing apart the meaning of the many variations found in what were presumed to be universal human characteristics and practices. Perhaps most pertinent to this chapter's topic was the accompanying recognition that hypothesis testing and systematic characterization through the statistical calculations of data patterns was only useful when understood as a chosen focus and slice of a more complex and varying picture; that every study was not intended to isolate universal laws of behavior, but instead quantification and probability hypothesis testing informed through providing elaborate and more useful description of a recognized focus on a particular issue or area (Tolan, Keys, Chertok, & Jason, 1990). A closely related important criticism of the neopositivist and postpositivist "law identification" approach was that theories and methods carry many assumptions that can and often are unrecognized by those using them. This fact led to an understanding of scientific methodology as working within a set of assumptions, and framework for analysis, that is contextually socially situated; that research goals and method cannot be split into separate "watertight" compartments (see, e.g., Hanson, 1958; Kuhn, 1977; Lakatos, 1978). The recognition of these limitations of a model for developmental science derived from the strictures of the neopositivist's methodology spurred interest in a different understanding of the relation of method and results (not objectively independent) and for development of methods that could inform differently than could be extracted from statistical estimates of chance occurrence of quantified relations.

In line with this differentiation between the physical and social sciences, Ragin and Amoroso (2011) identify seven goals that can be a purpose of social research. Some of these are consistent with interests of research in the physical sciences, whereas others are distinct in social science:

1. Identifying general patterns and relations.
2. Testing and refining theories.
3. Making predictions.
4. Interpreting culturally or historically significant phenomena.
5. Exploring diversity.
6. Giving voice (e.g., providing opportunity for perspectives, interests, and experiences of those who otherwise would be disenfranchised, marginalized, or otherwise not likely to be considered or influential on understanding obtained from research).
7. Advancing new theories.

Ragin and Amoroso's (2011) goals, particularly refining theories and exploring diversity, touch on the central interest in developmental science of explaining unifying patterns, variation of subgroups, individuals' relation to subgroups and overall patterns, and of richly informing about stability as meaningful components of patterns. Notably, although all of these goals or these guiding central interests are unlikely to be the purpose of a given study, all are important aspects of research to achieve understanding of human development. And perhaps most pertinent to this chapter is that no single method can enable all goals and juxtaposition of different methods is an important tool for improving contributions to the overall field. This expansion of the purpose of research in the important goals for adequate understanding and in the recognition of the contextual nature of scientific inquiry also point to the value of mixing of methods with different capabilities and limitations.

This variety of goals has motivated researchers to develop new frames for combining different methodologies (e.g., qualitative in addition to quantitative). Although less recognized within discussions of mixed methods, these goals also have spurred recognition that different methods within quantitative and qualitative approaches serve different purposes and can be useful to combine as mixed methods. In the main, there has been focus on which research goals are best met through qualitative versus quantitative methods. For example, identifying general patterns across persons or groups, and making predictions to test theories about variable relations are typically considered best suited to quantitative methods. Similarly, qualitative methods are generally considered preferable for interpreting culturally significant patterns, particularly subtle influential ones, exploring diversity within groups and across settings, giving voice, and providing and advancing new theories (Ragin & Amoroso, 2011). However, these distinctions about method and subject matter are not complete nor fully directive but rather indications of the complimentary value of the different methods and perhaps more importantly, of the need to consider scientific interest and methods in tandem. For example, qualitative methods may be quite helpful to test and refine theories, a purpose more traditionally ascribed to quantitative methods. The study of the New Hope antipoverty program (Gibson-Davis & Duncan, 2005) provides a useful model of how both qualitative and quantitative methods, when mixed can provide a richer answer to the question of "does this program work" by permitting consideration of overall rates of intended benefits, identification of patterns in how participants utilized program benefits that might explain differences in effects, prediction, and validation of which subgroups seem best able to benefit from the programs, and exploration and understanding of diversity in outcomes with the program (e.g., boys' versus girls' outcomes). Given the population the program was seeking to serve, mixing methods also provided crucial voice to the participant experience to inform judgment of its overall value (Gibson-Davis & Duncan, 2005).

In addition to helping address the challenges of understanding varying patterns and uniqueness, transition and stability, and different goals of research, the value of mixed methods has been recognized increasingly as permitting enhancement of scientific understanding because of the varying strengths and limitations of any given method. Quantitative and qualitative methods have often-complementary strengths that when used for comparison of results allow scientists to get a more complete picture of the complexity of human development as it occurs in context. As Yoshikawa and colleagues state, "The combination of words and numbers can bring us closer to the complexity of developmental change by providing divergent as well as convergent data" (Yoshikawa, Weisner, Kalil, & Way, 2008, p. 345). Certainly no one would argue that the only knowledge needed about the world is of either quantity (numeric) or quality (nonnumeric). For example, in chemistry, typically thought of as a quantitative science, chemists use qualitative analysis to "identify the components of a substance or mixture" (Merriam-Webster, 2013).

In much this same way, quantitative developmental scientists often draw on qualitative methods to determine the meaning and basis for quantitative relations. This use of mixed methods has produced identification of many of the important considerations related to mixing methods. Similarly, the relating of qualitative and quantitative methods in a study or series of studies has demonstrated key contributions multiple method use can bring to developmental science. However, this limited approach to mixing methods privileges quantitative methods as primary and by implication as more authoritative. This may be a serious misdirection in a given application. Furthermore, such a view ignores the value of qualitative inquiry in its own right and of the multiple ways quantitative and qualitative methods can be mixed for different purposes. Moreover, the framing of mixed methods as only or specifically about combining qualitative and quantitative methods obscures the fact that the issues raised are also relevant to mixing of methods within qualitative or quantitative methodologies. The value of mixed methods for a Relational-Developmental-Systems approach is in how two or more methods can be applied and related to improve understanding, sophistication, accuracy, and context irrespective of specific type of data and analyses.

A Relational-Developmental-Systems Approach: Recognizing Partial Understanding Inherent in Any Given Method

An important implication of the Relational-Developmental-Systems approach to developmental science is that robust findings emanate from recognition of the framework and context within which specific hypotheses and reliable measurement are applied (Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2003). Thus, an essential assumption is that any given measure, study, or method can only provide a partial understanding and that it is through the pattern of study and results, including purposeful replication that sound understanding advances. Moreover, understanding is rooted in recognition by the researcher and explanation of the framework guiding theory and research design for a given study or set of studies. For purposes of organizing work being done in various areas of the developmental sciences in a manner that reflects cognizance of this principle, Lerner (2006; Lerner & Benson, 2013; Lerner & Overton, 2008) and Overton (2006, 2013, Chapter 2, this *Handbook*, this volume) have proposed a Relational-Developmental-Systems perspective. They propose that this perspective is a preferable alternative metatheoretical framework to the classic Cartesian-Split-Mechanistic research paradigm because it carries explicit expectation of attention to assumptions and recognition of the limits accompanying those assumptions as well as emphasizing the consideration of patterns of results and consistencies and inconsistencies that emerge with competing theories. They offer this frame to assist in reconciling the disparate interest of developmental investigators concerning the aforementioned interest in development as universal, yet systematically varying, and also unique within individual self-organization, and as oriented toward reconciling "the ceaseless flux and variability of real-time action with the orderly, organizational flow of development" (Lerner, 2006, p. 5). The dynamic, multilevel, contextually based formulation of individual development against well-defined patterns that represent the shape and shift of group and organism characteristics over the life span carries strong implication of an inherent limitation in each analytic method, even as the sophistication and number of these methods increases (Lerner, 2006; Overton, 2014). Yet this formulation also implies the value of replacing identification of the correct theory, method, or study with the correct use of a given theory, study, or method to form a coherent understanding through systematically relating carefully determined sets of findings from multiple theories, studies, and methods.

Within this framework, mixed methods is the purposeful juxtaposition of partial understandings from a set of specific methods within a given study or set of studies to better incorporate the knowledge gained from a given method into an understanding of the overall dynamic systems of development while also acknowledging each method's inherent limitations. As methodological tools are increasingly differentiated for characterizing specific features of relational developmental systems (e.g., multiple levels of causality, cascading patterns of developmental influence, and between and within individual fluctuations), the value of turning toward multiple methods becomes increasingly apparent. The use of multiple methods is critical to enriching understanding and improving confidence in the meaning of scientific concepts and scientific findings. Mixed methods serve to (a) explicitly characterize how a given method reflects an underlying theory, (b) expand understanding of a given phenomenon through providing different types of knowledge (e.g., generalizable patterns, contextual understandings), and (c) improves confidence in the meaning of constructs and findings when the same topic is studied using two or more methods. The systematic employment of mixed methods is consistent with a Relational-Developmental-Systems framework because it facilitates the understanding of development through the reconciliation of multiple partial meanings.

QUALITATIVE METHODS: A BRIEF OVERVIEW

Because most developmental scientists are trained in quantitative but not qualitative methods, a brief overview is provided of some prominent qualitative methods and analytic approaches. Qualitative methods are primarily naturalistic (Lincoln & Guba, 1985), meaning that data are grounded in and represent people's daily lives (versus constructed or manipulated scenarios). Yet within qualitative traditions, a number of methods and approaches exist. Different types of qualitative methods have advantages for addressing different research questions and purposes. The presumptions and purposes of each can also point to how different methods can be mixed with others to provide a richer understanding. Here a brief overview of different qualitative methods and the types of information each provides can highlight its uses and limitations within developmental science. This overview includes both data collection methods (e.g., interviews) and analytic approaches (e.g., discourse analysis), which can be combined in different ways for different purposes.

Observations

Observation in qualitative methodologies refers to naturalistic observations of people interacting within their ordinary environments without experimental manipulation (as opposed to observing people in lab-based, experimental settings as is common in psychology). These observational techniques stem from those used in ethnography, an anthropologic approach to studying culture. Ethnography is not merely observing a culture, but using what von Geertz (1973) has termed *thick description* to capture the rules and behaviors governing any given culture. Frake describes ethnography as follows:

> To describe a culture, then, is not to recount the events of a society but to specify what one must know to make those events maximally probable. The problem is not to state what someone did but to specify the conditions under which it is culturally appropriate to anticipate that he, or persons occupying his role, will render an equivalent performance. This conception of a cultural description implies that ethnography should be a theory of cultural behavior in a particular society, the adequacy of which is to be evaluated by the ability of a stranger to the culture . . . to use the ethnography's statements as instructions for appropriately anticipating the scenes of the society . . . the test of descriptive adequacy must always refer to informant's interpretations of events not simply to the occurrence of events. (Frake, 1964, as cited in Wolcott, 1975, p. 121)

Ethnography relies on participant observation, a method in which the investigator learns about a culture by participating in it while simultaneously observing the culture through detailed field notes. The use of participant observation has expanded, however, to include studies that are not specifically ethnographic in nature but which draw on the basic method of observing and recording what one observes through detailed field notes. Field notes capture both the "being and observing" that is part of participant observation (Spradley, 1980). The field notes themselves (also called the running record) capture the observing, or what occurs, through thick descriptions of the physical setting, people, and actions (Marshall & Rossman, 2011). The analytic notes capture the *being* or observer's comments on what is occurring, including subjective feelings as well as questions and analytic insights (Marshall & Rossman, 2011).

In addition to ethnographic and participant-observation techniques, there are also more specified observational methods that use observations to accumulate specific types of data. Kinesics and proxemics, for example, refer to the study of movement and how people use space. Both methods can be somewhat unobtrusive, relying on observations of body movement/body language and interactions in public (or private) spaces. At the same time, such methods rely heavily on the investigator's interpretation of the *meaning* of the movements and spatial use, requiring knowledge of specific cultural contexts and understandings (Marshall & Rossman, 2011). For example, although it is common to code parent-child play interactions using a set of predetermined categories (e.g., autonomy facilitating, responsive to child), these can be seen as attempts to describe how space and movement use are informing scientific assessment of the impact of parenting practices on child action (and vice versa). These coding schemas are typically intended to form quantitative indicators of tendency (frequency of a given set of categories of movement), but they can also be seen as thematic coding of movement useful for qualitative analyses.

Observations are useful in developmental science for providing information about how development occurs within a given setting. By giving the researcher a direct view of what occurs, in context, over time, observations can help unpack the "black box" of what occurs within a setting that may be influencing development (see, for example, Hirsch, Deutsch, & DuBois, 2011, described later). Yet observations' value depends on the skill of the observer. Further, it must be remembered that all observations are filtered through the lens of the researcher, whose presence can also influence the setting/phenomenon of interest. Participant-observation also typically includes interviews (either formal or informal) allowing for the collection of simultaneous data about people's beliefs and the meanings they make of interactions.

Interviews

Interviews are "conversations with a purpose" (Burgess, 2005). Whereas observations allow investigators to record what people *do*, interviews allow investigators to uncover what people *think, believe, and feel*. There are multiple types of interviews, ranging from unstructured to standardized in format, which differ in their level of formality and flexibility to shape and revise the order and focus of interview topics and questions (Patton, 2002). In more informal interviews, questions arise from the setting and are unstructured and flexible, occurring naturally in the course of events. Interviewers using an *interview guide approach* have a list of topics to cover, but no specific questions, and are free to explore the topics as they occur naturally in the flow of the interview. In a *standardized interview*, either semistructured or structured, the interviewer is provided with specific, open-ended questions for the interviewee, although between structured and semistructured the approach differs in terms of whether the interviewer is permitted to reword or adjust the order of questions (Marshall & Rossman, 2011; Patton, 2002). There are also specialized forms of interviews, such as the *life story interview* (McAdams, 1993), that are used to gather specific types of narrative data (see narrative approaches, below) through an interview format. Such specialized forms follow particular protocols related to their aims (e.g., in life story interviews asking specifically about nadir moments; McAdams, 1993).

What all interviews share is a focus on gathering information about the specific topic of relevance to the investigation under consideration. Good interviews include open-ended questions that are written in the interviewees' language. Good interviewers are prepared to ask follow-up questions, both prepared probes based on information desired from specific questions and spontaneous probes based on topics that emerge in the interview that are relevant to the study. Interviews are usually audio-recorded and transcribed, with the transcription serving as the data. However, it is also important for qualitative interviewers to make notes about aspects of interviews such as the interviewee's body language and tone of voice to help provide more meaning and nuance to the printed transcript. Finally, interviewers must be both well-trained and possess good interpersonal skills, as a foundation of good interviews is trust. Interviews are relational interactions and, thus, rely on particular relational foundations (Josselson, 2013).

One of the common criticisms of interviews as a data source is that they are self-report data and therefore are susceptible to the types of bias inherent in self-report data (e.g., social desirability, memory). However, Seale (1998) points out that interviews can be treated as both a *resource* and a *topic*, addressing the self-report bias issue.

Interviews as a resource refer to using interviews to gather information that is assumed to represent some truth/valid understanding about an individual's life. This approach works well for information that may be observable or verified by another means (e.g., where someone went to school or how many children someone had). Yet treating all interview data as a resource that possesses a level of accuracy that may or may not be appropriate can be problematic for other types of information, such as descriptions of social interactions or events.

Interview as a topic attempts to address this potential self-report bias head-on by taking advantage of that very potential weakness as a potential strength. Treating an interview as a topic refers to considering both the interview context and its discursive content as sources of information about the interviewed person's life. In other words, rather than considering only the content of information that is provided in the course of the interview as data, the interviewer also considers other aspects of the exchange such as the way language is used and how the interviewee approaches being interviewed as relevant basic data (Seale, 1998). Indeed, the interviewer cannot erase him- or herself from the interview. Interviews are social interactions and the interviewee is reacting to the interviewer, both in terms of the interviewer's self-presentation and the specific questions asked (Josselson, 2013). Therefore, researchers must be sure that their analysis of interview data recognizes that, and includes their own place in the interview context (see Seale, 1998, for details). Considering how someone tells a story about an interaction can allow the researcher to make interpretations about the individual's identity, based on how the interviewee desires to be regarded in the interview situation, regardless of whether the description of the interaction is "accurate" as would be verified by an outside observer. For example, in Deutsch's (2008) case study of John, a 16-year-old biracial male member of an urban youth organization, the interview data are interrogated to consider not the literal veracity of John's statements but what his statements—made to the European American, female, adult researcher—say about how he constructed a preferred identity within that setting. Treating interviews as both resources and topics allows investigators to extend the value of this method through a more complete description of the phenomenon of interest.

Interviews are particularly useful in developmental science for understanding how people perceive and make meaning of their own experiences. Researchers have used interviews to find out what aspects of developmental change are salient to youth (e.g., Wood, Larson, & Brown, 2009) as well as to understand people's experiences of developmental settings. Yet researchers need to be cognizant of the limitations of interview data, and approach the analysis of interviews with the issues outlined above in mind.

Focus Groups

Focus groups emerged from consumer research as a means of understanding decisions that people make within social contexts or following the presentation of particular information (e.g., one advertising message versus another). In psychology, focus groups were used early on to study the effects of media (Stewart, Shamdasani, & Rook, 2007). Although they are often treated as simply group interviews, focus groups constitute a specific methodology and should not be considered as a means for merely increasing the number of people in an interview sample. This methodology is designed to elicit information that relies on other people for meaning (e.g., consumer decisions that involve reactions to other people's opinions and media messages). Focus groups allow participants' to respond to each other, generating additional information through the conversation itself. Focus groups typically involve between 4 and 12 participants. They are usually audio- or video-recorded and the conversation transcribed verbatim for later review of content, theme, and dynamics (see Marshall & Rossman, 2011, and Stewart et al., 2007, for an overview). It can be useful to have both a facilitator and a note taker present for a focus group. This allows the facilitator to focus on asking questions, following up on responses, and guiding the conversation while the note taker can record the order in which people are speaking and pertinent nonverbal aspects of expression and reaction such as body language and tone of voice.

It should be remembered that focus groups are social contexts in and of themselves. As such, aspects of groups, such as how well people know each other outside of the focus group and the relative social status of different participants, can affect interactions and what is shared within the group (Hollander, 2004). Therefore part of focus group methodology must include consideration of group inclusion criteria (e.g., a heterogeneous or homogeneous sample), how the discussion is framed and directed (seeking opinions versus promoting group discussion), how structured the discussion should be, and methods of creating a safe and inclusive space wherein participants can voice diverse perspectives.

For developmental science, focus groups can be an important tool for understanding the social processes that can have an impact on individual development (e.g., the role of peers in adolescence). They are a means for understanding

> the group dynamics that affect individuals' perceptions, information processing, and decision making. The main logic for conducting the research in a group rather than an individual setting is to allow observations of how and why individuals accept or reject others' ideas. (Stewart et al., 2007, pp. 9–10)

The limitations of focus groups include the lack of confidentiality for participants, due to their social nature. As a result this method is not appropriate for collecting sensitive or highly individualized data. Many of the analytic considerations noted for interviews are relevant for focus groups as well (e.g., considering the data within the context in which it was provided).

Artifacts

In addition to talking to and observing people, qualitative investigators often draw on already existing or created artifacts. Already existing documents are one such source that investigators can analyze and use on their own or in conjunction with other sources to explore the social world. For example, for an investigator studying a youth development program, the program's mission statement may be used in conjunction with information provided by program administrators and staff through interviews. The investigator can then triangulate between these sources of data, compare whether what is stated in the documents converges with what the investigator was told in interviews, and probe the meaning behind any inconsistencies. The mission statement could also be analyzed on its own to provide insight into how the organization presents itself to the public and what that says about its goals.

Photographs, either investigator- or participant-generated, can be used as either tools within interviews or focus groups (e.g., provide focus for or prompts for interview or discussion) or as data sources in their own right (e.g., providing evidence about the topic of interest). Scholars in visual sociology and anthropology have documented the benefits of using photographs in social science research (e.g., Becker, 1995; Henny, 1986; Secondulfo, 1997). Photographs allow the investigator to freeze a segment of reality at a point in time. This can be useful to developmental investigators interested in being able to look back at events over the course of a longitudinal study. Furthermore, photographs present the subjective view of the photographer, providing literally a lens on what aspects of a given setting the photographer sees as important (Secondulfo, 1997). Within psychology, photographs have been used as a means of documenting self-exploration (Henny, 1986). In sociology, photographs have been used to make statements about cultural patterns and social structure. Yet sociologists have also pointed to the importance of recognizing that photographs take their meaning from context, emphasizing the risks inherent in analyzing photographs in isolation (Becker, 1995; Secondulfo, 1997). Whereas content analysis of photographs may be useful for identifying patterns of meaning and linking photographic data to theories, such analysis can also misrepresent or make false assumptions about the image (Orellana, 1999; Secondulfo, 1997).

The practice of *photo elicitation*, in which photographs are used as a basis for conversation with a research participant, attempts to address some of the potential pitfalls of investigator-initiated content analysis. Photo elicitation privileges the participant's meaning-making of the photograph and can serve as a useful adjunct to conventional interviews because it allows the photograph to be a basis for discussion, expanding the interview to reflect not just the investigator's frame of reference but also the participant's (Harper, 1986). One such example of this method within developmental research can be found in Deutsch's (2008) study of youth at an urban after-school center. Deutsch used photographs taken by the youth as both a tool for engaging youth in interviews and as sources of data about the youth's lives. The photographs were analyzed both independently and in conjunction with the youth's interview data. In this work, the photographs served as a jumping-off point for youth to tell stories about their lives and identities as well as a source of data that could be content analyzed and triangulated with interview and observational data.

Maps also provide a creative and visual source of data, which allow investigators to understand how participants make meaning of a given experience. Futch (2013) defines mapping as "a creative method that asks participants to map or draw their 'selves' (or other phenomena of interest) in a way that incorporates time, space, context, history, and environment depending on the research questions and experiences under investigation" (p. 1). The overarching goal is to "elicit a full, holistic representation of personal experience" (p. 1). This method has similar intention and guiding principles as other creative, visual methods that have been used by investigators, such as having participants draw or create collages or arrangements of objects representing their perspective, experience, or reaction to the topic of interest to the research (e.g., Luttrell, 2003). Mapping provides opportunities for engagement with the participant in describing the resulting artifact and for analysis of the resulting artifact by the investigator independently. These types of creative techniques can be useful to developmental researchers interested in individual representation and/or looking for innovative ways to help youth open up during interviews.

Overall, artifacts provide developmental scientists with a variety of alternative approaches for examining and understanding developmental processes and contexts. From content-analyzing artifacts to using them as sources of triangulation to engaging participants in their creation as part of the research project, artifacts can provide important sources of information. Yet their limitations need to be kept in mind, and researchers should remain aware of how they are approaching the artifacts (e.g., as discrete sources of information about the world versus as expressions of participants' subjective views) and analyze the data collected accordingly.

Surveys

Although *surveys* are typically thought of as a quantitative tool, open-ended questions can also be included in surveys. Follow-up questions for clarification can be asked of survey takers via email or technologies allowing asynchronous discussions can be added to surveys to provide more qualitative data (Marshall & Rossman, 2011). Open-ended questions on surveys can then be analyzed qualitatively or transformed into numeric information and analyzed quantitatively.

Digital and Video Data

There is increasing use of video and digital data within qualitative research. This ranges from the use of videotape to capture observations that can then be compared to ethnographic field notes to online ethnographies, in which investigators treat online communities as sites for participant-observation. As Marshall and Rossman (2011) point out: "the Internet provides a disembodied site where social identities (gender, social class, sexual orientation, etc.) are hidden. Thus emerges the possibility of studying the construction of identity solely through text" (p. 182).

For research on adolescents in particular, but for other populations increasingly, the Internet can be a very versatile tool and focus of research. For example, a study of adolescents' social adjustment as related to their behavior on social networking sites suggested important value of that form of social interaction while also linking it to traditional social concerns (Mikami, Szwedo, Allen, Evans, & Hare, 2010). Others have used it to gather data from underrepresented groups about sensitive or risk behavior (see, for example, Mustanski, 2001). As this is a still rapidly developing technology for data collection, sampling, and increasing understanding of development, it is hard to estimate how versatile and important the Internet might be in permitting further reach and innovation in research, particularly mixed methods (Lenhart, 2013). For developmental scientists, the possibilities inherent in both watching developmental processes unfold in real time in digital environments and for archiving digital data for longitudinal analysis are appealing. Digital information can be difficult to verify (i.e., are identity claims made online factual) but again, such data can provide a context for understanding and analyzing preferred representations. Given the rapid and early stage of development some ethical issues related to such research are still being formulated. There are, however, ethical issues involved with using video and Internet data that investigators need to consider (Marshall & Rossman, 2011).

Narrative Approaches

Narrative approaches focus on the stories that people tell about their lives, treating those as data that help us understand how humans develop. Narrative investigators focus on narrative as a form of discourse and as a distinct, socially situated activity (Chase, 2005). Working from Bruner's idea that humans make meaning of their worlds in part through narrative (McAdams, 1993), narrative analysis focuses not only on what is said but on the structure that the participant provides to her story. Thus, the structure of the narrative is analyzed along with the content of the narrative. For example, McAdams (1993), a personality psychologist who studies people's personal myths as a means of understanding individual identity, found that the life stories of highly generative adults share common components, such as highlighting the presence of early advantages in life and narrating negative events so they have a "redemptive" turn (McAdams, Diamond, de St. Aubin, & Mansfield, 1997). Such identifications of common narrative structures and themes can help developmental scientists understand how individuals make sense of their own developmental trajectories. This is an appealing tool for researchers who recognize that the meaning people make of their environments and experiences can be as powerful a developmental influence as the environments and experiences themselves.

Narrative approaches rely on interviews as data sources but are differentiated from other interview approaches by their focus on lengthy, life story interviews and on the emphasis given to the structure of the narrative along with its content. As interview-based analytic techniques, the limitations of narrative approaches mirror those of interviews, noted above. Narratives must be understood and approached as the individual's subjective report of their experiences.

Discursive Approaches

Analysis of *discourse* is a qualitative approach that may be applied to either naturally occurring conversations or to discourse constructed through an interview or focus group. Silverman (2011) describes two approaches to such analysis: *conversation analysis* and *discourse analysis*. Conversation analysis focuses on understanding how social interactions, and their concomitant rules and norms, are constructed through discourse. Based on the work of Sacks (e.g., Sacks, Schegloff, & Jefferson, 1974), conversation analysts assume that talk is structured and are interested in the organization of talk within naturally occurring interactions (Wooffitt, 2005). Thus, conversation analysis focuses on patterns of back and forth in conversation and conventions such as how conversations are begun and ended in various social settings and situations (Silverman, 2011). Discourse analysis treats language as a text, examining talk as a "social practice" and how language is used to construct specific practices and meanings (Potter, 1996). Although originally developed out of sociology (Wooffitt, 2005), discourse analysis has a historical positioning in psychology as a means of examining how people create and display underlying psychological issues in everyday interactions (Potter, 2003). Discourse analysis, then, focuses on the language choices that people make and considers how language reflects both its function and the context in which it is used (Wooffitt, 2005).

Discursive approaches share a focus on the language that people use and the meaning of that language for shaping the social world. For developmental science, such a focus on language can help reveal developmental patterns in an individual or group's meaning making or learning over time. For example, analysis of discourse has contributed to knowledge of how gender influences behavior and relationships in childhood and adolescence (e.g., Maccoby, 1990).

COMBINING METHODS

The potential utility of mixing methods along with the rich set of methods within the overall grouping of qualitative methods also raises important issues about which methods to juxtapose, how to do so, and what are the methodological assumptions and implications of such an approach to study. Combining methods, whether within qualitative or quantitative or across the two groupings carries multiple implications for developmental research.

Qualitative Methods and Concomitant Issues for Mixed Methods

Qualitative methods emerged as part of postpositivism's critiques of science (Lincoln & Guba, 2003). Yet they also began in recognition that a rush to quantification can present a number of problems, including (a) obscuring important variations, (b) foreclosing consideration of the full domains of interest for measure, (c) restricting exploration and descriptive work that could improve the robustness of quantitative studies, and the richness gained form contextual framing of the chosen focus, measures, and methods. Although quantitative methodologies have been applied, in large part, with a concern that subjectivity is a threat to measurement validity, qualitative methodologies are based on the principle that removal of context is equally problematic in making judgments concerning validity. Perhaps most critically, the emergence of qualitative methodology highlights the importance of articulating guiding assumptions, of recognizing the close bond of theory and methods, and further recognizing that all inquiry is by definition incomplete. Concordantly, inductive analysis that starts with the data and develops theories and hypotheses from the observed patterns is needed along with deductive analysis and reasoning, analysis that develops a hypothesis from prior theory and uses data to test that theory (Lincoln & Guba, 1985). Rather than debating which is more useful or scientifically sound, it seems more useful and more expeditious in furthering knowledge development to view these as complementary approaches to scholarship, each adding to the other if integrated thoughtfully in a study or set of studies (Shweder, 1996).

Historically, qualitative methods became associated with interpretive paradigms, with a growing presence of postmodern, poststructural, and critical epistemologies guiding the method organization and data interpretation (Lincoln & Guba, 2003). These paradigms challenge the possibility of the kind of objectivity that requires a mind-independent reality, and investigator-subject independence, assumptions that underlie positivism and neopositivism, and that often are at least implicit in developmental research (Lincoln & Guba, 2003). Postmodern, poststructural, and critical epistemologies also question the ability to assess "truth" apart from its political and social place (see, e.g., Hanson, 1958; Kuhn, 1977; Lakatos, 1978; Overton, 2006). As such, qualitative methods often incorporate catalytic goals, making explicit the social and political ramifications and forces affecting research. Thus, the use of qualitative methods can include social change as a more explicit goal of research through the contention that social influence is inherent in all research. Although social change or improving human conditions is a goal of a substantial portion of developmental science, positivism, neopositivism, and postpositivism assume one can separate such goals from the research process or a given program of study. On the other hand critical epistemologies and others like it (e.g., relational epistemology) stress incorporating such goals in the design of research, to be overtly intended not just acknowledged. Overall, qualitative methods are grounded in recognizing the social nature and contextual boundedness of inquiry and of knowledge.

Strengths of Qualitative Methods for Mixed Methods Developmental Science

Qualitative methods are particularly well-suited for capturing two important aspects of developmental phenomena that are integral to a Relational-Developmental-Systems approach to human development: process and context (Denzin & Lincoln, 2003). Combining qualitative and quantitative methods allows for measuring structure and process with both contextual and generalizable understandings (Bryman, 2006). Thus, understanding can be gained of local meanings and context and of the transferability of findings to other settings (Boker & Martin, 2012). For example, in their study of three youth organizations, Hirsch et al. (2011) provide detailed case studies of both organizations and youth that provide in-depth understanding of how specific youth interact with contextual features of particular organizations to promote or inhibit developmental change. At the same time, the knowledge generated is made transferable to other youth and settings by both detailed descriptions of context, which allows others to infer how such processes may be similar or different in other specific settings, and by linkages to generalized developmental processes.

Although qualitative methods have traditionally been criticized as a means of understanding causal relations, scholars are now recognizing the strengths of qualitative approaches in identifying the processes of causal relations (Yin, 1993; Yoshikawa et al., 2008). This primarily comes from the ability of qualitative methods to gather in-depth information about the "how and why" of phenomena. Thus, just as chemists use qualitative analysis to identify the subtler aspects/components of a chemical compound as part of a reaction, qualitative developmental science allows investigators to identify the "components" of human development as it "catalyzes" within particular contexts.

Qualitative research, in general and as applied by developmental investigators from quantitative traditions, has been considered to have advantages because it is inductive and flexible. Thus, qualitative methods are seen as having strengths in drawing propositions from data (as described earlier) and as being modifiable based on emergent results. These features allow researchers to respond to data as it is collected, thereby maximizing the potential to collect meaningful data. For example, if participants in an interview study are found to talk frequently about a topic that was not included in the original interview protocol, that theme may be hypothesized to be an important part of the phenomenon under investigation even if not presupposed to be, and questions may be added to the interview to explore that theme. Although these characteristics of qualitative research are somewhat accurate, especially as compared to traditional quantitative research, among qualitative methods there is actually considerable variation in the balance of induction and deduction and the amount of prestructuring (i.e., how much a study's structure in terms of specific methods, questions, and instruments, is determined prior to undertaking the study) as opposed to design elements emerging through the process of research. However, even highly prestructured, more deductive qualitative studies (e.g., those with more set questions and focus and designed to test specific hypotheses) tend to retain flexibility for revising methods as needed based on emerging data, and so differ from the prizing of fully predetermined measurement and analyses that has driven most quantitative methods (Maxwell, 2005). As Maxwell reminds qualitative investigators: "the decision you face is not primarily *whether* or *to what extent* you prestructure your study, but *in what ways* you do this, and *why*" (p. 81; emphasis in original). To illustrate these distinctions, envision two qualitative studies of children's interactions with peers at preschool. Both use a framework drawn from the literature on early childhood education and use interviews and observations as data collection methods. One researcher approaches the study with a set of specific research questions and hypotheses about patterns of interactions that will be found across classrooms. Interview questions are specified at the proposal stage to test the specified hypotheses and a coding structure for the observations is developed to apply structured observation focus and recording. The researcher may add or adjust questions or codes (e.g., break one code into two) as the study proceeds but the major constructs of interest and tools for exploring them are predetermined. The second researcher proposes a set of general topics of interest with research questions that are designed to begin exploration and that may change as data is collected. This could be because the focus of the study narrows as initial questions seem to be answered, because new constructs (elaborations from original formulation) emerge as additional contextual influences are recognized and incorporated or because of understanding of the implications for theorizing given the specific classrooms being observed. Interview topics are suggested with specific questions developed after some observations occur. Observations are open-ended (not predetermined coding or focus), with field notes starting out broad and shifting or narrowing in focus as constructs and themes of importance arise during data collection.

This notion of flexibility and feedback from data informing method has not yet been widely applied within quantitative methods. Yet consideration of such iterative approaches suggests some provocative and potentially important opportunities. One example of this emerging in quantitative methods is the practice of modification of structural equation models. Users typically make use of indications of errors in relation between major constructs or specific indicators from modification indices to modify the theoretical model (actual model tested). Such considerations of strategies for incorporating the strengths of one methodology into the methods of another is one way in which researchers can use the logic of mixed methods to increase the sophistication of their research even within a single method study.

Expanding Knowledge of Multiple Aspects of Developmental Phenomena

Within qualitative methodology, an important assumption, if not always stated, is that better understanding is gained by understanding more than one aspect of a phenomenon. This results in the frequent use of multiple qualitative methods to triangulate and expand the types of knowledge gained. This is founded on the recognition that methods have different assumptions, capabilities, and limitations that should be acknowledged and applied as appropriate to advance scientific understanding. Multiple methods are thus advantageous for capitalizing on and countering these differences with the goal of expanding the aspects of a phenomenon that is being studied. For example, observations are well suited for assessing *what people do*. Interview techniques are better suited for understanding the meanings people make of their environments and interactions—or *what people believe*. Together, they help inform about actions, which are conceptualized as more than behaviors and which represent two aspects of any given phenomenon. The educational investigator Frederick Erickson (1986) defined *behavior* as the physical act and *action* as behavior plus intention. According to Erickson, actions (rather than behaviors) should be the focus of qualitative inquiry (see Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume; Mascolo & Fischer, Chapter 4, this *Handbook*, this volume; Overton, 2006, Chapter 2, this *Handbook*, this volume; Witherington, Chapter 3, this *Handbook*, this volume, for extended discussions of the central role of action in developmental science). This highlights the importance of understanding both *what* is done and *why* things are done (or the meaning behind what is done). Similarly, Rogoff (2003) points out that to understand human development it is important to capture both what happens and what people believe about what happens:

> To understand development, it is helpful to separate value judgments from observations of events. It is important to examine the meaning and function of events for the local cultural frameworks and goals, conscientiously avoiding the arbitrary imposition of one's own values on another group. Interpreting the activity of people without regard of their meaning system and goals renders observations meaningless. (p. 17)

This focus on intentional meaning giving (action) and activity as important components of each behavior points out the conflation of methods and values. Action and activity have traditionally been studied separately in developmental studies using quantitative methods with priority given to what is observable by others. Rarer are studies that try to relate meaning/action to activity or to study both as important components of developmental patterns. One implication of recognizing the value of relating these within and across studies is to theorize how what individuals experience and intend is related to what they do; as both what is expressed in terms of personal meaning and its relation to behavior may also have developmental trajectories (Boker & Martin, 2012). The relative stability and assimilative and accommodative change that characterizes development can and should elucidate not only what a person does and believes about her or his context, but also how the person's perspective with respect to context may be developing and reorganizing (see Overton, 2006, Chapter 2, this *Handbook*, this volume).

Quantitative Methods and Concomitant Issues for Mixed Methods

Combining quantitative methods, particularly with qualitative methods, can bring into relief the theoretical basis of any quantitative effort and therefore the advantages of reliance on multiple methods in a complimentary fashion to enhance certainty, reliability, and robustness of understanding. As noted earlier, qualitative methods provide a different type of data and data processing that often provides understanding, specificity, or contextual information not likely to be identified by quantitative methods, particularly a single method. Such differential capability reveals that although quantitative methods were originally cast as objective in the sense of free from theory and therefore preferable, these methods are no freer from theory than any qualitative method, and different quantitative methods have different theoretical assumptions. Quantitative methods do offer advantage over qualitative methods in differentiating in a methodic way source bias, theory, and reliability. Quantifying measurement facilitates consistency in measurement by objectifying coding and scaling prior to observation and to replicate measurement and methods of analyses across studies (Kuhn, 1961). However, for much of the history of developmental science, and presently for many within the field, there remains a conflating of quantitative methods' emphasis on external verification as a standard of measurement with being free from theory. As the distinguishing characteristic of quantitative methods is that each is based on using numerical (nominal/categorical to ratio scaling) measurement of information, there is by necessity, theorizing required to formulate how scaling represents accurate (defined as reliable and valid) measurement and the appropriate differentiation of degree of the phenomenon of interest. This means all quantitative studies are based in and carry statistical theory but also a particular developmental theory about what constitutes adequate measurement based on criteria of adequate definition of the domain to be studied (critical components, differentiation from adjacent or related constructs, developmental patterns), appropriate dimensionality of domain (more than one dimension, relation of dimensions), and scaling thought to capture how variation in the domain occurs. For example, a scale may be developed with assumption that items represent multiple sampling of an underlying domain, as is the case in traditional factor analyses or with items meant to represent increasing levels on a dimension, as is the case in item response scale analyses. However, which is the appropriate scaling procedure depends on theory about the dimensional attributes (what represents more or less of that dimension) and how variation by subgroups or over time is to be understood. Scale content formulation and psychometric analyses are not just derived via statistical theories that define the mathematical basis for the calculations, but also developmental theories, which provide foundational assumptions about how developmental processes operate, what aspects of a phenomenon are important to assess, and what questions or measures can serve as indicators of underlying phenomena. Recognition of this developmental theory aspect of quantitative method selection is, too often, in practice, implicit or unacknowledged.

Other critical measurement concerns such as how sources and methods relate to validity of measure and expectable variation on the construct are also judged from a theoretical frame. In some cases the level of inference is low (e.g., simple counts of observable phenomena such as counting rates of smiles of a mother in looking at her child) and in some cases the metrics and methods for measuring are well-developed and refined (e.g., measuring height and weight). In many cases in developmental science, however, the information sought requires indirect measurement (e.g., executive functioning measured by a set of performance tasks thought to be affected by such functioning; Eisenberg, Spinrad, & Eggum, 2010) and predetermined definition of what constitutes the essential indicators of the construct of interest (e.g., distraction inhibition, working memory, set shifting, feedback utilization to define executive functioning). In addition, there is often need for locating the measurement in some reference to typicality (distribution of scores on the scale across a representative population of interest, including how this varies by age/development) and health (relation to inadequate, adequate, and/or exceptional development). Thus, although not typically explicitly noted, quantitative method-derived measures in developmental science carry expression of theory about invariance over time, groups, and situations that are not simply and implicitly determined via statistical theory. Whether low or high inference measures and of more or less conceptual complexity, much too often the quantification is presented as though arising without specific developmental theoretical framing (with attendant limitations) that frames what statistical method is most appropriate/useful.

As developmental scientists expand the complexity of the conception of patterns of stability and change, variation on multiple levels, and benchmarking rates and patterns of growth (including periods of stability) the number and variety of analytic methods available for quantitative analyses has grown. In many cases there is notation of different frameworks for the application including limitations and what other methods might augment or complement results obtained with a given method. For example, with the elaboration of *hierarchical models* (Raudenbush & Bryk, 2002) that can emphasize interdependence of smaller units (usually individuals) and larger unit patterns (e.g., student learning within a more structured or less structured classroom), effects can be differentiated as to level (individual versus group) and also specify relation of effects across levels (e.g., how students with school readiness skills achieve differentially depending on the classroom structure) including intercept or level differences, directions and rates of growth, and shape of growth (Tolan & Brown, 1998). Another example is person-oriented analyses (see von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume), often contrasted to variable-oriented analyses, which organize data and analyze configurations of individual growth over time or of a set of variables across individuals. The different orientations lead to a different understanding of variation within a group (e.g., attention to heterogeneity within sample in identifying meaningful subgroups via configuration of scores on several indicators or in growth pattern over time). In contrast to variable-oriented methods, these approaches treat within group variation of interest for reasons other than estimation of averages (Henry, Tolan, & Gorman-Smith, 2005).

These are just two examples of the expanding array of quantitative methods, which indicates the potential gain from juxtaposition of more than one method to elaborate understanding gained from a given study or series of studies. Emerging from this plethora of methods and the recognition that each has differential utility is expectation of and attention to explicitly consider how measurement and analyses represent important theoretical expressions. When juxtaposed thoughtfully, competing theories can be tested and/or theories elaborated. The many innovations and elaborations of statistical models designed to examine change and stability, uncover variations in growth patterns within and across populations and conditions, consider how larger and smaller units relate in affecting results, and/or reveal person as well as variable related patterns, lead naturally toward the use of mixed methods. Such innovations provide a general perspective on multiple methods (whether qualitative or quantitative) as being applied to piece together a more complete characterization from the partial understandings obtainable from each specific method, thus approximating more fully the conceptual principles of Relational-Developmental-Systems (Lerner & Benson, 2013).

Challenges of Modeling Complexity and Variations in Change With Quantitative Methods

Mixing methods helps with understanding the many forms and levels of change that can be relevant in a quantitative modeling of a theoretical developmental issue. Mixing methods facilitates piecing together different findings in an effort to reconcile the research interest in individual, group, and overall patterns and to consider varied relations between stability and change at each level and between levels. The research interest in characterizing relative stability and change in a given study or set of studies can be as simple as a linear difference in values of a variable over an interval of time (e.g., does aggression of young children increase over time?). But many other types of change are possible and can be observed during development. For instance, there may be quickly occurring changes when a child acquires a new skill or cognitive concept (nonlinear growth). Near a skill acquisition transition point, there may be times of both progress and regression (see Witherington, Chapter 3, this *Handbook*, this volume). Change may occur as shifting rank in distribution of a characteristic within a reference group (e.g., what explains a given child's greater increase in interest in helping others compared to classmates?). Change can also be focused on divergence of trajectories or how subgroups may vary in level, rate of change, pattern of change (e.g., curvilinearity), and probability for future developmental opportunities and risk (e.g., how does increased involvement in after-school program increase likelihood of engagement with prosocial promoting peers?). And, many levels of Relational-Developmental-Systems can be evaluated for change (e.g., what explains schools becoming more engaging to students over time; how does that vary by student academic motivation and teacher skills). The focus on growth as characterization of change and stability emanates from viewing these patterns as forms of developmental processes. With that conception stability is relative and refers to little or no change in level or organization over a given period of time. All of these foci of change represent opportunities to be juxtaposed to one another to form a mixed-methods quantitative study or to be combined with qualitative methods.

Measuring change becomes more challenging when one tries to incorporate meaning or perceptions of persons and interpretations of behaviors into quantitative modeling. This may be where the contribution from qualitative methods is most apparent. One aspect of the challenge of such characterization is that an individual's perception, including sense of self or of key relationships, may be central in the nature and course of reorganization or may be what is reorganizing at these transition points. The meaning of indicators of sense of self or other developmentally interesting characteristics may change not just the likelihood of a given indicator being endorsed, so that change in scale reliability and validity may result (Millsap, 2011). The measure's representation of the phenomenon of interest will have shifted in an unrecognized manner because the meaning of responding has changed in an unmeasured way. Similarly change in the words and nonverbal communication a person uses to describe his or her subjective experience may also undergo developmentally based semantic shifts or in relation to sensitivity to characteristics of the communicative context (Kagan, 2008).

Typically, quantitative measurement of subjective experiences is through self-report across multiple items that, in the mind of the investigator, have similar meaning and as a group represents the same construct to all individuals reporting, acting as repeated sampling of the same subjective experience within and across respondents. The administration of multiple items is introduced in order to identify a latent variable; a construct that can be said to represent what is shared among the items. If an individual is measured with the same indicators/items over several occasions, the change in the value of this latent variable is taken as an estimate of change in the individual. However, if the meanings of items are changing over time within individuals, even sophisticated quantitative methods for measuring change, such as latent growth curve analysis, can leave obscured important developmental phenomena and give rise to apparently reliable results that are dependent on artifacts from aggregation. For example, one could find adequate invariance in measurement over time to conclude a given model fits across developmental stages, when that may only indicate the sampling inadequacy or the measurement insensitivity or the countervailing effect of diverse subgroups on the overall pattern (rendering "no difference overall").

To illustrate how this limitation can point to the value of mixing methods, two types of aggregation limitations are described here, using the example of physical development during childhood. Physical growth is a frequent prototypical process used in attempting to track and model developmental processes. Thus, models of physical growth have become influential in thinking about how change occurs and the parameters of interest in quantitatively modeling it well. Sophisticated techniques such as latent growth curve structural equation models (e.g., Duncan & Duncan, 1994; McArdle, 1986; McArdle & Anderson, 1990; McArdle & Nesselroade, 2002) are applied to fit quantitative models for data measured over multiple occasions. These models can work well when one is describing a process if it is similar to physical growth in two ways. First, the developmental process must be assumed to occur from the same start time and value for every individual in the group. Second, as a developmental phenomenon, the interest is in progression, such that the starting point is the lowest value that will occur (does not regress). In the present example, there is a moment of start for every individual's physical growth and in general, this is the smallest that every individual will ever be. Thus, the rate of change in height (i.e., the first derivative of height with respect to time) is positive until the person reaches her or his maximum height. Second, the assumption is that all meaningful change occurs for all individuals in the group at the same way at the same times. During childhood time, age since birth relates well to attained growth, well enough to be considered a universally applicable pattern. For instance, there is a period of rapid growth during the teen years, but much slower growth (if any) in the early twenties. When these conditions are met, an aggregate representation of individual development can provide a good description of the developmental process such that the form of the aggregated growth cure is representative of each individual's developmental change.

Applying this model derived from physical growth is a frequently used strategy to aggregate the rate of change within age ranges to create an average curve as shown Figure 19.1.[1] Here, height is plotted against age for eight hypothetical individuals whose growth is simulated as a negative exponential curve: rapid growth early, coming to a stable value in adulthood. Each person only differs in one parameter: the exponent of the curve. The mean of these eight curves is similar to an exponential curve and provides an acceptable description of the average growth. As can be seen in Figure 19.1a, the mean of the

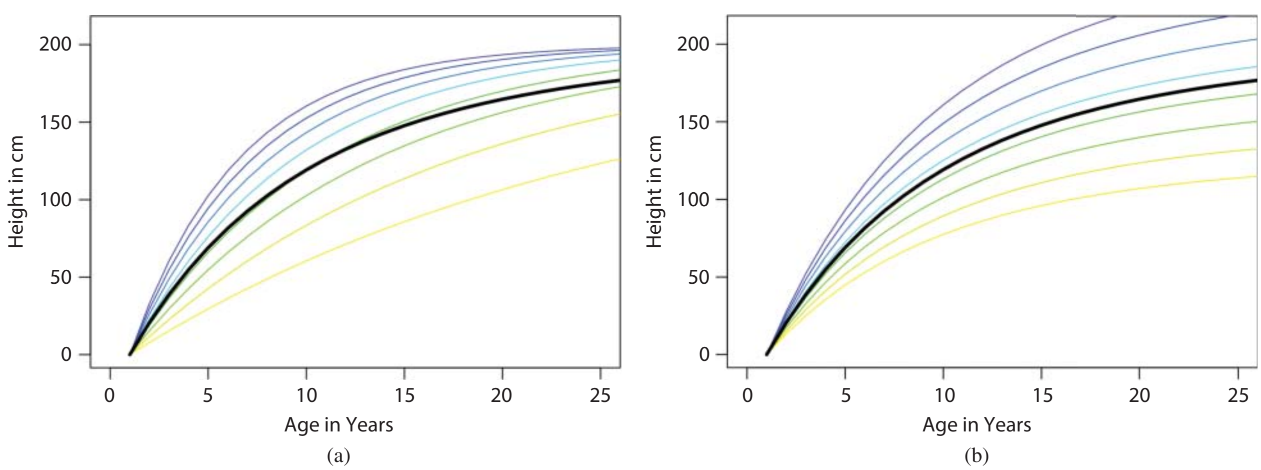

Figure 19.1 Hypothetical growth data and their mean growth curve. (a) Eight hypothetical growth curves simulated as exponential growth to asymptote with the mean growth curve plotted in the wide dark curve. (b) Even though the mean curve is approximately like an exponential curve, eight proportional amounts of the mean growth curve do not necessarily do a good job of representing the shapes of the original individual curves.

individual growth curves shown in the dark black line is a reasonable approximation to each of the individual curves. Latent growth curve models apply this approach to modeling each person's growth. The approach is most often specified as estimates of an average latent intercept, slope, and curvature (an aggregate curve) and variances for each of these latent variables (a measure of the individual differences in the sample). Another strategy is to use what is known as a free-form basis function. This function does not specify how the change occurs, it just estimates an average aggregate cure and the individual differs as a variance of the curve. In essence this gives each person an "amount" of these latent variables, whether intercept, slope, and curvature, or free-form basis function.

In the simulated sample of developmental processes in the figures, if a free-form basis function growth curve is fit to the data, it aggregates to the same mean of individual growth curves as shown in the wide black line in Figure 19.1b, the same aggregate curve as in Figure 19.1a. The latent growth curve models estimates a variance term for the latent basis functions, essentially assuming that each individual follows the same function and has an "amount" of that function. If the individual scores are used to plot the model-predicted individual growth curves the form will be as illustrated in Figure 19.1b. Even though commonly required conditions were met for using a latent growth curve to approximate these data and the aggregate curve looks like the simulated individuals in Figure 19.1a, once the result is plotted, the model predicted curves in Figure 19.1b do not look like the original individual curves in Figure 19.1a.

This simple elaboration of growth variation renders model fit and derived explanatory value substantially less adequate. One approach to increasing fit and explanatory value might be to elaborate the model with more latent variables to characterize multiple variation parameters. However, it is not certain that adding variables will achieve a better fit to the original individual data or better understanding of the developmental process. Thus, the assumption that the same changes are happening at the same ages is unsupported, and this leads to poor prediction of individuals' growth. In the simulated data used in this example, everyone eventually reached the same height, but did so at differing rates. In the model-predicted data, people who grew faster ended up being taller. This is because the model carries a theoretical contention that growth rate and eventual state are universally related, and cannot consider multidimensional difference. When modeling change, it is important to consider what level of change is of interest and how the data aggregation might obscure important differentiating patterns. This aggregation that acts as one-size-fits-all curve fitting can lead to errors because of its assumption of homogeneity of growth within a population, of stability when there is substantial change, and of overlooking important order and disorder in change as change occurs. It may be that subgroup comparisons or consideration of how within individual fluctuations that affect overall growth patterns or other analyses based in biological determinants of height could, as additional quantification would complement the overall growth model but also show important information not available in that model (the limitations of the fit of that model). Mixed quantitative methods can improve certainty and reduce limitations so that understanding gained from one can complement that gained from another.

A more extreme example of aggregation to rely on a single method and model yielding poor understanding can occur when a developmental process is one of fluctuation, that is to say when a process has both positive and negative slopes (i.e., positive and negative first derivative with respect to time) as part of the overall pattern across time. Examples of this type of process include most forms of self-regulation. For instance, self-regulation of affect will include times of more and of less distress. Learning to regulate affect is not a simple growth process, becoming more controlled or more positively consistently across time (nor is either necessarily desirable). Instead, over development individuals increasingly recognize important cues in the environment and from their physiology and cognition that prompt regulation and affect fluctuation. This type of process is inherently dynamic and fluctuating while directional. If the developmental process of interest in a given study is fluctuating, sometimes is positive and sometimes is negative, growth curve analysis to yield a sample average can yield a poor characterization. Consider the simulated data plotted in Figure 19.2a, which represents such growth patterns for some members of a sample. Each individual is fluctuating in exactly the same way, a simple fluctuation that takes six units of time to go through one complete cycle. However, each person is at the peak of his or her cycle at a different time. The dark horizontal line at a score of zero is the average growth curve of the group. An average growth curve would lead one to the conclusion that there is no regulation process. This conclusion would clearly be misleading. It would also be misleading to conclude there is no group pattern; that the growth pattern for any given member is unrelated to an overall developmental trend. Mixing methods, particularly which elaborate the

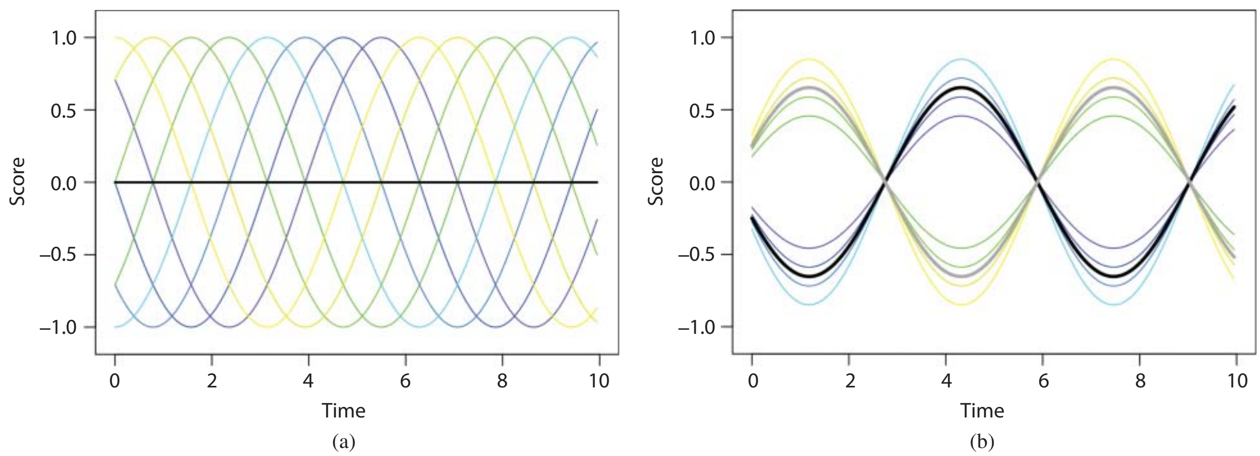

Figure 19.2 (a) Eight simulated individuals with the same frequency and amplitude of fluctuation (here a perfect sine wave) but with different starting values at the first occasion of measurement. The mean of these eight curves is equal to zero at all times, as plotted by the wide dark line at score equal zero. (b) A growth mixture model with two classes applied to the same simulated data. Although two classes would be found to provide significant improvement in fit over a single class growth curve, the data is actually composed of only one class.

modeling of the individual to group relation can enhance not only statistical fit but also interpretation of the meaning of fluctuation.

One approach that combines methods, developed to account for individual differences in growth curves in this way is *mixture distribution modeling*, sometimes called *growth mixture modeling* (Muthén & Muthén, 2000; Nylund, Asparouhov, & Muthén, 2007). Notably, the approach is designed to *mix* categorical (or subgroup) and linear characterization of growth patterns. Growth mixtures posit that a given sample is composed of a mixture of different classes of curves or groups within the overall pattern. If one were to specify a growth mixture model with two classes for the simulated data in Figure 19.2a, one would find two classes similar to those plotted in Figure 19.2b. One class is composed of those curves that started with an increase and the other class is composed of those curves that started with a decrease. Again, the mean growth curve tends to reduce the true variance in the fluctuations, but does not reduce it to zero. Model comparison between the growth curves with one and two classes would show clear evidence that more than one class was necessary. Although this modeling approach improves the description of the fluctuation process, it is important to recognize that the classes provide additional description of the overall growth and do not without additional theory and verification determine there are two actual groups; there are two variations forming the overall pattern. For example, it can be attractive to reify the variations as fully explanatory and externally valid descriptions of growth as being either an “early descender” or “early ascender.” Application of an additional method of quantifying the data for checking the completeness, sensitivity, and robustness of fit to individual subjects or that can improve understanding of the meaning of these groups and the dependency of the patterns on limitations of the sampling or data collected would greatly improve specificity of the findings and confidence that should be accorded the results. Moreover, such additional analyses could improve confidence about the generality of findings. Among the methods that could add such understanding are autocorrelation functional analyses, time series analyses, or dynamic systems analysis and also qualitative methods that can verify the developmental and social meaning of the two group finding and “this model fitting better” than alternative pathway models. Theory and methods that might elaborate what is found in this modeling can provide critical understanding of the validity, robustness, and meaningfulness of this statistical rendering (see Muthén & Muthén, 2000, for an example of such mixed quantitative methods).

The data in Figure 19.2a were simulated to represent only one regulatory process growth pattern with individuals in different phases of their cycle when the measurement started. It may be important to recognize that modeling individual development through multiple related processes requires organization of a set or sets of techniques representing different approaches that are intended to reveal meaningful variation as well as characterizing the aggregation adequately (see Molenaar & Newell, 2010). Although approaches such as mixture models are important for permitting consideration of variations in growth patterns, like all methods they carry assumptions of theory driven measurement and interpretation. Accordingly, there can be value gained by additional analyses that might elude even complex single model characterizations attempting to account for all individual patterns as reflecting a universal or group underlying process. For example, one could characterize growth by how different aspects or explanatory variables cluster within individuals and be paired with mixture modeling to provide more elaborate explanation (Muthén & Muthén, 2000). Similarly, spectrum analyses can be used to augment group growth modeling to reveal the unitary regulatory processes while individuals are in different phases (Brillinger, 1975).

Another aggregation issue can arise that is not well identified by a single method. This is the attempt to aggregate based on measures without consideration of how individuals may differ in the context or circumstances and/or meaning they bring to reporting about the self or acting in response to a performance measure. If there are important variations in how questions or tasks are understood, how responding is understood, social desirability, personal salience, and/or susceptibility to uncertainty, the variation in responses may reflect other than the specific characteristic or ability of interest (Fendrich, Johnson, Wislar, & Nageotte, 1999). For example, with respect to the interpretation of research findings, research on the association between race and self-esteem highlights the importance of understanding the meanings of both self-esteem and race for the individuals being studied (Gray-Little & Hafdahl, 2000). Similarly, one group might respond to a questionnaire about *family relationships* with an understanding that the important concern in items meant to be about communication are about parent-child boundaries and appropriate respect whereas another group is responding with attention to equity and autonomy granting as what is important in communication (Nesselroade, 2010; Tolan et al., 2013). Moreover, there is likely unarticulated variation in how individuals or groups label a given experience as representing communication even if interpreting the type of emotional experience similarly (e.g., both respond about talking between family members). Variation in meaning is not just applicable to self-reports but applies to ratings and to coding schemas and occurs at group and individual levels (Fendrich et al., 1999). That it occurs with any quantification is a compelling argument for qualitative probing of respondents to further certainty about what similarity and differences in overt responses mean.

However, there are also additional quantitative methods that can be applied in a mixed methods approach to augment understanding variation among respondents that is otherwise unmeasured. One approach developed to address shifting or varying meaning that might be attached to responses, codes, or rating levels is called *idiographic filtering* (Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2010). This approach uses multiple items to measure a construct for which one can estimate a latent value based on the items' shared covariance. The interest is in the latent construct and others remaining stable across the group(s) studies. Nesselroade and Molenaar (2010) applied a new measurement theory in which the interpretation of each factor is based on this factor's invariant pattern of correlations with other factors. However, item factor loadings can be subject-specific. This model makes an important distinction between invariance between persons in manifestation of underlying factors and consistency in relation among underlying factors. For example, if the interest is in how anxiety and depression codevelop, the interest in that relation is as consistent or as stable for the population of interest. However, as noted, there may be variation among individuals in regard to what are considered symptoms of depression or anxiety as well as which are manifest. Accordingly, what is identified and therefore reported may vary from individual to individual. For example, one person may respond positively to an item listing "needless worry" due to depression whereas another may respond positively to the same item as a result of anxiety. Similarly, someone who experiences depression as great sadness may respond to a depression inventory differently than one who experiences depression as inertia and hopelessness. Idiographic filtering acknowledges this individual variation by allowing difference in loading of items on the construct among individuals. The perspective is that the reliability of interest is in the covariance between the latent variables. Semantic or meaning reliability occurs between the constructs, not the meaning for each respondent/participant of individual items (Molenaar & Nesselroade, Chapter 17, this *Handbook,* this volume; Nesselroade & Molenaar, 2010).

These aggregation limitations, of even these sophisticated statistical models reveal that partial understanding is likely with any given method. Combining elements of methods into an overall statistical model is one approach that is emerging (see Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Muthén & Muthén, 2000). Even though developmental scientists seek to discover nomothetic principles that apply broadly, those principles need to be able to account for meaningful variation in groups within the overall population and of individual development within the overall and group patterns. Modeling aggregate growth is useful only insofar as the group patterns account well for individuals and capture most meaningful variation. This is not to suggest aggregation efforts are inherently flawed and to be considered futile. To the contrary, the important advances of such efforts in modeling development as multiparameter growth has produced a change in how research is conducted, how sophisticated understanding is, and the utility of such research. As hybrid and multiple method models are promulgated, there is potential for not just complementary and adjunctive mixed methods, but of carefully related results. Nevertheless, there are likely to be limitations of even the most sophisticated singular method and how complex statistical quantitative or lexical qualitative methods can be. Instead of seeking the correct method or the always applicable approach, what may be more useful is to appreciate the utility and limitations of a given statistical emphasis and technique for modeling developmental phenomena and applying multiple methods to create a fuller, more sophisticated, and more useful understanding. Mixing methods rests on careful attention to the reason and purpose of relying on a given statistical or qualitative model and careful attention to how the assumptions of that model are met/fit with the purpose of a given study. Accordingly, a second step in such applying attention to capabilities and limitations of a given model should be to consider what method is a good complement to that, that is, that has capabilities which address the limitations of the first method and provides additional/different information to expand or deepen understanding.

Growth and Stability

A major challenge for developmental science is to characterize the ongoing cascading of growth and fluctuation that is marked by states of organization or constancy (Bronfenbrenner, 1979; Sameroff & Fiese, 2000). Quantitative methods (e.g., sophisticated growth models that incorporate nonlinear change and can consider periodic fluctuation as part of that growth pattern) have been developed and applied to measure developmental variation (Multisite Violence Prevention Project, 2013; see also Ram & Grimm, Chapter 20, this *Handbook*, this volume). Moreover, models that specifically address transitions from one class of relative stability such as latent class analysis and latent transition analysis have improved ability to conduct analyses sensitive to this issue (Bray, Lanza, & Collins, 2010). Yet, there are important and constraining assumptions underlying any model, which if not met might lead to misinforming about the stability and change and the relation between them. For example, how variation in timing of relative stability or how well the "stability" of the group represents individual variations are not captured well by most current models (Molenaar & Newell, 2010). In addition, these models cannot determine, apart from theory or reliance on other methods for convergence, when there is a shift from stability to instability/change. Addition of qualitative and other quantitative methods to systematically examine features of fluctuations, individual variation in timing and orderliness of change, and qualitative differences that can mark a shift from one state to another or from stability to instability are needed to adequately characterize developmental shifts and patterns. For example, individual timing of onset of puberty, in order of secondary sex characteristic change, and in synchrony and length of time of change all occur within an overall pattern of a marked developmental change (Richards & Peterson, 1993). Understanding what is meaningful pubertal change and what is inconsequential even if measurable change and when puberty has "started" and is "completed" require multiple methods that can, as a set, attach meaning to biological and related psychological and social shifts, model variations in patterns, pace, and synchrony of changes, and relate individual change to developmental variation.

Within Individual Change and Developmental Variation

As noted by Molenaar and others (Molenaar & Campbell, 2009; Molenaar & Newell, 2010) developmental science has a basic interest in individual development or time-dependent variation within a single individual. This is a hallmark of the Relational-Developmental-Systems approach (Overton, 2013, Chapter 2, this *Handbook*, this volume; Overton & Lerner, 2012). This focus begins with a premise that "each person is initially conceived of as a possibly unique system of interacting dynamic processes, the unfolding of which gives rise to an individual life trajectory in a high-dimensional psychological space" (Molenaar, 2004, p. 202). As important is the irreducibility of individual change to a simple reflection of the group pattern. Molenaar begins with describing a contrast between ergodic and nonergodic processes in the time-related structure of measured characteristics. Ergodic and nonergodic processes differ in terms of whether group patterns can capture all that is meaningful about individual patterns. Molenaar and others have gone on to demonstrate that group models can capture little of actual individual variation over time (Borsboom, 2005; Molenaar & Campbell, 2009; Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Velicer & Molenaar, 2012). Given this problem with group data, *time series models* have been elaborated and are applied to model individual development, and to then relate these individual patterns, rather than trying to represent all growth as simply a single pattern, bringing individual variation and group consistency together in understanding development (Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Molenaar & Newell, 2010; Nesselroade & Molenaar, 2010).

The intent of the time series approaches of Molenaar and colleagues and of the idiographic filter approach of Nesselroade and colleagues is not to displace group modeling or attention to group patterns. Instead it is to purposefully elaborate what can be discerned if individuals are not simply treated as instances of a population. With these additional methods, growth approaches to quantitative characterization can accentuate the complexity of the relation of individual development to any group observable patterns. Along with well-established person-centered approaches (see von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume for an extended discussion of person-centered approaches), the juxtaposition of time series models and idiographic filters with more group-oriented approaches can provide multiple characterizations through mixed methods to enrich understanding.

Levels of Analysis Issues With Quantitative Methods

One of the major changes in developmental science over the past 10 to 15 years has been the widespread incorporation of relations at different levels of dependency into estimating models for statistical analyses (Raudenbush & Bryk, 2002). A close corollary of that interest is how levels are interrelated or how group differences might be responsible for individual differences. In Relational-Developmental-System approaches, level of analyses or nesting of levels focused increased attention on context and dependencies that arise due to grouping. Applications of these methods have promoted more careful consideration of both how the grouping of individuals is accomplished and the measurement of contextual influences on individual patterns of development (Sampson, Raudenbush, & Earls, 1997; Tolan, Gorman-Smith, & Henry, 2003). The characterization of settings, and groups as more than the mathematical aggregation of individuals, along with consideration of dependency across levels have provided not only more informative results but also promoted attention to context and of specific theory about the nature of group-member relations in a given study. For example, one can see progress, in part from need to model family effects as related to neighborhood effects, from viewing neighborhoods as superfluous once family influences were considered, to transactional and interactive models that consider family influences as occurring within neighborhood contexts and with the impact of family influences depending on neighborhood demands and resources (Tolan et al., 2013). At present, these models are being elaborated and paired with additional analyses to improve quantitative representation of the interplay of dynamic systems operating at different levels to influence development (Tseng & Seidman, 2007). For example, classroom norms can be modeled as behavior setting variables that affect individual students but also as dynamic influence systems arising out of the network of relationships between students and between the teacher and the class (Henry, Farrell, Schoeny, Tolan, & Dymnicki, 2011). By applying social network analyses as well as moderation use of hierarchical models, these different frames can be applied in complementary fashion to aid understanding.

When multiple-level frameworks are applied to developmental analyses, they can advance understanding of the dynamics between groups as collections of individuals and as influences on individuals. For example, consider how neighborhood crime level affects youth development with respect to delinquency. One can treat neighborhood crime level as a surrounding context that pervades development and affects youth to delinquency involvement, as a contextual influence that varies in importance depending on family and individual susceptibility, or as a dynamic system that transactionally (relationally) affects development dependent on age, other contextual factors, and prior tendencies (Tolan et al., 2003). By considering applications representing different perspectives, but sharing incorporation of multiple-level influences as interdependent, more robust and useful explanation is likely.

BEYOND QUALITATIVE/QUANTITATIVE PARADIGMATIC INCOMPATIBILITY

It is evident that quantitative and qualitative approaches can differ in many aspects of the research process and in characterizations of the subject of interest (Johnson & Onweugbuzie, 2004). Some have argued against mixing qualitative and quantitative methods because the paradigms that underlie most quantitative and qualitative methods are seen as incompatible (Teddlie & Tashakkori, 2003). This view posits that there are differences between qualitative and quantitative approaches in epistemology and ontology that represent fundamentally different scientific goals. These differences, it is argued, make reconciliation of findings or mixing of methods within a single study impossible. However, this view assumes that complex epistemological issues are themselves wholly determined by whether data used are numbers or not. It also implies that once data type is chosen the important theoretical specification is done. This is a simplistic and sweeping characterization of both qualitative and quantitative approaches. It overlooks both the important heterogeneity of the scientific underpinnings within each set of methodologies, as well as their shared, overarching goal of understanding human development. For example, it is possible to quantitatively analyze qualitative data and to qualitatively analyze quantitative data (Yoshikawa et al., 2008), indicating that the paradigm split is not between the methods themselves but between popular uses and presumed analytic goals of qualitative and quantitative inquiry. In other words, it is not the data collected or even the different method of collecting that determines paradigmatic meaning, but actually it is the paradigmatic framework that determines what a given type of data means and the appropriateness of a given method.

In contrast to the assumption that data collection procedures are simply derivative of epistemological and ontological issues are free of affecting what knowledge with what purpose, there is a substantial lineage of appreciation for multiple methods. This appreciation stretches back through early consideration of the epistemological implications of different ontologies and continues through multiple methods arising within qualitative and quantitative traditions that had different assumptions, disciplinary foci, and practical interests (Campbell & Fiske, 1959). For example, program evaluators were early utilizers of mixing methods, matching methods to different evaluation purposes, and organizing multiple methods into coherent reports of the processes and outcomes of programs (see Greene, Caracelli, & Graham, 1989). This early work often operated out of a *pragmatism* that emphasized that pluralistic measurement increases understanding but also the writings describing these pragmatic choices are clearly based in understanding of epistemology and ontology assumptions/preferences. The goal, identified early, is to find the right tool (actually the right set of tools) to measure the topic of interest well based on a given conception of the question or problem, rather than starting with a method and limiting inquiry to the tools found within a narrow definition of that method (Creswell, 2003). In fact, despite their differences, two foundational methodologists, Cronbach and Campbell, both recognized the inherent promise of moving beyond the qualitative-quantitative research divide for increasing the validity and usefulness of evaluative studies (Campbell, 1979; Cronbach, 1982).

Mixing quantitative and qualitative data allows for the shifting of a measurement paradigm depending on (a) the needs of a given step in a study, (b) a given study in a program of research, and (c) the need to elaborate understanding of a given phenomenon from multiple perspectives. For example, in a longitudinal study of youth risk development in inner-city communities in the United States, Tolan and colleagues (Gay, Quintana, Scrimshaw, Willis, & Tolan, 1998) conducted qualitative interviews of late-adolescent men and women to understand how youth viewed involvement of young men in parenting. These findings led to abandonment of a presumption of difference in fathering interest by whether young men were high risk (defined as involved in substantial delinquency and low school involvement) and also to how fathering was viewed. As is still prevalent in many developmental studies, the guiding assumption was that father's engagement with children was relevant for effects on biological children. Qualitative interviews showed that emphasizing only biological children was misleading. Paternal role and engagement was common with children that were not the young men's biological children but were the children of their partner and involvement with biological children often dropped off if the relationship with the child(ren)'s mother was curtailed or changed substantially (Gay et al., 1998). Also, ties could continue beyond any relationship with the mother but not simply because of a biological relationship (Gorman-Smith, Hunt, & Robertson, in press). Further interviews revealed that fathering was tied to identity as a male through activities and relationship orientation not captured by traditional measures of childrearing. These findings led to a quantitative study that included in the design study of fathering as related to male identity, as well as activities typically not assessed in parenting studies and attention to these activities with all children "fathered," biological or social.

Mixing qualitative and quantitative methods has also been argued for because the intentional mixing of paradigms within a study engages "the tensions that emerge from the juxtaposition of these multiple diverse perspectives" (Teddlie & Tashakkori, 2009, p. 96). For example, in a study of the Young Women Leaders Program, a combined group and one-on-one mentoring program for early adolescent girls, researchers were interested in understanding youth outcomes, both as traditionally considered within a postpositivist framework, and youth experiences, reflecting a more constructivist (relational) epistemology (Deutsch, Reitz-Krueger, Henneberger, Futch, & Lawrence, 2013). The researchers recognized that to contribute to the program and policy literature, they needed to measure outcomes in a manner that promotes generalizability and causal inference. At the same time, they recognized that understanding the experiences of the girls in the program would allow them to make better knowledge claims about how the contexts of the mentoring groups influenced girls, the group processes that may contribute to outcomes, and the ways in which different girls may experience the groups differently. These knowledge claims would allow more meaningful contributions to both program changes and development as well as theory about the processes in group mentoring that contribute to youth development.

Combining these qualitative and quantitative frames led to a design in which a qualitative study of girls' experiences in the program was embedded within a randomized controlled trial of program impact. As a group, the research team was forced to reflect on the meaning behind differences in results across the different methods (e.g., differences in outcomes reported; see Deutsch et al., 2013) as well as what they learned from engaging the more constructivist methods to help explain results from the more postpositivist methods (e.g., Deutsch, Wiggins, Henneberger, & Lawrence, 2013). The juxtaposition of paradigms, methods, and findings also forced the researchers to confront their own constructions of and assumptions about knowledge and to make decisions about which types of knowledge would be privileged in research reports and program development. As these examples suggest, the interest in mixing quantitative and qualitative methods arose both because of pragmatic interests and recognition that juxtaposition of different methods helps reveal framework assumptions and permit elaborations that would otherwise be elusive. In addition, these considerations led to recognition that it is not simply pairing of qualitative and quantitative as classes of data and methodologies that carried the yield to be gained by comparing and contrasting methods within a study or program of studies.

More Than Mixing Quantitative and Qualitative Data Collection

The growing interest in qualitative approaches and of mixing qualitative and quantitative methods in developmental science systematically signals a more general interest in greater attention to how method affects knowledge gained (and not) and therefore the value to be gained by juxtaposing methods. This recognition is not limited to use of qualitative in addition to quantitative data or analytic techniques associated with one or the other. Rather, the recognition extends to a growing interest in how comparison of two methods, including comparisons of methods within qualitative or quantitative approaches, can inform findings. Examples of the use of such comparisons in developmental science include the increasing combination of person-centered and variable-centered analyses (e.g., how growth in aggression affects subsequent psychopathology versus how presence of aggression along with other psychopathology affects subsequent risk; Tolan & Henry, 1996). Similarly, mixed quantitative methods can be useful for examining intraindividual variation in relation to interindividual variation, as exemplified by Nesselroade and Molenaar's (1999) argument for the evaluation of homogeneity of individuals' lagged covariance matrices to foster selective and informed aggregation of individuals' data for group analysis.

Qualitative methods can be mixed to provide enriching scientific understanding as well. For example, individual adolescent narratives about their attitudes concerning sexuality might be explored to illustrate important variations in youth experience, while the same data, in the aggregate, could be explored for themes that cut across any variations to suggest how group norms are carried and to theorize how these might affect individual perceptions. Two lines of inquiry investigating different levels of a phenomenon can also be achieved through combining qualitative methods. Such an approach was taken by Hirsch et al. (2011), who combined case studies of organizational structures with individual youth case studies through ethnographic observations and interviews to portray the dynamics of youth engagement in after-school programming within a developmental-contextual dynamic framework.

In each of these cases, mixed methodology provides a rich understanding that includes a design more consistent with the developmental systems framework for developmental science, which explicitly acknowledges the limitations of each utilized method by aligning it with another method that emphasizes what the first method may ignore, minimize, or render invisible without warranted sensitivity. The juxtaposition of multiple methods may also help differentiate key unresolved theoretical issues from those that are method bound. By bringing methodology more to the fore, articulating the theoretical frame carried by the method, and in acknowledging the limits of a single method, mixed methods research can bring scientific quality and contribution to cumulative knowledge advancement that may otherwise prove elusive (Teddlie & Tashakkori, 2003; Yoshikawa et al., 2008).

ORGANIZING/MIXING MULTIPLE METHODS

Mixing methods effectively rests on consideration of the purpose of mixing methods, the arrangement or type of complementarity sought in mixing methods, and the framework within which the overlap and differences in findings are interpreted.

Purposes of Mixing Methods

Mixing methods can serve many purposes. Bazeley and Kemp (2011) note interdependence, integration, and improving completeness as criteria for mixing methods. Similarly, the valuing of details in relation to summarizing the whole, exploration versus confirmation as the study goal, and theory fit or testing versus development or elaboration can all affect the purpose of mixing methods. Among the primary purposes are verification of findings, ascertaining generalizability, expanding breadth/depth for causal explanation, communication to more audiences within the field, and documenting the relations across levels of influence or among different foci provided by each method (how micro and macro patterns relate).

Verification: Triangulation Principle

The concept of triangulation in research refers to use of more than one approach or method in studying a given phenomenon in order to improve adequacy of description, understanding, and confidence in the inferences drawn (Campbell & Fiske, 1959). Drawn from analogy to the landscape survey method of using a series of triangles to map accurately distance, proportion, and variation in geography, the implication is that by juxtaposing mixed methods systematically, greater certainty of findings (verification) and more confidence in results can be achieved. This was the initial reasoning behind using multiple methods in quantitative analyses as proposed by Campbell and Fiske (1959), who focused on how multiple methods can differentiate method bias from construct measurement (Johnson, Onwuegbuzie, & Turner, 2007). In qualitative research, triangulation is used to ensure trustworthiness of findings (Lincoln & Guba, 1985). Triangulation serves to enhance credibility and persuasiveness of a research account because inferences are drawn based on more than one estimate of the relations and patterns. If similar results are found with more than one method, it provides greater certainty that the results are not an artifact of method, a singular and unreliable result, or heavily conditional (would change substantially if conditions of measurement were slightly altered). For example, convergence of findings between a latent construct model test of influences on youth engagement in prosocial activities across sources reduces concern that what is measured only captures a particular view of a given source. When converging with reports from focus groups of providers and youth about what appears to promote involvement, there is greater confidence in the validity of the results. This increased confidence is based not only in the differentiation of findings from source and method artifacts (not simply due to source or method) but also because the convergence is evidence of replication, an important criterion for choosing between alternative scientific hypotheses and theories (Valentine et al., 2011).

Facilitating the differentiation of findings from method artifacts and providing replication are two primary arguments for mixed methods to provide triangulation. In addition, triangulation can also provide a richness and complexity of description in the examination of the pattern of verification and nonverification of results across methods. For example, when a longitudinal study of protective factors for risk for delinquency was conducted using a multiple regression approach, neighborhood social processes and parenting practices both emerged as significant independent contributors (Tolan et al., 2003). When an approach of family functioning configurations within more and less supportive neighborhood relationships was applied to the same sample, what emerged was that having neighbors engaged in supervision of each other's children was protective for children whose parents, while engaged in discipline and monitoring, were not as warm emotionally with the children. For those children with parents providing all three types of positive parenting, the neighborhood protective effects were not evident. By mixing person-centered and variable-centered analyses, the study helped indicate what might be underlying neighborhood social processes and family characteristics that affect risk and then what configuration of family characteristics related to different need for neighborhood supportive processes.

Triangulation can also serve a verification purpose when there is explicit recognition that two methods do not share a common framework, focus, level of analysis, or formulation of causality and the study or overall analyses are constructed to make use of the known differences. In this case the meaning of the results, including the validity and robustness of inferences, is based on the contrast of findings from the different methods. This approach begins from attention to the recognition that, because of bias and measurement error, any method, perspective, and/or level of analysis carries limitations in precision. What makes a methodology and measures operating within that methodology advantageous also carries the limitations and constraints of its and their utility. Understanding is increased through purposeful consideration of capabilities and limitations of contrasting methods. By providing multiple perspectives, characterizations, or estimates of a relation or developmental system, there is an increase in ability to judge meaning, quality of understanding, robustness of conclusions, and fullness of understanding of specific findings. For example, comparing findings from growth modeling of intellectual capabilities across the first five years of life with different configurations of intellectual skills in trying to explain school readiness enables both overall population trends but also the extent of meaningful subgroups within the population.

Types of Triangulation in Mixed Methods

Mixed methods triangulation can occur in multiple ways: within a study, across studies, or across groups of studies. Denzin (1970) suggested the differentiation of mixed methods designs into four types.

1. *Data triangulation* refers to gathering data through several sampling strategies, to juxtapose data slices from different times, situations, with different samples, and/or with different but related emphases. Through data triangulation verification and or elaboration of description, hypothesis testing, or pattern recognition is achieved. This can also refer to planned application of multiple data analyses methods to a given set of data.
2. *Methodological triangulation* refers to use of more than one method for gathering data and is differentiated from data triangulation by being more than multiple sampling or multiple data analyses of a given set of data. It is the most commonly considered, particularly when multiple methods refers to mixing qualitative and quantitative data from the same sample.
3. *Investigator triangulation*, or study replication, extends the systematic juxtaposition of data collection to multiple studies perhaps by more than one investigator team to understand convergence and divergence in findings.
4. *Theoretical triangulation* extends the emphasis to varying theoretical formulations. This involves incorporating constructs and hypotheses derived from multiple theoretical frames and using multiple theories to help understand the data.

Limits of Verification via Triangulation

The function of multimethod as triangulation rests on the presumptions that all methods used are sound (reliable and valid) and that any convergence is not merely due to shared bias or error of estimation. Also, there is at least an implicit assumption that all methods are ultimately drawn from the same theoretical formulation; they can be reconciled theoretically and are formulated within the same inferential frame of causality and dynamic systems relation. So in the example used above, where configuration of abilities at the person level are used to determine robustness of variable based whole-population relations, both approach school readiness with a focus on individual skills of the child as affecting performance and have the same predictive interest. To the extent they converge, one would conclude that different skills are more or less important. Convergence as confirmation rests on the inference that similarity of findings reflects the extent of reality of a given phenomenon of interest, the relation tested, and/or the theory guiding the study. Similarly, lack of convergence is interpreted as only due to limitations in the theory or measurement limitations (Teddlie & Tashakkori, 2003). In the example of school readiness prediction, lack of convergence would likely be attributed to the limitation of the measured skills in capturing most of what is important in individual school readiness skills or potential need for readiness to be viewed as depending on the configuration of skills rather than relative level of any one skill. Clearly, method precision, reliability, and conceptual overlap all can affect convergence (Campbell & Fiske, 1959). For this reason among others, the extent to which these features are assumed and there is sound reason for such assumptions is a critical characteristic in evaluating any given triangulation effort and should be a explicit part of research plans.

A critical limitation of triangulation as a scientific tool occurs when it is applied without sensitivity to the context and framework within which the comparison of results from methods vary (Johnson & Onweugbuzie, 2004). The extent to which differences in measurement theory, construct definition, relations presumed, and location of the multimethod approach within a dynamic systems are not directly considered can lead to misunderstanding of the meaning of the pattern of results from mixed methods. For example, a survey and in-depth interviews on adolescent friendship influence may not converge because they do not measure the same constructs, because they do not have reconcilable measurement methods (e.g., one is interested in group trends, one is interested in individual configurations of responses), because the underlying theory and epistemological frameworks differ, or because they are not administered and interpreted with the same level of care. The triangulation value of mixed methods rests on formulation of each of the methods from a particular framework of relation to and advantages for capturing the developmental phenomenon and features of interest and on carefully formulated presumption about how results should converge or not across the methods applied.

Generalizability Determination. Generalizability of findings is an important consideration in evaluating the meaning of any study (Shadish, Cook, & Campbell, 2002). Mixed methods provides an understanding of the generalization of findings that can go beyond the simplistic approach of comparing groups differentiated by age, gender, ethnicity or some other distinction and interpreting consistency in findings as evidence of general effect. A mixed-methods approach aids consideration of both the continuity across groups and discontinuity/heterogeneity within groups at the same time in a way that can be more informative than simply using a single method such as hierarchical linear models. For example, in a study of Latino/a and African American families raising children in an inner-city (economically impoverished, high crime communities) a multiple regression prediction indicated that for the African American adolescent participants' family cohesion mediated the positive relation between exposure to life stress and delinquency involvement. However, the same result was not found for the Latino/a adolescents. In fact, family cohesion positively related to risk (Gorman-Smith, Tolan, & Henry, 1999). If considered simply as the result of demographic group and predictor statistical interaction, it would be hard to identify why the results should contrast. Interview notes, however, revealed that Latino/a parents were more prone to view independence and autonomy as threats to family coherence and overall to value these characteristics in their male children as much as African American parents did. For Latino/a parents, time spent together as a family and dedication to family were more valued and, within that cultural frame though, overvaluing closeness (high cohesion scores) was not enabling of the youth to negotiate social challenges of adolescence and seemed to lead to rebellion and more time out on the street, where exposure to delinquency risk increases (Gorman-Smith et al., 1999). For one ethnic group, underdeveloped family cohesion meant more risk whereas for the other in ways that made sense once it was evident there were cultural differences in how "cohesion" items were understood by parents. This example shows how qualitative data does not just augment quantitative data but can help provide a sound understanding of the data, including the limits of generality and its relation to nuances of context, social meanings and development.

Expanding Breadth/Depth for Causal Explanation. Related to the issues of generalizability is the importance in specifying understanding of the causal processes that are thought to be responsible for results. Combining methods can help identify and test explanatory processes, which may not be apparent through use of a single method. For example, in the New Hope study mentioned earlier (Gibson-Davis & Duncan, 2005), investigators found positive outcomes for boys in families in the program group but not for girls. The survey data analyses did not provide any significant results to answer why this might have occurred. The qualitative data, however, revealed that families were focusing resources gained from the intervention on their sons because they were worried about safety of the boys due to the neighborhood presence of gangs. This explanation of the quantitative effect was obtained because of the qualitative data gathering.

Communication With More Audiences in the Field

One basis for valuing multiple methods is that areas of developmental science, as well as multiple disciplines that share common areas of study with developmental science, have different interests in constructs, developmental systems, relations of individuals to conditions and settings, and other aspects of scholarly inquiry. Often these interests spur reliance on methods that are a good fit within that disciplinary perspective or particular interest. This can occur absent needed cognizance of the assumptions and limitations of the favored method. The results may not be as accessible by others or as easily relatable to other areas of study if the assumptions and constraints of that approach are not evident. Similarly, when methods are not favored or appear to carry a different interest, presumption of relations, or characterization of variation, it may be difficult for investigators to appreciate those results even if they are relevant. By utilizing multiple methods, additional ways of understanding the study meaning occur. This may make what are otherwise undervalued or misunderstood methods and results accessible to a broader group of scholars and knowledge-utilizers. For example, as economists and psychologists work to try to understand the benefits of prevention efforts and educational practices, the way in which influences such as parenting or school quality are conceptualized and modeled can be quite different. One group's nuisance variable or minor consideration can be another group's key consideration. Considering cost-benefit oriented analyses as well as those that track effects through theorized developmental processes increases the disciplinary cross-talk that can occur and enriches the value of results from studies to each field.

Mixing methods cannot only provide opportunity to have methods within a given study or program of research that can speak to different constituencies but also aid in translation of findings across areas. Developmental scientists share broad topical interests with many other fields. Anthropologists, for example, often study children and families. Yet anthropologists, who privilege in-depth, qualitative methods, are unlikely to consume research that is purely quantitative. Similarly, psychologists, who privilege valid and reliable instruments, are more likely to discount purely ethnographic work (Weisner, 2005). Thus, mixed methods can help broaden the audience for research, helping scholars who may share topical interests but come at studies from different methodological angles learn from each other's work. Such translation can lead to thoughtful discussion of the limits of each method and each specialized interest, and hopefully to how a more sophisticated consideration of complementary utility of each (Cook & Wong, in press; Shadish et al., 2002).

Relating Levels of Analysis and Developmental Influence

Of increasing interest to developmental scientists is how changes at different levels relate to each other and, in particular, what dependencies (direction of dependency and extent) are evident. For example, how might child aggression in school relate to changes in the norms of the classroom they enter in each of a set of succeeding years (Henry et al., 2000) or how do peer relationships affect reaction to a family-based prevention intervention (Multisite Violence Prevention Project, 2013)? The advance of multilevel models that consider such dependencies have helped spur theoretical cognizance of how systems and setting characteristics help explain relations of different level phenomena, patterns of change, and enrich understanding of the meaning of different relations (Raudenbush & Bryk, 2002). However, obtaining adequate data and proper sampling frames for these analyses can require considerable control and resources, particularly to obtain more than cursory measurements of more than one level. These requirements carry accompanying practical issues (e.g., costs, burden to those providing data), and important limitations in how complexly levels can be related in a given model (e.g., if one wants to model how males and females differ in response to classroom social network characteristics within classrooms, within schools, and within different economic conditions may have several levels and some cross-level groupings while also some within level groupings). It may not be plausible to model all the relations either because the data cannot be obtained in all but a few instances or because the statistical models and underlying theory are not developed yet that can account for the complexity of the multiple relations comprising the theorized model. Although it is preferable to have models that can incorporate the complexities of dynamic system theories with multiple levels and subgroup variations, there are statistical and practical challenges to this occurring, as well as measurement and sampling compromises that accompany large complex modeling. A practical alternative is to collect and analyze data focused on a subset of the overall multilevel model and in a series of studies piece together the overall model. Although not actually statistically testing the whole model, one provides pieces of the theorized pattern that, through consistency with the overall model provide multiple partial understandings and together portray a fuller and more extensive characterization of development within context.

Within the general interest in relating levels, a key subtopic is the *relation of micro and macro patterns,* such as how individual growth and group growth patterns might relate (e.g., how do patterns of individual self-control development relate to the overall pattern of classmates, how setting or education process dependent are individual patterns). Similarly, the meaning of variation within subgroups differentiated by experience of particular developmental influences is often of interest (e.g., how does development of self-control differ for youth with higher intelligence than those with lower intelligence in a structured classroom)? While it may be plausible and even desirable to attempt to capture the overall relation between individual and group variations and overall growth, this may also foreshorten measurement complexity and sensitivity for each level. By mixing methods, more in-depth consideration of the relation and more perspectives on the relation can be undertaken to compose a fuller understanding.

For example, in their study of urban after-school centers, Hirsch et al. (2011) utilized multiple methods and in-depth case studies to explore how organizational and individual characteristics interact to influence youth experiences and outcomes. The researchers initially surveyed 265 youth at three centers. From that sample they drew a subsample of 10 youth per center to follow in-depth over the course of a year, during which they conducted ethnographic observations, structured observations, and semistructured interviews with youth and staff. Interviews included traditional open-ended interview questions as well as a number of psychological and relational scales and methods such as timelines and social network maps. From the in-depth sample of 30, six youth (two from each center) were selected as exemplars of different kinds of experiences and outcomes and case studies of these youth were conducted to illustrate how different contextual factors can interact with individual factors to influence youth's experiences of a setting and subsequent outcomes over time.

Finally, the researchers compiled the quantitative and qualitative data across all data sources from within each center to conduct organizational case studies, using data such as quantitative social climate ratings and youths' ratings of their relationships with center staff to provide setting-level descriptors. Through use of these multiple data sources and individual and center level case studies Hirsch et al. (2011) were able to construct a theoretical model of the ways in which "various individual, group, and organizational factors combine to lead the centers to influence, positively and negatively, the lives of the young people who participate in their activities" (p. 9). The three main features of the model are: (1) programs and activities, (2) relationships, and (3) cultures, or PARCs. These three areas emerged from the data and in-depth case studies demonstrated how these factors came together to influence youths' developmental trajectories within the after-school centers.

Design Considerations in Mixed Method Research

There are several mixed method design variations that can be useful, with particular utility depending on the purpose of a given study or set of studies and the epistemological, ontological, and measurement assumptions guiding the researchers' interests. A number of typologies of mixed methods designs have been proposed (see Creswell, Clark, Gutmann, & Hanson, 2003; Leech & Onwuegbuzie, 2009; Morse, 2003). Whereas the nomenclature differs slightly across typologies, investigators have focused on four major areas in classifying mixed methods designs:

- Level of integration (or mixing) of the methods (partial or full).
- Order in which methods are used (concurrently or sequentially).
- Priority given to one method in relation to each other (which method is dominant).
- Goals of the method with regards to the research questions (e.g., exploration, confirmation, triangulation).

Rather than discussing the various combinations of design elements that lead to different categorizations of research designs as others have done, review of each area is presented separately with references provided to previous reviews of typologies, for specific designs.

Level of Integration

Mixed methods designs can differ in the extent to which methods are integrated within a study, from partial to full mixing. Creswell et al. (2003) provide a framework for deciding to what extent, at what stage of the project, and in what form methods should be integrated. They suggest researchers base these decisions on four major aspects of research design: (1) the research questions/purpose (e.g., confirmation versus exploration), (2) the type of data collection (e.g., numeric versus non-numeric data), (3) the intent of analysis (e.g., descriptive or inferential statistics versus descriptive thematic analysis) and (3) interpretation of the results (e.g., generalization versus particularization). The greater the similarity of goals and purposes across the methods within a study, the more integrated the mixing can be. In partially mixed studies, the methods are implemented separately and combined only during the interpretation of data. Leech and Onwuegbuzie (2009) defined fully mixed studies as those that:

> [use] both qualitative and quantitative research within one or more of the following or across the following four components in a single research study: (a) the research objective (e.g., the researcher uses research objectives from both quantitative and qualitative research, such as the objective of both exploration and prediction); (b) type of data and operations; (c) type of analysis; and (d) type of inference. (p. 267)

Ordering of Methods

The ordering of methods refers to whether quantitative and qualitative methods are used concurrently or sequentially within a study. In concurrent studies, both types of data are collected simultaneously and the data can be analyzed and compared (Creswell et al., 2003). In sequential studies one type of data is collected first and is followed up on with the second method (Creswell et al., 2003). It is also possible to collect multiple phases of quantitative and qualitative data over the course of a study. As Creswell et al. (2003) point out, the ordering of methods is driven by the objectives of the study and the goals of the multiple methods and relies on "understanding the important interrelationship between the quantitative and qualitative phase in data collection" (p. 219).

Priority of Methods

Within mixed methods studies investigators may treat one or another method as dominant or consider both methods to have equal weight (Creswell et al., 2003). This is often noted through the use of upper and lower case letters in depicting the use of methods in relation to their ordering. For example, QUAL → quan would depict a study in which qualitative methods are dominant and precede quantitative methods whereas QUAN + qual would refer to a study in which quantitative methods are dominant and conducted concurrently with qualitative methods. This could occur with two quantitative or two qualitative methods, as well. Some typologies assume the possibility of methods being given equal weights (see Creswell et al., 2003). Others suggest that investigators are typically driven by either a primarily inductive or primarily deductive frame and that these frames define which set of methods will be dominant, with qualitative methods dominant within inductive studies and quantitative methods dominant within deductive studies (Morse, 2003).

Goals of Methods

The goals of the methods refer to the research objectives that are driving the use of mixed methods. Early on Greene et al. (1989) identified five major purposes of mixed methods within evaluation studies: triangulation, complementarity, development, initiation, and expansion. Although others have described the goals of studies differently, these five remain a useful overarching framework for understanding how investigators use mixed methods.

Triangulation Designs

Triangulation designs are perhaps the most common mixed method design (Creswell et al., 2003), and harken back to the initial impetus for mixed methods as set forth by Campbell and Fiske (1959), as discussed earlier. Because triangulation designs focus on using one method to validate or confirm findings gathered by another method, the different methods are typically given equal weight. Across qualitative and quantitative approaches, triangulation designs could include examples such as using interview and survey data with a focus on convergence of findings. As noted above, triangulation, although typically used to refer to interest in convergence for validation, can help reveal important divergence as well.

Complementarity Designs

Complementarity designs use multiple methods "to measure overlapping but also different facets of a phenomenon, yielding an enriched, elaborated understanding of that phenomenon" (Greene et al., 1989, p. 258). This would include examining different levels as well as different aspects of a given topic. The methods are used in conjunction to expand on what could be learned about a phenomenon from either method alone, as well as sometimes to elucidate findings from one method through examination of data from a second method. For example, investigators may use surveys to assess the prevalence of a particular phenomenon and interviews to examine its meaning to participants.

Development Designs

Development designs use one method to help inform the second, for example, using focus groups to help develop survey measures or using survey data to help identify a sample for qualitative interviews (Greene et al., 1989). In development designs methods are implemented sequentially, as one is dependent on the results of the other.

Initiation Designs

In *initiation* designs multiple methods are used to help uncover new questions and paradoxes (Greene et al., 1989). As noted in the discussion of triangulation, above, data does not always converge in expected ways. One of the strengths of mixed methods studies are their ability to use such contradiction to produce otherwise invisible findings. Greene et al. (1989) note that initiation designs may emerge from studies as unexpected findings occur within either method alone, but mixed methods investigators can also intentionally plan to use the multiple data sources to interrogate contradictions and develop new questions.

Expansion Designs

In *expansion* designs multiple methods are used to examine multiple components of a phenomenon. This examination allows investigators to expand the breadth of a study, for example by assessing both outcomes and processes of a program (Greene et al., 1989).

Specific Mixed Methods Designs

In their chapter on advanced designs in the *Handbook of Mixed Methods in Social and Behavioral Research*, Creswell et al. (2003) delineated six specific mixed-methods research designs that incorporate the level of integration, order of methods, priority of methods, and goals of the research.

Sequential Explanatory Designs

Sequential explanatory designs are those in which one set of methods (typically qualitative) is used to help interpret the results of the other method (typically quantitative). Investigators are focused on "explaining and interpreting relationships" (Creswell et al., 2003, p. 227). Such designs typically consider quantitative methods as dominant, and use qualitative data to help explain the quantitative findings.

Sequential Exploratory Designs

Sequential exploratory designs focus on understanding and exploring a phenomenon, and thus qualitative methods are typically used first and considered dominant. Quantitative methods are then used to gather additional data to help the investigator interpret the qualitative findings. "At the most basic level, the purpose of this design is to use quantitative data and results to assist in the interpretation of qualitative findings" (Creswell et al., 2003, p. 227).

Concurrent Triangulation Designs

In *concurrent triangulation* designs, multiple forms of data are collected at the same time and used to examine convergence around a construct or phenomenon, as described above. Either method may be dominant or they may have equal weight within a study. The goal of such studies are to triangulate data toward greater validity (Creswell et al., 2003).

Concurrent Nested Designs

Concurrent nested designs are used when a investigator wants to expand the reach of a study by addressing additional questions or studying different levels of a phenomenon. Within this design one method is given more weight with a secondary method embedded within it, which differentiates nested designs from triangulation designs. The goals of such designs can include both complementarity and expansion (Creswell et al., 2003).

Transformative Designs

Transformative designs are those that are focused on advocating for change. In such designs, values and theoretical assumptions are explicitly included in the study's design (Creswell et al., 2003). *Transformative designs* may be either sequential or concurrent. In *sequential transformative* designs multiple methods are used in distinct phases. "By using two phases sequential transformative investigators may be able to give voice to diverse perspectives, to better advocate for participants, or to better understand a phenomenon or process that is changing as a result of being studied" (Creswell et al., 2003, p. 228). In *concurrent transformative* designs the investigators is still guided by an advocacy or change perspective, but employs methods simultaneously in order to enhance those goals. Either method may be given priority or they may be weighted equally.

EXAMPLES OF MIXED METHODS RESEARCH IN DEVELOPMENTAL SCIENCE

A body of mixed methods work has developed within child development studies. Below are a few examples of mixed methods work, drawn from across disciplines but focused on developmental science as an overarching topic. Many examples can be found in Weisner's (2005) edited volume, *Discovering Successful Pathways in Children's Development*, which includes a number of studies with investigators from across disciplines that have contributed to developmental science through using mixed methods. Weisner provides an overarching definition of development as occurring "along pathways that are given to us by culture and society and that are actively chosen and engaged in by parents and children within some particular cultural ecology" (p. 1). He continues on to note that "these pathways . . . [consist] of everyday contexts and activities" (p. 1). Weisner argues that mixed methods are the best means for scientific understanding of development as approached from this conceptualization. The volume is exceptional because the authoring investigators, who have used mixed methods, reflect on their practice and on how the multiple methods were used within and contributed to their lines of research. As Weisner notes in his introduction, one theme is that contributors highlight findings that would not have been possible without mixed methods designs.

Johnson's chapter within Weisner (2005) highlights the use of mixed methods across three studies of African American children's racial socialization and coping. Rather than demonstrating what has become a more traditional use of mixed methods, that is, triangulating or expanding findings on a particular construct through multiple methods used to assess that construct, Johnson illustrates how mixed methods can include use of a single instrument to assess a construct across different samples in different ecologies. She presents a series of three studies using the Racial Stories Task (RST), in which youth are asked to respond to vignettes about racial conflict, with three different samples of African American youth. The studies focus on socialization and coping in three different contexts: family, school, and community. Thus, the data gathered from the same instrument is analyzed differently within each study. In the first study, focused on family socialization, parent-child dyads were videotaped engaging in the task and the data was qualitatively coded to examine parental behaviors in relation to the child's expressed coping strategies. Johnson (2005) notes that:

> This approach to analyzing the data fostered an understanding of what parents do that supports or undermines the acquisition of coping competencies and how race meaning is potentially disentangled from the strategy development process. (p. 96)

In the second study Johnson reports (2005), youth responses to the RST were quantitatively coded and the influence of school racial composition on coping strategies was assessed. The racial composition of schools was found to influence the prevalence of different coping strategies among students. Finally, a third study was conducted to examine the interaction of community and individual level influences on coping strategies. In this case domains of coping orientations were examined rather than individual coping strategies and youth self-esteem was used to predict youth's domain with community-level factors included in the model as a moderator. It was found that self-esteem was linked to particular coping orientations, with both child's age and community violence as influencing that relationship.

Thus, across these three studies, Johnson (2005) used a single measure for both qualitative and quantitative analyses to identify and relate types of racial coping (individual strategies and coping domains) as well as the utility of these within different contexts. Across the set of studies she carried out, there were variations in type of data analyzed and also in how the same data was analyzed, with multiple qualitative and quantitative methods applied.

A different approach to mixed methods can be found in Guerra, Williams, and Sadek's (2011) use of a combination of surveys and focus groups to study bullying in schools. The authors utilized a *triangulation* design (comparing data gathered from the surveys and focus groups) with some *expansion* aspects (using qualitative data to elaborate on the quantitative findings). The goals of the study were to better understand both individual and contextual predictors of bullying with an aim of informing prevention programs. Quantitative survey data was used "to assess the relations between self-esteem, normative beliefs about bullying, and perceived school climate and both bullying and victimization from fall to spring of the school year" (p. 298). Surveys were collected from youth (N = 2,678 at pretest, 2,261 at posttest) at 59 schools within Colorado. Qualitative data from focus groups of students who were not part of the survey sample (but who were the same ages as the survey participants) "[explored] these predictors and other individual and contextual factors that emerged" (p. 298). Focus groups were conducted with students (N = 115) who were not part of the survey sample at seven of the survey schools. Focus group data corroborated some of the survey findings regarding why people bully, such as low self-esteem. Yet the focus groups also helped elucidate how bullying could be just a normal part of school life, and something that everyone does. Additional reasons for bullying also emerged from the focus group that had not been assessed in the surveys, such as bullying being "fun" and bullying being related to "power, jealousy, and status" (p. 305). Whereas the survey pointed to low self-esteem and negative school climate as being related to victimization, students in the focus groups mentioned individual characteristics such as weakness, timidity, small physical stature, or being annoying or different as leading to victimization. The focus group participants also discussed how girls are often bullied around issues of sexuality. They did not report school characteristics as contributing to victimization. Overall, the survey and focus group data together provided information about the "dynamics of bullying of victimization" (p. 209), allowing for both corroboration (triangulation) and elaboration of results across methods.

Another example of mixed methods is by Wallace, Ye, and Chhuon (2012) who conducted a *sequential, corroborative* mixed methods study in which they used focus groups and surveys to identify and assess subdimensions of adolescents' sense of school belonging. The authors first conducted focus groups with youth (N = 72) participating in youth development programs in three states. In addition to traditional open-ended discussion questions, the focus groups included innovative techniques such as:

> a "continuum of opinion" activity that used a line of tape on the floor to solicit individual interpretations and experiences of relationships with adults. We asked the adolescent participants, "If this end of the line represents 'knowing nothing,' and this end of the line represents 'knowing everything,' please stand on the line to show how much the adults in your life know about you." (p. 126)

Findings from the focus groups suggested that three areas were important to adolescent sense of belonging in school. The first was self-presentation, and the ways in which adolescents worked to align people's views of them with their own views of themselves. The results suggest that disengagement from school was often "to avoid incongruences between an adolescent's public self, as perceived by school-based adults, and an adolescent's personal goals and ideals" (Wallace et al., 2012, p. 128). The second theme focused on classroom experiences and caring teachers and the third involved experiences in noninstructional spaces, including extracurricular activities and disciplinary situations. In addition, an emergent finding, not reflected in current theories of belonging, emerged: being known by a teacher. From the focus group findings the investigators developed a nine-item "being known" scale, which they tested in the quantitative phase of the study. Students (N = 902) at an ethnically diverse high school took a survey including the nine new items along with two additional scales related to belonging that have been used by investigators. The data was then factor analyzed to empirically test the subdimensions of belonging that emerged from the focus groups and from theory. Four factors emerged: generalized connection to teachers, connection to a specific teacher, identification and participation in school, and fitting in with peers. Together, the data collected suggests that there are identifiable and mutually contributing interpersonal, intrapersonal, and institutional subdimensions of feelings/perceptions of belonging. Thus, in this study, qualitative data was used to help construct a measure to assess the phenomenon of interest, quantitative data was used to test the factor structure of that phenomenon, and the two types of data together were used to theoretically expand the construct of school belonging.

In a study of religion and childbearing in Nepal, Pearce (2002), used survey data to select cases for ethnographic study, which then allowed for theoretical elaboration and measurement refinement. The author began by using multivariate regression models to predict family size preferences for unmarried (N = 959) and married with children (N = 864) men and women in south Nepal. Pearce "tested a variety of models to arrive at one that best explained the relationship between religion and childbearing preferences for each group" (p. 108). To better understand the relationship between religion and childbearing, the author identified cases within the survey sample that were incorrectly predicted by the regression model, focusing on those whose preferences were underpredicted by the model. She then stratified the sample by gender and group (married with children versus unmarried) and selected seven respondents from each cell (N = 28) for ethnographic study, including participant-observation and interviews. The interviews began with three structured questions that were repeated from the original survey, allowing for direct comparison with prior responses, and continued with open-ended questions about religious beliefs and practices and family-size issues and preferences. From the qualitative data the investigator "was able to code new, more informed measures of religion from the survey data for further analyses" (p. 115) as well as to develop new measures for factors not assessed by the initial survey (e.g., influence of media about fertility issues). The qualitative data also allowed her to better understand unexpected results, places where her hypotheses about how religious beliefs would influence fertility preference were not borne out by the statistical models. This allowed for refinement of the theoretical frame guiding the creation of the statistical models to include the role of family as an important context of religion. Thus, in this iterative mixed methods study, Pearce was able to use quantitative data to select a sample for qualitative study that then allowed for both methodological and theoretical refinement of the quantitative data and results.

Suárez-Orozco and colleagues (Suárez-Orozco et al., 2010) conducted a *longitudinal, complementary* mixed methods study of newcomer immigrant youth to identify trajectories of academic achievement, factors that contribute to patterns of trajectories, and challenges faced by immigrant youth during adjustment to school. Statistical models were used to identify trajectories of achievement and individual and contextual factors related to trajectories and case studies were undertaken to identify processes underlying the trajectories and "unanticipated causal links, which quantitative data do not reveal" (p. 605). Together the methods allowed the authors to both triangulate and elaborate their findings. Immigrant youth (N = 407 in Year 1; 309 by Year 5; 294 with dependent variable data for all 5 years) between the ages of 9 and 14 were recruited from two cities for the larger study. A subsample of 75 youth representing different academic engagement profiles was selected for case studies in Year 3. The investigators used latent class growth modeling "to identify clusters of individuals based on developmental trajectories in order to establish the number of groups that best fit the data based on both patterns of individual change and probability of group membership" (p. 607) and multinomial logistic regression to ascertain factors associated with group membership. Five patterns were identified: consistently low, consistently high, improving, precipitous decline, and slow decline. A number of contextual and individual factors, such as living in a household with two adults, attending a more segregated school, having limited English proficiency, mental health, age, and gender, among others, were associated with membership in different trajectory groups. The case studies were then grouped by trajectory and coded and investigators identified patterns that emerged within groups. The case studies confirmed many of the factors identified in the statistical models and also brought to light new factors, such as the context of immigration (e.g., immigrating with one's whole family, preimmigration experiences such as war or parental death, documentation status), the role of parental education and family instability, the presence of a mentor or advocate, and the decision to opt out of school for paid work in order to protect one's self-esteem in the face of poor academic achievement. For the slow decliners, a fully new factor emerged from the case studies; it was common for youth in this group to switch from low to high achieving schools partway through the study. Although this may be viewed on the surface as a potential positive contextual factor, the case studies revealed that students were often moved before their English skills were adequate to guarantee success in a more competitive environment and thus, "without adequate social and academic supports, early high grades drifted downward" (p. 611). Overall, the quantitative and qualitative data in this study was combined to provide both generalized and contextualized conclusions, with the two forms of data validating each other but also providing different types of knowledge and levels understandings.

Perhaps one of the best-known mixed methods studies is the New Hope Study, an experimental evaluation of an antipoverty program, which included an embedded ethnographic study of families from both the control and program groups. The use of mixed methods within this study overall has been discussed by Gibson-Davis and Duncan (2005) and there are multiple examples in the literature of findings from this study. One such example is a report from that study by Lowe, Weisner, Geis, and Huston (2005) examining childcare instability. The New Hope Child and Family Study included a sample of 745 families from the experimental study, including both program and control families. From within that group a stratified random sample was selected for ethnographic study ($N = 44$). Visits were made to families in the ethnographic families multiple times each year and investigators visited with families, engaged them in semistructured interviews, and took detailed field notes. For this study, investigators selected excerpts of field notes that referred to childcare arrangements and coded data based on type of arrangement and whether or not it was a change from previous arrangements. Predictable change (e.g., starting school) was differentiated from unexpected change and the data was quantified to provide a percentile measure of childcare instability as well as to describe overall patterns of change within the sample. Overall, 84% of the families experienced a change at least once over the course of the study. Between 20% and 50% of families experienced instability in childcare during any given period. New Hope reduced instability, with program families experiencing instability in an average of 24% of time periods versus the control group who experienced instability in an average of 43% of time periods. The reasons behind childcare changes were also coded and quantified. These included child maturation, changes in family resources, and changes in family routine, among others. Three case studies were then used to "describe the dynamic relation among various features of the family cultural ecology and how these features produced stability or instability" (p. 132). Thus, in this study, a large quantitative dataset was used to select a sample for an embedded ethnographic study. The qualitative data was coded and quantified for quantitative analysis to identify patterns of childcare within the sample. In-depth qualitative case studies were then used to provide explorations of how the identified factors worked together in particular family contexts to influence the outcome of interest (childcare).

Ungar and Liebenberg (2011) used a mixed methods design to facilitate the construction of a new, culturally sensitive measure of youth resilience. This study is unique in its use of multiple methods to provide both generalized and culturally specific understandings of a topic, which has long been studied quantitatively without in-depth consideration of the applicability of the construct to different contexts. Youth between the ages of 12 and 23 ($N =$ 1,451) were drawn from 16 sites across 11 countries for the quantitative sample. These youth completed the Child and Youth Resilience Measure, which was then analyzed via exploratory factor analysis. A subsample of 89 youth was purposefully selected for qualitative interviews based on a site leader's identification of the youth as "doing well despite facing severe risk" (p. 135). The qualitative data were analyzed using a constructivist, grounded theory approach and results were used to "investigate the validity of the CYRM allowing youth voices to inform interpretation of the quantitative data" (p. 135). The original 58 items on the CYRM were reduced via the factor analysis, with some items being added back in based on the qualitative findings for a resulting scale length of 25 items. The authors note that the results of the study indicate that:

> Although all questions showed relevance to each geographic subpopulation, the varying factor structures observed in response patterns indicate heterogeneity in how resilience is understood and negotiated across cultures and contexts. Furthermore, as the qualitative data showed, not all constructs held the same importance in all cultures. (pp. 141–142)

Overall, this study used mixed methods to provide both generalizable and culturally specific understandings of a commonly studied construct in child development. Through use of quantitative and qualitative data together, the authors facilitated measurement development, quantitatively validating the scale and testing its generalizability while using qualitative data to retain scale items that were not statistically relevant according to factor analysis but appeared practically important to youth during interviews. Yet the investigators were also able to use the results to provide theoretical elaboration of the construct of resilience, gaining a more nuanced understanding of what resilience *means* for youth in different cultural contexts.

MOVING FORWARD WITH MIXED METHODS IN DEVELOPMENTAL SCIENCE

Developmental science and the central considerations of how universal, group, and individual development proceed and how change and state are dynamically related are qualitatively shifting the way theory is formulated and how methods are chosen and related to theory. Among quantitative and qualitative methodologists there is increasing sensitivity to the complexity of a developmental approach and to closely tying methods to theoretical expression. Concordantly, there is a convergence of interests toward the vitality of mixed methods for the major perspectives guiding the field's study and for helping elaborate and relate partial understandings into coherent and useful explanations of developmental phenomenon. The purpose of this chapter was to outline important issues and features in mixed-methods research and to advance consideration of these beyond the typical approach of inclusion of qualitative with quantitative methods. Among the vectors of influence within developmental science are advances in theory and methods reflecting: (a) sensitivity to complexity in determining action, (b) recognition that context is implicit in individual measurement and merits measurement attention equal to that applied to individual characteristics, (c) consideration of multiple levels of dynamic system influences, (d) the importance of careful mapping of the relation of micro and macro change, (e) the nuances of relations between meaning and behavior, and (f) the value of elaboration and connection of results over isolation of fundamental putative causes. Within each vector is a contribution that can be made through mixing methods. As methods have developed that attend to these different interests there has been increasing sophistication of understanding of the assumptions, purpose, capabilities, and limitations of different methods. This understanding is arising in discourse about qualitative as well as quantitative methods. As each has developed a broad set of techniques with careful and technical discussion among experts on each method and on the epistemology framing the purpose of that method, there has also been increasing attention to choosing methods purposefully rather than privileging one presumptively. The latter tendency was referred to as akin to ethnocentrism by Yoshikawa et al. (2008) in their discussion of mixing methods, who termed it *methodcentric*. They relate that methodcentricity, like ethnocentricity, can help promote certainty of understanding and build group cohesion among subscribers but may also promote reification of certain views and presumptions of universality that are not warranted. Most pertinent to this chapter's focus, unexamined methodcentrism can obscure the contextual base for any particular set of findings.

Similarly, Guba and Lincoln (2005) note a shift from how one method and related framework or focus is given virtue over others to one of how mixing frameworks with open consideration of the assumptions and limitations of each can promote better knowledge. This shift to an integrative approach not by a particular finding or method but by the juxtaposition of methods and studies, means methods are of interest because they complement each other in a particular scientific endeavor (Guba & Lincoln, 2005). As noted by others within quantitative and qualitative methods and by those on the frontiers of mixing these two major categories of methods, there is an inevitable framework shift once methods are considered as different lenses, each of use rather than as more or less correct (Creswell, 2011; Teddlie & Tashakorrie, 2003). This shift deepens appreciation of context, of meaningful variation, and of the fact that a method of analysis is a critical part and expression of the theoretical framework guiding the scientific study (even though that guidance can vary from very structured to more basic and from more deductive to more inductive). This shift also provides a basis for a focus on interpretation across studies rather than favoring a given study with a given method. Included in this valuing would be that diverse methods provide more confidence about meaning of results for forming a robust understanding of a larger set of findings and interests.

Consideration of multiple methods has been more present and overt in qualitative approaches but is now evident in quantitative methodology discussions. Qualitative methods are quickly moving from marginal and "augmentations" to approaches with equal status and value, with specific utility, rather than presumptions, guiding choice of qualitative methods. However, these methods remain not well understood by many, including both critics and proponents. Similarly, there can be insistence within quantitative methods about which method is more accurate, which can lead to approaches to mixed methods that still treat qualitative methods as a means of "illustration" of results or "exploration" of outliers rather than as equal contributors to the understanding of developmental phenomenon. Yet, one can see more such discussions of key methodological features and differences to be about issues that apply across quantitative and qualitative methodologies with some overt incorporation of such recognition.

Mixing methods can serve important purposes of scientific such as knowledge plausability, replication, reliability, and validity of measurement, sampling adequacy, and generalization and robustness of theories (and conditions of such features) while also serving to note the contextual and bounded nature of results from a given study or reliance on a given method. Moving forward, mixed methods should be considered as combinations both within and across classes of methods, with the critical consideration being thoughtful determination of what combination is most appropriate and informative combined in what manner and for what purpose. These considerations, then, reside in initial theorizing that might frame a study as well as considerations of the assumptions underlying that theory and the boundaries and ordering of what about development and of the particular topic of interest are present. In addition, the methods to be combined may, and probably should, jointly inform sampling, whether it is to conduct multiple samplings within a given study or across a series of studies. Indeed, sampling and measurement design for different purposes of combining methods and prototypical designs combining different methods are topics in need of more discussion and articulation within the field (Creswell, 2011).

In general, mixed methodology, although having advanced in conceptualization, technical quality, and variety of methods and acceptance, is still early in its development. At the same time, mixed methods as an approach is rapidly forming with limited stability in the dominant paradigm and a lack of consensus about its value or the needed next steps (Johnson et al., 2007). For example, there is considerable difference in how mixed methods are viewed even among those well trained in this approach and appreciative of its value. Variations and disagreements about what is necessary for a study to be mixed methods (as opposed to multimethod), when and how a mixing plan should be determined, the extent of overlap versus distinction that is important, and the validity of different rationales for mixed methods are still widespread.

Perhaps most prominent among these areas of debate, and one this chapter takes a more uncommon view about, is whether mixed methods only refers to the combining of qualitative and quantitative methods (Morse & Neihaus, 2009). The differences in historical basis, initial interests, and thoughtful expressions of epistemological and ontological differences of quantitative and qualitative methods in the main are important in framing the understanding of mixed methods. Thus, it can be expected that applying a quantitative method with a qualitative method will and should continue to be a prominent application of mixed methods. Yet many of the issues revealed in the discourse specific to mixing *between* qualitative and quantitative methods are as applicable to mixing *within* qualitative and quantitative methods as well (Vogt, 2008).

For example, Duncan (2012), in his call for increased breadth in developmental science, points out that even within quantitative methodologies, different fields (e.g., economics and psychology) have different measurement traditions that influence both the questions asked and the information gleaned from any given set of studies. He provides the example of the limitations of developmental studies in directly assessing the impact of social policies. Due to psychology's methodological traditions, he argues, developmental science has emphasized program and policy affects demonstrated through random assignment experiments or closely approximating quasi-experimental designs, which are rarely plentiful regarding a specific developmental topic. While noting limitations of economic traditions, and the growing overlap of the fields, Duncan suggests that there is substantial knowledge that can be procured through natural experiments, and their concomitant methods, on which economists and sociologists have historically capitalized. Duncan notes (2012), in accompaniment to this suggestion, that with the benefits of developmental theory and analytic interpretation methods these opportunities would be enriched as well. Duncan's suggestion is that enrichment comes from multiple methods with focus on reconciliation through theoretical triangulation.

Furthermore, given advances in quantitative and qualitative methods that allow for measurement at various levels, and therefore permit addressing different types of questions, mixing methods within quantitative and qualitative methodologies can also provide valuable and still varied views on developmental phenomenon. Recognizing the overlap between methodological approaches, as well as the often-overlooked distinctions within any given methodological approach, make more evident the benefits that can be reaped even from combining methods within a single methodology. Indeed, many of the differences attached to qualitative and quantitative data are in fact less clear distinctions than they are tendencies, sometimes tendencies that are present but unrecognized in the opposite methodology as well. For example, it is evident that there is considerable qualitative judgment applied by investigators in formulating and analyzing quantitative measures (Sandelowski, Voils, & Knafl, 2009), making investigator subjectivity a presence within quantitative as well as qualitative methodologies.

As has been discussed extensively elsewhere (see, for example, Teddlie & Tashakkori, 2009), a mixed methods framework extends research design beyond what is the best method to capture variation and consistency. Although beyond the scope of this chapter, it is important to note that a mixed methods approach shifts understanding of critical measurement criteria such as generalizability, measurement sensitivity, validity, reliability, bias, completeness, and meaning of measurement error and other design features such as sampling adequacy including representativeness. Most fundamentally it brings to the fore the importance of intentional consideration of these assumptions in what makes the selection of methods to be mixed, emphasizing complimentary strengths and limitations over specific characteristics of a given method or measure within method. Specifically, formulations of the vital characteristics for sampling, measuring, and modeling in analyses may be substantially different along with differences in what aspect of the phenomenon of interest is focused on or the form in which the data is collected. Moreover, the determination of utility includes explicit consideration of these "psychometric" features within recognition that such features must be understood as contextually bound and reflecting specific assumptions and purposes.

Within quantitative research, concepts such as validity, reliability, and measurement error and variance reflect mathematical theories that provide a basis for calculation of estimates of any given measure's fit to the concept (e.g., Cronbach's alpha provides a statistical measure of the reliability of a given scale, as measured by mathematical calculations across multiple responses). Generalizability, similarly, is based within mathematical theorems that allow for statistical extrapolation from a subset to a larger, unmeasured, set of which the subset is deemed to be representative. Bias is associated with error and researchers are expected to explicitly work to minimize bias effects on score. Yet, there are multiple statistical theories that can be applied to test these features and each carries some variation in how these important features are rendered. Within qualitative research, concepts such as validity, reliability, generalizability, and measurement error and variance are considered based on the specific study, context for understanding, and interest in relating the given results to the larger field of study. Meaning within specific study is critical for judging features such as reliability, validity, generalizability, and so on. In fact, some qualitative researchers reject the value of externally determinable characteristics such as reliability, validity, and generalizability, often noting incompatibility with the ontological principles of paradigms such as constructivism (e.g., Guba & Lincoln's notion of different types of authenticity; Guba & Lincoln, 1989). Many qualitative methodologists have attempted to reframe these concepts from a more qualitative perspective, highlighting the underlying shared interest represented by consistent meaning and measurement of concepts. This approach is based in the contention that validating the credibility of empirical knowledge is most essentially about how well it represents a particular, if localized, truth. Similarly, the criteria for credibility may vary to reflect different underlying epistemological beliefs. For example, LeCompte and Goetz (1982) use the language of quantitative research and identify the ways in which qualitative researchers can directly address the credibility of their knowledge claims in terms of validity (e.g., triangulation, spending a long time in the field, using multiple informants) and reliability (e.g., providing in-depth descriptions of research methods, site, participants, and coding categories, reflexivity). Others applied new labels to traditional constructs derived from statistical theory. For example, Lincoln and Guba (1985) identified quality criteria for naturalistic inquiry, which they termed *trustworthiness*, and which was judged based on characteristics of credibility, transferability, dependability, and confirmability to correspond respectively to internal and external validity, reliability, and objectivity. Researchers were encouraged to address these four areas of trustworthiness by engaging in specific design components and strategies, such as triangulation, member checking, peer debriefing, thick description, an inquiry audit and reflexivity (Lincoln & Guba, 1985). As referred to earlier in this chapter, Cresswell and Clark (2007) identified eight strategies that qualitative researchers frequently employ to ensure the validity of their knowledge claims. These include emphasis on thick description, which provides indication of the extent to which the knowledge generated is transferable to other sites and populations, akin to generalizability, adequate extent of measurement and reliance on triangulation across different methods, sources, and investigators to indicate validity of knowledge claims, peer reviews, and audits as basis for reliability and replicability of findings, and reflexivity, which is the explicit acknowledging of the researcher's position and biases and how those may influence the study (addressing objectivity). Differing values, criteria, and methods for determining important measurement features and forming the basis for conclusions and the contribution to knowledge advancement have emerged primarily as overt considerations from qualitative inquiry and differ from those that have been customary in quantitative methods and in how figural such considerations are. In addition, and perhaps more importantly, these differences provide a rich basis for consideration of how different approaches to and criteria for determining important issues such as reliability, validity, generalizability, measurement variance, and sampling considerations, or more generally, the overall quality and credibility of a study, should be formulated within a broad mixed-methods framework.

As noted by Creswell (2009), however, the binary distinction of qualitative and quantitative has served to guide discourse about mixed methods for several decades and so the dispensing of these as important markers of differences in interest, epistemology and ontology, and goals and method fit for a given study might be capricious. As he further notes, perhaps the advance should be to see the issues that have guided this discourse as poles or cluster centers that represent points on a continuum of methodologies. If so, then perhaps an aspiration of the field should be to articulate the basis and ordering of different methods as to how qualitative to quantitative they are in framework and assumptions, formation and measurement, and type of analyses to be utilized.

Teddlie and Tashakkori (2009) concur with Cresswell's understanding of methodologies as continuum rather than dichotomous categories, and consider mixed methods work as existing in the space between the two ends of the continuum. They suggest that within this mixed methods space issues of validity and generalizability be considered specifically in relation to the inferences made from the data, using the terms *inference quality* and *inference transferability* to capture the major domains of quality. Inference quality encapsulates internal and statistical validity from quantitative traditions and trustworthiness and credibility from qualitative traditions. Inference transferability speaks to external validity and generalizability from quantitative methodologies and transferability from qualitative methodologies. This nomenclature focuses on the quality of the interpretations made of the data (both the process of interpreting the data and the outcomes of that process, or the research results), rather than on the data itself. They propose an integrative framework for assessing the quality of inferences in mixed methods studies that incorporates standards from both quantitative and qualitative methodologies and that details quality issues and indicators of quality across the stages of the research process (see Teddlie & Tashakkori, 2009, Chapter 12, for details). Importantly, they point out the need to consider both specific standards of quality as applicable to each particular type of data analysis included within a study as well as integrative standards for assessing the quality of "meta-inferences" (p. 300) made from the integration of qualitative and quantitative data and analysis.

CONCLUSIONS

The emergence of appreciation for and use of mixed methods has been one of the more influential developments in scholarship in developmental science in the past decade. Such growing appreciation does not suggest mixed methods are superior to single methods nor is it a call for all studies to be quantitative and qualitative. That is not the contention presented here nor that seems useful for the field. Instead, the value of mixed methods seems to be to underline that the basis of all good science is that questions drive methods. Better science, more useful and informative results, and greater and more efficient progress in knowledge seem likely when the theoretical expression implicit (if not explicit) in a given method is considered as part of the research formulation. And, as part of that, whether related and systematic application of an additional method or methods can improve certainty, specificity, robustness, or other aspects of confidence in the findings. As it is increasingly recognized that methods choices can shape and consequently direct questions (what can be asked and how answers will be formulated) more attention to the role of method in informing and constraining knowledge is warranted. Mixing methods seems, therefore, not to be a new approach or simply an increase in how much is done within a given study, but a framework that hopefully brings forth more recognition of and consideration about the lens a given method provides and the accompanying capabilities and limitations for partial-understanding. Moreover, as developmental scientists probe more diverse phenomena and multiple levels of relational developmental systems, in more diverse populations, with greater sophistication of specific processes and across-level influences, the partial understanding of any study becomes more evident. Concordantly, consideration of how that partial-understanding is planfully expected to relate to larger understanding, including how methods may aid or limit clarity about that contribution seems to be an incumbent responsibility in scholarly work. Thus, whether through programmatic studies, within a given study, or as studies related by topic if not intention, a mixed methods frame can facilitate sophisticated and useful guidance about the role of that study within developmental science. This chapter is intended to help facilitate more informed, purposeful, effective, and broader use of a mixed-methods approach and mixing of methods to expedite advancement of developmental science.

Because the value of mixing methods and mixing any set of methods for a given study rests on the questions of interest, the reasons for using mixed methods, thoughtfulness of how the methods relate and differ, and what is the end product to be obtained should be an early step in research development and in framing a study or set of studies (Creswell, 2011). Whether that interest is based in a goal of increasing certainty, revealing otherwise undetected differences, elaborating descriptive or explanatory richness, providing "bit of information" to comprise a mosaic, or other scientific contribution, an early stage question in formulating a study should be what set of methods with what intended complimentary purposes will best advance knowledge about relational developmental systems (Bazeley & Kemp, 2011). Similarly, as suggested by Creswell (2011), how integrated the methods should be, how primary or preferred one is for interpretation direction, and how consistencies and discrepancies across methods are to be understood all merit consideration prior to any study launch. Certainly, given the complexities of the phenomena that developmental science seeks to understand, the challenges of reconciling interest in the universal, the irreducible group difference, and the uniqueness of each individual and the intricacies of portraying stability and recurrent patterns of change, a mixed methods framework seems advantageous.

For these reasons, this chapter has been organized to demonstrate that the utilization of mixed methods within developmental science as a whole is necessary for advancement of the field toward fuller understanding of the patterns and variations of human development within a relational systems framework. As noted, this does not mean that every study, or every investigator, should embark on a campaign to add increasingly more or even multiple methods to his or her studies. Just as blind adherence to a given method is going to misdirect understanding for some studies, simply increasing the methods applied in a given study will not lead to better science. Instead, the hope is that a mixed methods approach can lead to more purposeful use of varying methods, less because of adherence to a tradition (of whatever sort) than because after consideration of several possibly useful methods, the choice of method or methods is made. Instead, a mixed-methods approach that progresses through a set of explicit steps is warranted. In addition to questions driving the research and its most likely/useful methods, the assumptions and technical requirements of methods themselves should be considered. But also, researchers should consider the limitations and strengths of the form of logic of primary method, the attention to individual, subgroup, and overall patterns emanating from that method, and implications of structuring of inquiry using that method for the form and substance of results. Then, based on that understanding critical consideration should be applied to the question of which methods might be offer complementary strengths including alternate forms of reasoning and inference. As part of that evaluation, which method(s) might best compliment the other method toward the study goals is important (e.g., perhaps using the differentiation of designs offered by Creswell et al., 2009). For example, how deductive and inductive inferences might be useful in a given study might affect what methods are most useful and the relation between results to be used in a given study. Additionally, the ordering, integration, and prioritization of results from different methods need overt formulation. Finally, identification of the sampling, measurement, and contextual-sensitivity of the methods individually and collectively needs consideration and incorporation into the specific study or studies to be conducted. Framing research with consideration of how methods can shape (inform and constrain understanding) using this mixed methods framework should improve the quality of each given study as well as the ability to relate across studies yielding a fuller and more useful understanding of human development.

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NOTE

1. The R program that rendered these curves is:

```
# -----------------------------------
# Program: GrowthCurvePlots.R
#
# Variables
# Read libraries and set options.
options(width=110)
library(nlme)
options(width=120)
# Set constants.
# Read some data
tOsc1List <- scan("Mixed1.dat", list(t=0, x=0))
tOsc2List <- scan("Mixed2.dat", list(t=0, x=0))
# exponential aggregation.
b0 = -20
b2 = 5
b3 = 20
maxTimes <- 99
theTime <- c(0:maxTimes)
tMatrix <- matrix(NA, nrow=8, ncol=length(theTime))
for (i in 1:8) {tMatrix[i,] <- exp(-(.10 + (.10*i)) * theTime/b2)}
tmain <- paste("Exponential Equilibrium Change", sep="")
pdf("EqOscExpMultiCurve.pdf", height=5, width=6)plot(c(0, 25),c(0, 210),
 xlab="Age in Years",
 ylab="Height in cm",
 #main=tmain,
 type="n")
lines(theTime+1, 10*(b0 * exp(-.90 * theTime/b2) + b3), type="l", col=topo.colors(10)[1])
lines(theTime+1, 10*(b0 * exp(-.80 * theTime/b2) + b3), type="l", col=topo.colors(10)[2])
lines(theTime+1, 10*(b0 * exp(-.70 * theTime/b2) + b3), type="l", col=topo.colors(10)[3])
lines(theTime+1, 10*(b0 * exp(-.60 * theTime/b2) + b3), type="l", col=topo.colors(10)[4])
lines(theTime+1, 10*(b0 * exp(-.50 * theTime/b2) + b3), type="l", col=topo.colors(10)[5])
lines(theTime+1, 10*(b0 * exp(-.40 * theTime/b2) + b3), type="l", col=topo.colors(10)[6])
lines(theTime+1, 10*(b0 * exp(-.30 * theTime/b2) + b3), type="l", col=topo.colors(10)[7])
lines(theTime+1, 10*(b0 * exp(-.20 * theTime/b2) + b3), type="l", col=topo.colors(10)[8])
lines(theTime+1, 10*(b0 * apply(tMatrix, 2, mean) + b3), type="l", col="black", lwd=3)
dev.off()
meanCurve <- apply(tMatrix, 2, mean)
tmain <- paste("Exponential Equilibrium Change", sep="")
pdf("EqOscExpMultiCurveLGC.pdf", height=5, width=6)
plot(c(0, 25),c(0, 210),
 xlab="Age in Years",
 ylab="Height in cm",
 #main=tmain,
 type="n")
lines(theTime+1, 10*((b0 * meanCurve + b3) * 1.35), type="l", col=topo.colors(10)[1])
lines(theTime+1, 10*((b0 * meanCurve + b3) * 1.25), type="l", col=topo.colors(10)[2])
lines(theTime+1, 10*((b0 * meanCurve + b3) * 1.15), type="l", col=topo.colors(10)[3])
lines(theTime+1, 10*((b0 * meanCurve + b3) * 1.05), type="l", col=topo.colors(10)[4])
lines(theTime+1, 10*((b0 * meanCurve + b3) * 0.95), type="l", col=topo.colors(10)[5])
lines(theTime+1, 10*((b0 * meanCurve + b3) * 0.85), type="l", col=topo.colors(10)[6])
lines(theTime+1, 10*((b0 * meanCurve + b3) * 0.75), type="l", col=topo.colors(10)[7])
lines(theTime+1, 10*((b0 * meanCurve + b3) * 0.65), type="l", col=topo.colors(10)[8])
lines(theTime+1, 10*(b0 * apply(tMatrix, 2, mean) + b3), type="l", col="black", lwd=3)
dev.off()
maxTimes <- 100
thePlotData <- -20 + (0.2 * (100-tOsc2List$x[1:maxTimes]))
theTime <- c(1:maxTimes)
tSel <- seq(1, maxTimes, by=3)
tmain <- paste("Exponential Equilibrium Change", sep="")
```

```
pdf("EqOscExpMultiStartBW.pdf", height=5, width=6)
plot(c(0, 100),c(0, 40),
 xlab="Time",
 ylab="Y",
 #main=tmain,
 type="n")
lines(theTime[tSel], -25 + (0.25 * (100-tOsc2List$x[1:maxTimes])[tSel]), type="l", pch=1)
lines(theTime[tSel], -15 + (0.15 * (100-tOsc2List$x[1:maxTimes])[tSel]), type="l", pch=2)
lines(theTime[tSel], -5 + (0.05 * (100-tOsc2List$x[1:maxTimes])[tSel]), type="l", pch=3)
lines(theTime[tSel], 5 + (-0.05 * (100-tOsc2List$x[1:maxTimes])[tSel]), type="l", pch=4)

lines(theTime[tSel], 10 + (-0.1 * (100-tOsc2List$x[1:maxTimes])[tSel]), type="l", pch=5)
lines(c(0,100),c(0,0),type="l")
dev.off()
b0 = -20
b2 = 5
maxTimes <- 99
theTime <- c(0:maxTimes)
tSel <- seq(1, maxTimes, by=3)
tmain <- paste("Exponential Equilibrium Change", sep="")
pdf("EqOscExpMultiCurveBW.pdf", height=5, width=6)
plot(c(0, 100),c(0, 40),
 xlab="Time",
 ylab="Y",
 #main=tmain,
 type="n")
lines((theTime+1)[tSel], b0 * exp(-.90 * theTime/b2)[tSel], type="l", pch=1)
lines (theTime+1)[tSel], b0 * exp(-.50 * theTime/b2)[tSel], type="l", pch=2)
lines((theTime+1)[tSel], b0 * exp(-.30 * theTime/b2)[tSel], type="l", pch=3)
lines((theTime+1)[tSel], b0 * exp(-.15 * theTime/b2)[tSel], type="l", pch=4)
lines(c(0,100),c(0,0),type="l")
dev.off()

# --------------
# Sine aggregation.
tSinData <- matrix(NA, 8,200)
tSeq <- c(0:199)/20
for (i in 1:8) { tSinData[i,] <- cos(tSeq+(i*pi*.25)) #+ rnorm(length(tSeq), mean=0, sd=.5)}
pdf("AllSines.pdf", height=5, width=6)
plot(c(0, 10),c(-1.1, 1.1),
 xlab="Time",
 ylab="Score",
 #main=tmain,
 type="n")
 for (i in seq(1,8)) {
    lines(tSeq, tSinData[i,], type="l", col=topo.colors(10)[i])}
 lines(tSeq, apply(tSinData, 2, mean), type="l", col="black", lwd=2)
dev.off()
classOne <- apply(tSinData[1:4,], 2, mean)
classTwo <- apply(tSinData[5:8,], 2, mean)
pdf("AllSinesMixture.pdf", height=5, width=6)
plot(c(0, 10),c(-1.1, 1.1),
 xlab="Time",
 ylab="Score",
 #main=tmain,
 type="n")
 for (i in seq(1,4)) {lines(tSeq, classOne*((i*.2)+.5), type="l", col=topo.colors(10)[i])}
 for (i in seq(1,4)) {lines(tSeq, classTwo*((i*.2)+.5), type="l", col=topo.colors(10)[i+4])}
 lines(tSeq, classOne, type="l", col="black", lwd=3)
 lines(tSeq, classTwo, type="l", col="darkgray", lwd=3)
dev.off()
```

CHAPTER 20

Growth Curve Modeling and Longitudinal Factor Analysis

NILAM RAM and KEVIN J. GRIMM

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Articulating and testing theoretical notions about developmental phenomena often require dealing with a variety of entities, multiple levels of inquiry, and multidirectional change simultaneously occurring on multiple time scales (Baltes, Lindenberger, & Staudinger, 2006; Lerner & Benson, 2013; Overton, 2014, Chapter 2, this *Handbook*, this volume). Given these complexities, developmental researchers have demanded and continue to demand innovative analytical methods, research designs, and measurement tools (Baltes, Reese, & Nesselroade, 1977; Bergman, Magnusson, & El-Khouri, 2003; Molenaar, Lerner, & Newell, 2014; Ram & Gerstorf, 2009b). In turn, methodological innovations and the empirical results derived from this scholarship have challenged existing theoretical perspectives and pushed for further precision and refinement in how we think about behavioral change. Wohlwill (1991) described this dialectic interchange as a dance where theory and method stand toe-to-toe—each sometimes leading and sometimes following the steps and movements of the other. With this chapter we hope to contribute to this dance and the contributions longitudinal modeling makes to the progression of developmental inquiry.

Statistical models exist at the confluence of theory and observation (i.e., data). They are the workhorses of empirical methods. From them we get indications of how well theories approximate reality. The advent of structural equation modeling (SEM) in the mid-1970s made it possible for researchers to articulate and test theories about how the many characteristics of the person and his or her environment together influenced behavioral outcomes (e.g., Jöreskog & Sörbom's, 1976, LISREL). This class of multivariate methods had an impact on how researchers considered, designed, and conducted empirical studies. It was, for the first time, possible to examine both multiple predictors and multiple outcomes within a statistically rigorous confirmatory framework. A great deal of progress has been and continues to be made via the application of such techniques to data.

This work was supported by the Eunice Kennedy Shriver National Institute of Child Health and Human Development (R01-HD076994, R24-HD041025), National Institute on Aging (RC1 AG035645), the National Science Foundation (REAL-1252463), and the Penn State Social Science Research Institute. Portions of the writing were completed while Nilam was at the Center for Advanced Study in the Behavioral Sciences at Stanford University. Special thanks to Mike Coccia, Jennifer Morack, and Li Ge for artwork and comments.

The classic and modern theories of development all promote the idea that human functioning proceeds simultaneously on multiple levels (e.g., cells to society) and timescale (e.g., seconds to decades). For example, Relational-Developmental-Systems theories (Lerner, 2006; Lerner & Benson, 2013; Overton, 2013, 2014, Chapter 2, this *Handbook*, this volume), developmental systems theory (Ford & Lerner, 1992), the life-span developmental framework (e.g., Baltes et al., 2006), probabilistic epigenesis (Gottlieb, 2007), and the bioecological framework (Bronfenbrenner & Morris, 2006) purposefully describe, explain, and make predictions about how, when, and why individuals and their contexts change (see also Li, 2003). In dealing with the complexities inherent in developmental processes, developmentally oriented methodologists have advanced a wide variety of longitudinal methods for accurately charting how individuals' behavior changes across multiple assessments. For example, cohort sequential and longitudinal panel studies have enhanced our capability to describe and test hypotheses about within-person change (Hertzog & Nesselroade, 2003; Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Nesselroade & Molenaar, 2010; Schaie, 1983; von Eye, Bergman, & Hsieh, Chapter 21, this *Handbook*, this volume). Similarly, experience sampling, diary, and other intensive longitudinal study designs are providing rich data about the variability in individuals' perceptions, evaluations, and actions (Bolger, Davis, & Rafaeli, 2003; Csikszentmihalyi & Larson, 1987; Mehl & Conner, 2012; Shiffman, Stone, & Hufford, 2008). These traditions and their associated study design and data analytic frameworks are merging—pushing forward development of precise theory about *change processes* and the *timescales* on which they proceed.

In this chapter we review a variety of longitudinal models and consider how they can be applied to individual-level and sample-level inquiry to examine intraindividual change and interindividual differences in change (Lerner, 2006; Nesselroade & Molenaar, 2010; von Eye et al., Chapter 21, this *Handbook*, this volume). We first present a taxonomy of change processes, and then tether a selection of contemporary models to that taxonomy. Although the distinctions among types of change processes and among analytical frameworks are necessarily fuzzy, our hope is that by explicitly discussing the methods as abstract representations of core aspects of change, researchers will be able to select study designs and analytical procedures that map onto and more precisely test their *theories of change*. We finish the chapter with some notes on implementation and some suggestions for what the future may bring.

TAXONOMY OF CHANGE PROCESSES

In psychological science, developmentalists are often interested in examining and understanding change processes related to psychological dimensions, such as fluid intelligence, personality, and behavior problems. Researchers often use growth models to obtain descriptions of the change process, including information about within-person change, average change, between-person differences in change, and determinants of change (Bryk & Raudenbush, 1992; McArdle, 1986, 1988; Meredith & Tisak, 1990; Molenaar et al., 2014; Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; von Eye et al., Chapter 21, this *Handbook*, this volume). A selection of the types of data we seek to describe and extract meaning from are shown in Figure 20.1. Many studies consider and model linear change patterns because of their simplicity and interpretability. However, developmental processes are complex and the core theoretical notions of development, as represented by contemporary relational developmental systems models (Lerner, 2006; Overton, 2013, Chapter 2, this *Handbook*, this volume; Overton & Lerner, 2012), other classic frameworks (Baltes et al., 2006; Bronfenbrenner & Morris, 2006; Ford & Lerner, 1992; Gottlieb, 2007), and the core objectives of longitudinal research (Baltes & Nesselroade, 1979) do not posit simple linear change. As might be noted from Figure 20.1, only in rare circumstances are empirical longitudinal data best, or solely, characterized by simple linear change patterns. As we hope to demonstrate in the following sections, researchers can obtain greater theoretical and empirical accuracy by considering models capable of representing nonlinear developmental patterns and being specific about where between-person differences appear in those patterns (see Burchinal & Appelbaum, 1991; Grimm & Ram, 2009; Grimm, Ram, & Hamagami, 2011; Ram & Grimm, 2007).

Building from descriptions provided by Relational-Developmental-Systems theorists (see Overton, 2013, for a discussion), processes involved in behavioral change can be considered as being of three types: (1) incremental change processes, (2) transformational change processes, and (3) stability-maintenance processes (see also Ford & Lerner, 1992, pp. 151–159). Icons representing general features of each type of process are shown in Figure 20.2, along with a prototypical model equation.

1. *Incremental change processes* are those in which an existing characteristic is refined, elaborated, made larger or more complex. Progression is characterized

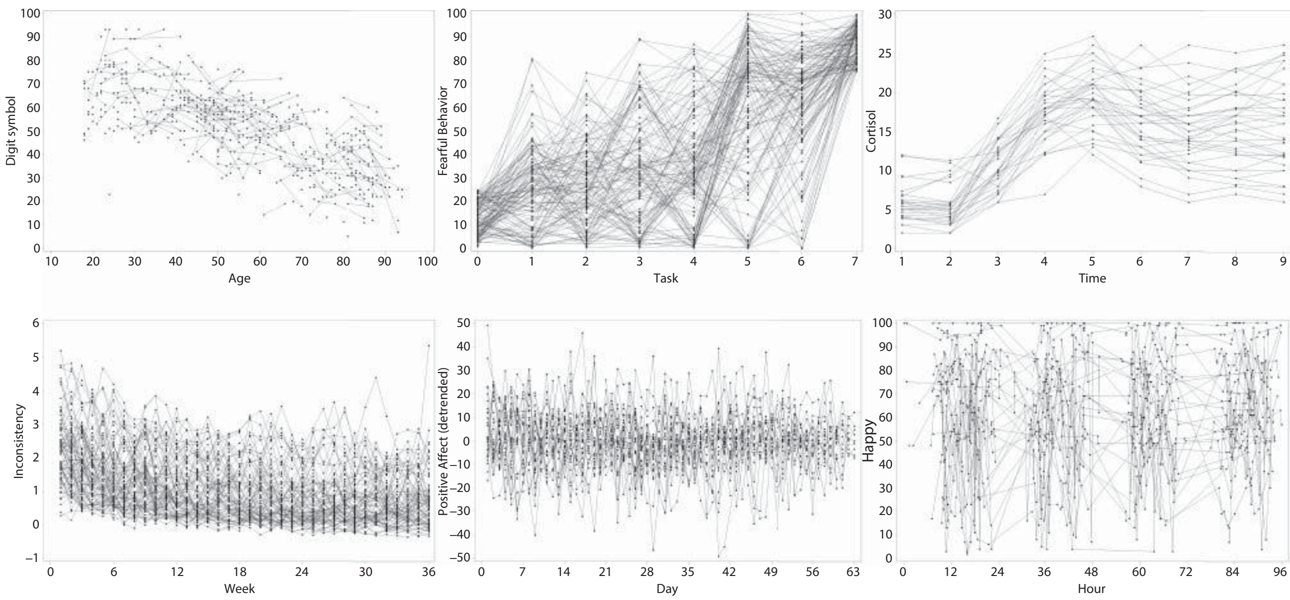
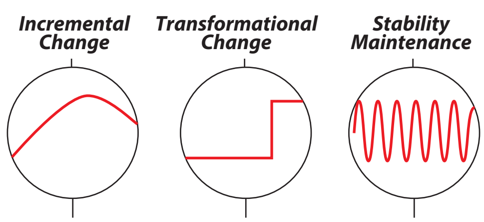


Figure 20.1 Developmental data from a variety of longitudinal studies. Some repeated measures are characterized by "strong" shapes, others by oscillations or fluctuations around some equilibrium, some by discrete shifts among categories.



$$\frac{dy(t)}{dt} = \alpha y(t)\left[1 - \frac{y(t)}{k(t)}\right] \qquad \frac{dy(t)}{dt} = \alpha + \beta y(t) - y(t)^3 \qquad \frac{d^2y(t)}{dt^2} = \beta y(t)$$

Figure 20.2 Types of change processes: (1) incremental change, (2) transformational change, and (3) stability maintenance. Curves within each circle and the associated equations represent one potential model that might be used to articulate a process of that type.

by relatively smooth directional changes. A classic example that often manifests over the short term would be reinforcement learning. For example, the icon in Figure 20.2, and associated equation, depict a process that evolves over time (x-axis) where level of function (y-axis) increases smoothly toward an asymptote. The associated equation in the figure represents one potential model that might be used to articulate such a growth process (see, e.g., Banks, 1994).

2. *Transformational change processes* are marked by discontinuities that involve a relatively rapid reorganization of an existing state or pattern into a qualitatively different state or pattern. Examples include classic notions of stage transitions (e.g., Overton, 2006; Piaget, 1977). The icon in Figure 20.2 depicts a transformation where level of function suddenly changes at a specific point in time. The associated equation indicates the utility of mathematical models based on the catastrophe cusp for articulating such processes (see, e.g., van der Maas & Molenaar, 1992).
3. *Stability-maintenance processes* are those that maintain and restore the system's organizational and functional unity. Examples include maintenance of physical, emotional, and cognitive function during or return to equilibrium after endogenous or exogenous perturbation/challenge (e.g., thermoregulation). For example, the icon in Figure 20.2 depicts a process where level of function is maintained within a specific range around the equilibrium across time. The associated equation in the figure represents one potential model that might be used to articulate such a process (see, e.g., Chow, Ram, Boker, Fujita, & Clore, 2005).

In the sections that follow, we attempt to illustrate how various models and modeling frameworks can be used to articulate these processes (and combinations of these processes).

MODELING CHANGE PROCESSES

In previous eras there were many distinctions between models based on whether the outcomes were continuous (e.g., ANOVA) or categorical (e.g., logistic regression), or whether latent variables were continuous (e.g., latent factors) or categorical (e.g., latent classes). With the advent of modern computing and the speed of calculation and parameter estimation, these distinctions have become more and more blurred. Many models that developed out of different traditions and frameworks are now seen simply as specific implementations of a generalized latent and multilevel modeling framework (see, e.g., Skrondral & Rabe-Hesketh, 2004). We purposefully do not make a strong distinction between models that have emerged from the structural equation and multilevel modeling traditions. These frameworks have merged.

Rather than using the modeling traditions, we work from a conceptual distinction that emerged in the study of life-span development, the distinction between *intraindividual change*—"more or less enduring changes that are construed as developmental," and *intraindividual variability*—"relatively short-term changes that are construed as more or less reversible and that occur more rapidly than the former" (Nesselroade, 1991, p. 215). Depicted graphically in Figure 20.3 by the long smooth line in the larger circle, intraindividual change is usually conceptualized as *directional change* that manifests at more macro timescale (e.g., months, years, decades) as a result of long-term change processes. As a complement to intraindividual change, *intraindividual variability*—depicted in the shorter, jagged lines within the smaller circles in

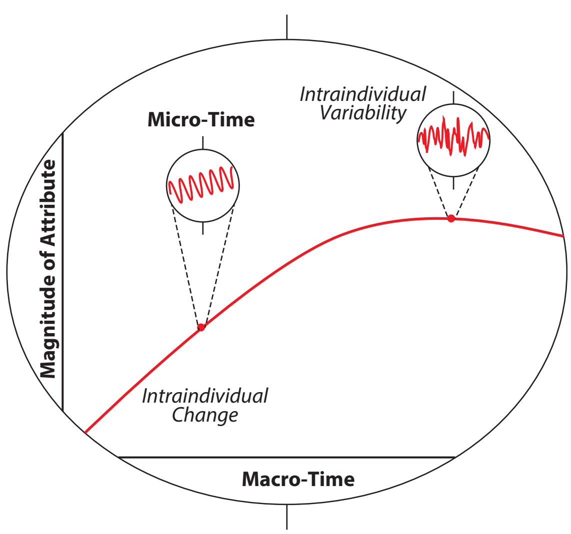


Figure 20.3 Intraindividual change and intraindividual variability distinguished as change processes proceeding at a macro timescale or a micro timescale, embedded in circles to indicate that incremental change, transformational change, or stability-maintenance processes may manifest at either time scale.

Figure 20.3—is usually conceptualized as *fluctuations*, instability, oscillations, or "noise" that manifest at more micro timescales (e.g., seconds, minutes, hours, days) as the result of short-term change processes. The intraindividual change and variability terminology effectively distinguished two timescales of behavioral change—one driven by processes that evolve on a macro timescale, and one driven by processes that evolve on a micro timescale.

Traditionally, the study of intraindividual change has involved modeling of *incremental change* or *transformational change* processes and is typically characterized by repeated measurement of many individuals' attributes over a few or several relatively widely spaced occasions (e.g., 3 to 10 waves) at macro and meso timescales—*T-data* (Cattell, 1952). For example, longitudinal panel study designs wherein many individuals are measured at monthly, yearly, or longer intervals (see, e.g., Schaie, 1983, for a compilation) are typically analyzed using some variant of *growth curve models* to examine interindividual differences in intraindividual change (McArdle & Nesselroade, 2003; Ram & Grimm, 2007; Singer & Willet, 2003).

In contrast, the study of intraindividual variability has traditionally involved modeling of *stability-maintenance* processes and is typically characterized by repeated measurement of relatively few individuals' attributes over many relatively closely spaced occasions—*P-data*. The many reports or assessments obtained over a relatively short span of time using experience sampling, multitrial assessment (e.g., reaction time tasks), physiological recordings, and other intensive longitudinal study designs (Bolger et al., 2003; Csikszentmihalyi & Larson, 1987; Mehl & Connor, 2012; Shiffman et al., 2008; Thelen & Smith, 2006) are typically analyzed using some variant of *time-series analysis* to examine interindividual differences in intraindividual variation or covariation (Bolger & Laurenceau, 2013; Nesselroade & Ram, 2004; Ram, Chow, et al., 2005; Walls & Schafer, 2006).

With an eye toward the *big data* streams on the horizon, we purposively make fuzzy the tethering of intraindividual change with incremental and transformational change processes that manifest at more macro timescales and that are typically modeled with growth curve models. Similarly we make fuzzy the tethering of intraindividual variability with stability maintenance processes that manifest at more micro timescales and that are modeled with time-series models. We acknowledge that there are both stability maintenance processes that manifest at more macro timescales and incremental and transformational change processes that manifest at more micro timescales. That is, all three types of change processes may manifest at any timescale—macro, meso, micro, nano, and so on (Lerner, Schwartz, & Phelps, 2009; Ram et al., 2014). Thus, the embedded circles in Figure 20.3 (micro timescale within macro timescale) are meant to be interchangeable with any of the circles in Figure 20.2 (incremental change, transformational change, or stability-maintenance). The configuration of change processes driving a particular set of behaviors may be described as a micro timescale stability maintenance processes embedded within a macro timescale incremental change process, as depicted in Figure 20.3. A different set of behaviors, though, may be described as a micro timescale transformational change process embedded within a macro timescale stability maintenance process. Blurring the classic (timescale based) definitions of intraindividual change and variability (Baltes & Nesselroade, 1979; Baltes et al., 1977; Nesselroade, 1991), the "exchangeability of circles" across micro and macro timescales purposively expands our own notions of both how and for what purpose the methods traditionally applied to data collected at specific timescales may be used.

For clarity, and to not raise false hopes, we note at the outset that our push for full exchangeability of circles (and the modeling frameworks associated with them) across timescales is necessarily incomplete. We were invited to write a chapter on *growth curve modeling and longitudinal factor analysis*—into which we have injected thinking that is emerging from our practical experience applying those models to longitudinal data collected from samples that range in size from 1 to 50,000 persons and at cadences that range from milliseconds to decades (i.e., nano to macro timescales). To cover the breadth of possible application across many timescales, we intentionally consider longitudinal factor analysis from a time-series perspective (e.g., P-technique, see Nesselroade, 2007), rather than from the more traditional longitudinal panel, measurement invariance, perspective (see Little, Preacher, Selig, & Card, 2007). In the sections that follow, we first consider a selection of growth models—with emphasis on models that are used to describe nonlinear trajectories—and a shift toward the use of differential equations. We then consider the bridge to a selection of time-series models—with emphasis on models that may facilitate analysis of the big data streams that will become available in few years.

Growth Curve Models: Linear to Nonlinear

Often a first task in studies of development is describing how individuals change (e.g., grow and/or decline) over time (Wohlwill, 1973). The advent of multilevel and latent growth curve models (Bryk & Raudenbush, 1992; McArdle, 1988; Meredith & Tisak, 1990; Rogosa & Willett, 1985; Singer & Willett, 2003) has made it possible to describe and test hypotheses about intraindividual change across multiple occasions of measurement, and interindividual differences in intraindividual change—two of the main objectives of longitudinal research (see Baltes & Nesselroade, 1979). Generally, growth curve modeling methods have been extremely useful in articulating incremental change processes and have been instrumental in elaborating how individuals develop and age (both normatively and nonnormatively) with respect to many different domains of function and during different phases of the life span. As the breadth of substantive applications has widened, researchers have begun considering and seeking to use growth curve methods to describe complex patterns of nonlinear change.

A small selection of the types of patterns that can be described are shown in Figure 20.4. In this section, we move systematically through these, covering in some detail how linear, quadratic, latent basis, exponential, sigmoid, sinusoid, spline, and other functions can be used to model a variety incremental change processes. The columns of Figure 20.4 each indicate how a specific class of mathematical function can be used to describe interindividual differences in key aspects of change, each of which is isolated in a specific row. Brought together, the final panel in each column provides an overview of the range of interindividual differences in intraindividual change covered by that specific model. The key message, looking at the total set of panels, is that the range of possibilities is large. Growth curve models can be used to describe many different types of incremental change processes beyond the straight lines captured by linear models.

In brief, the objective of growth curve modeling is to describe a set of time-ordered, within-person observations using only a few parameters. For example, the intraindividual change over time, or within-person learning, that occurs with practice might be described parsimoniously by two parameters (first column of Figure 20.4), one indicating an individual's initial level of ability (e.g., intercept), and another indicating linear rate of increase or decline in performance across multiple occasions of measurement (e.g., linear slope). Similarly, on a longer timescale, the development and decline of fluid intelligence (*Gf*) over an individual's life span, characterized by a rapid increase in abilities during the first 20 years followed by steady decline over the remainder of life, might also be modeled

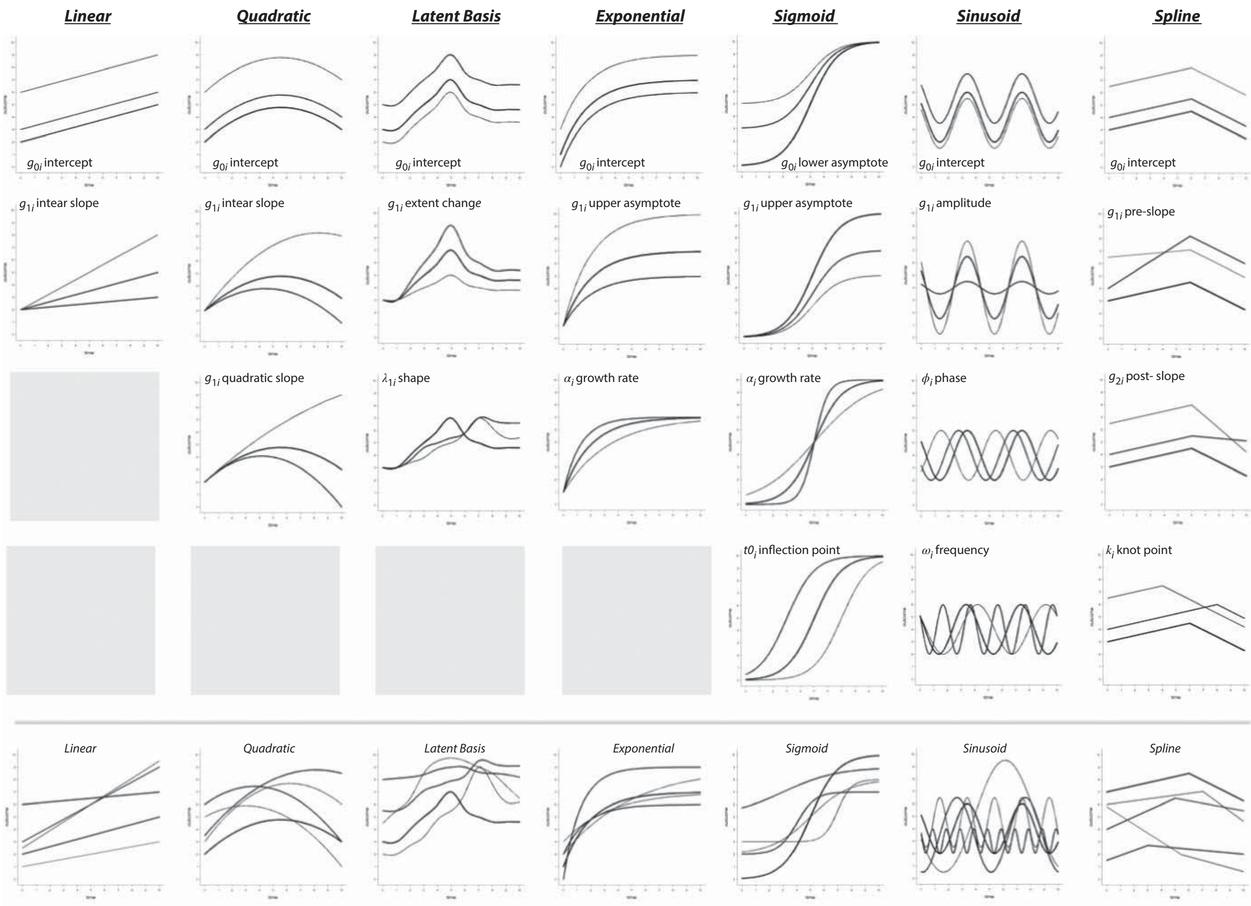


Figure 20.4 Types of growth curve models. Models built on different mathematical functions of change appear in different columns. Panels within each row depict interindividual differences in a specific parameter in the model (e.g., g_{0i} intercept). The bottom panel in each column shows a selection of individual curves produced by each model when all parameters differ across persons. The wide variety of possibilities is apparent when looking across all panels.

using relatively few parameters (e.g., dual exponential model of change; e.g., McArdle, Ferrer-Caja, Hamagami, & Woodcock, 2002). In addition to providing descriptions of intraindividual change, growth curve modeling methods also allow us to describe and test hypotheses about interindividual differences in intraindividual change. Further, by allowing the parameters used to describe intraindividual change to vary between individuals, we can also model and examine how (and potentially why) individuals differ in their initial levels of performance (intercept), rates of improvement or decline over time (linear slope), asymptotic levels of performance, and so on. Examining how the interindividual differences in the particular aspects of intraindividual change captured by each parameter relate to other interindividual differences (e.g., covariates such as socioeconomic status) brings us one step closer to understanding how and why individuals follow different paths of development.

Conceptually, the basic growth modeling framework is used to describe the average trend or pattern of change over time and between-person differences around the average trend. That is, we model the average trajectory and quantify in specific ways how each individual deviates from that trajectory. Analytically, given repeated measurement of a variable, y, for $i = 1$ to N individuals measured on $t = 1$ to T occasions (or ages), a general form of the growth model can be written as

$$y_{it} = g_{0i} + [g_{1i} \cdot timefun1_{it}] + [g_{2i} \cdot timefun2_{it}] + \cdots + [g_{ki} \cdot timefunK_{it}] + e_{it} \tag{20.1}$$

with

$$g_{0i} = \gamma_{00} + u_{0i} \tag{20.2}$$

$$g_{1i} = \gamma_{10} + u_{1i} \tag{20.3}$$

$$g_{ki} = \gamma_{k0} + u_{ki} \tag{20.4}$$

Equation (20.1) describes each individual's pattern of intraindividual change using a set of person-specific coefficients (factor scores), g_{0i} to g_{ki}, that are paired with a set of *time functions* (factor loadings, labeled *timefun* in the equations) to capture key aspects of change (e.g., intercept, linear slope). Occasion-specific deviations from the specific pattern of change are treated as residual error, e_{it}. Equations (20.2) through (20.4) describe the person-specific coefficients (factor scores) using a set of sample-level parameters, γ_{00} to γ_{k0}, that describe the average or prototypical trajectory, and individual deviations around that trajectory, u_{0i} to u_{ki}. Importantly, means, variances, and covariances among the between-person differences in specific aspects of change are structured in specific ways, usually as

$$u_{0i}, u_{1i}, \cdots u_{ki} \sim MVN\left(\begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_0^2 & & & \\ \sigma_{01} & \sigma_1^2 & & \\ \vdots & \vdots & \ddots & \\ \sigma_{0k} & \sigma_{1k} & \cdots & \sigma_k^2 \end{bmatrix}\right), \tag{20.5}$$

and among the occasion-specific residuals as

$$e_{i1}, e_{i2}, \cdots e_{iT} \sim MVN\left(\begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{e1}^2 & & & \\ 0 & \sigma_{e2}^2 & & \\ \vdots & \vdots & \ddots & \\ 0 & 0 & \cdots & \sigma_{eT}^2 \end{bmatrix}\right). \tag{20.6}$$

Practically, the framework can be implemented in both structural equation modeling (SEM) and multilevel modeling traditions, and can be estimated in many SEM software packages, including M*plus* (Muthén & Muthén, 1998–2013), LiSRel (Jöreskog & Sörbom, 1996), AMOS (Arbuckle & Wothke, 1999), OpenMx (Boker et al., 2011), and EQS (Bentler, 1995) and mixed-effects or multilevel programs, including HLM (Raudenbush, Bryk, Cheong, & Congdon, 2004), PROC MIXED in SAS (Littell, Milliken, Stroup, Wolfinger, & Schabenberber, 2006), SPSS MIXED, and lme4 and nlme in R (Bates, 2007; Pinheiro, Bates, DebRoy, & Sarkar, 2010).

As a multilevel model, the basic growth model is fit as the two-level model given above, where the time functions are variables defined in the data matrix (see, e.g., Singer & Willett, 2003). Within SEM, the basic growth model is fit as a restricted common factor model (Meredith & Tisak, 1990) with the time functions serving as constraints on the factor loadings. For example, Figure 20.5 is a path diagram of a growth model with only two growth components, g_{0i} and g_{1i}. In the diagram, squares indicate manifest variables y_{i1} to y_{iT}, circles indicate latent variables g_{0i} to g_{ki}, and the triangle represents the unit constant. Directive relations such as regression paths and factor loadings are represented as one-headed arrows; variances and covariances are represented as two-headed arrows. Arrows are labeled to indicate correspondence with the above equations and covariance structures. Readers may find further explication of the SEM-multilevel correspondence throughout the literature (e.g., Chou, Bentler, & Pentz, 1998; Curran, 2003; du Toit & du Toit, 2008; MacCallum, Kim, Malarkey,

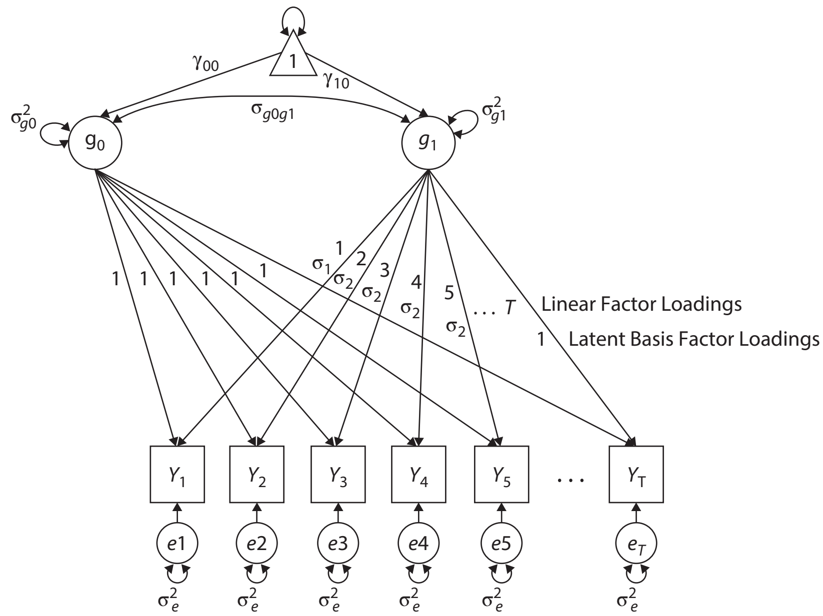


Figure 20.5 Graphical depiction of *growth model* as an SEM path diagram. Upper row of factor loadings for the $g0$ factor are structured to articulate the *linear growth model*. Lower row of factor loadings are unstructured and estimated from the data (besides needed 0,1 identification constraints) to articulate the *latent basis growth model*.

& Kiecolt-Glaser, 1997; Willett, 2004; Willett & Sayer, 1994), how basic growth models can be fit in a variety of multilevel and SEM programs (Ferrer, Hamagami, and McArdle, 2004; Grimm & Ram, 2009), and the advantages and disadvantages of fitting growth models within each of these frameworks (Ghisletta & Lindenberger, 2004).

Key to the specification of the growth model, whether conceptualized as a structural equation or multilevel model, are the values and structure of the *time functions* (factor loadings). In the SEM framework, these are conceptualized as a set of basis vectors (which we have labeled elsewhere A_1 through A_k; e.g., Ram & Grimm, 2007) that define the factor loadings and thus the *meaning* of the growth factors, g_{0i} to g_{ki}. That is, they are used to define the specific pattern of intraindividual change being fit to the data. For example, if a linear pattern of change is desired, the time function (elements of A_1) would be defined to progress in a linear manner (e.g., 1, 2, 3, . . . ; "*time*" scores, factor loadings in Figure 20.5). As is presented shortly, more complex patterns of change are accommodated by fixing or adjusting the time functions to reflect the desired change pattern (e.g., Gompertz, logistic).

On our path from simple to complex models, we first review linear, polynomial, and latent basis growth models. Building on these, we then discuss nonlinear latent growth curves with additive and multiplicative random coefficients. Our general thesis is that nonlinear growth curves with multiplicative between-person differences are among the tools necessary for adequately modeling many types of developmental change processes. Although complex, these models provide opportunities for and enable separation of multiple aspects of change, such as the amount of change, rate of change, and timing of changes in developmental processes, in ways that allow researchers to distinguish them and obtain more precise representations of the underlying developmental processes and determinants of change.

Linear Growth Curves

In the study of development thus far, longitudinal data are usually described using straight lines. The linear growth model (the model in Figure 20.5) can be written as

$$y_{it} = g_{0i} + g_{1i} \cdot \left(\frac{time_{it} - c_1}{c_2} \right) + e_{it} \tag{20.7}$$

In this model, we have defined a single time function using an index of *time* (e.g., variables such as time-in-study, age) and two constants that facilitate the substantive interpretation of the growth factors. The constant c_1 is used to center, or adjust, the time index (i.e., *time*) so that g_{0i} is an *intercept* (predicted value of y) located at the point in the change process where $time = c_1$. Similarly, the constant c_2 is a scaling variable used to adjust the metric of the time index so that g_{1i} is a *slope* scaled so it can be interpreted as the rate of linear change in y for a one unit change in $time/c_2$.

Expanding from equations (20.2) and (20.3) earlier, person-specific intercepts, g_{0i}, and linear rates of change, g_{1i}, can be modeled as

$$g_{0i} = \gamma_{00} + \gamma_{01} x_i + u_{0i} \tag{20.8}$$

$$g_{1i} = \gamma_{10} + \gamma_{11} x_i + u_{1i} \tag{20.9}$$

where the interindividual differences are a function of sample-level parameters that describe the prototypical trajectory defined by an intercept and linear rate of change, γ_{00} and γ_{10} respectively, and other between-person difference variables, (e.g., x_i; sex, race). Any number of variables can be inserted here and examined as potential determinants or correlates of the interindividual differences in change (longitudinal research objective #5 in Baltes & Nesselroade, 1979; see Grimm, Davoudzadeh, & Ram, in press). Unexplained individual differences are captured as u_{0i} and u_{1i}.

The extent of (remaining) between-person differences in the two key aspects of change, intercept and linear rate of change, can be discerned from the (unexplained) variances, $\sigma^2{}_{u0}$ and $\sigma^2{}_{u1}$. The covariance between the (remaining) between-person differences in intercept and rate of linear change is given by the covariance σ_{u0u1}. However, extreme care should be taken when making these interpretations because the between-person variances and covariances are heavily dependent on the choice of c_1, that is, the choice of zero time. In technical terms, all growth curve models are *not invariant* under affine transformations of the time variable as is the case with all other applications of the General Linear Model. The choice of zero time affects aspects of the between-person differences, including the estimated effects of covariates (for further discussion see Elston, 1964; Rovine & Molenaar, 1998). In sum, care should be taken that the c_1 and c_2 have been used to appropriately locate the intercept and to scale the rate of change in meaningful units.

Separately, the time-specific residual scores are assumed to have a normal distribution characterized by a mean of zero and estimated variances, $\sigma^2{}_{et}$. However, it is important to note that growth curves can also be fit to nonnormally distributed data, such as dichotomous, ordinal, and Poisson (e.g., Muthén, 1996) using a variety of estimation frameworks (e.g., Bayesian methods). Often, the residual variance is constrained to be the same at all time points (In equation (20.6), $\sigma^2{}_{e1} = \sigma^2{}_{e2} = \ldots = \sigma^2{}_{eT} = \sigma^2{}_{e}$). The assumption of a single residual variance for all occasions is common in longitudinal analysis because the same entity is repeatedly assessed. However, this assumption is not necessary (in many applications) and is testable. Work on the topic (e.g., Ferron, Dailey, & Yi, 2002; Grimm & Widaman, 2010; Kwok, West, & Green, 2007; Sivo, Fan, & Witta, 2005) has suggested that the choice of residual structure can have a substantial impact on the estimation of covariance parameters and model fit. In ideal situations, the assumption of a single residual variance is reasonable; however, there are times to consider alternative structures, such as when variables show evidence of artificial ceiling or floor effects. For consistency and simplicity in the description of growth models, we treat $\sigma^2{}_{e}$ as a single residual variance throughout our presentation, acknowledging, but without further notes regarding the other available options (for further discussion, see Grimm & Widaman, 2010).

Note that for generality we refer to *time* in an abstract way, recognizing that different time metrics are used to operationalize different developmental process. Indices such as chronological age, pubertal age (e.g., Tanner stage), grade, time since marriage, time until death are used to model different aspects of development (see McArdle & Bell, 2000; Ram, Gerstorf, Fauth, Zarit, & Malmberg, 2010). The choice of time metrics is of the utmost importance when attempting to understand and model change processes and, therefore, should be thoughtfully considered. Within the linear model especially, additional care should be taken not to generalize to times outside the specific observation period (fixed by the study design). Projected onward (or backward) in time, individual trajectories will continue on their positive or negative slope, g_{1i}, to positive or negative infinity. Given the physical reality of human development, the lack of asymptotic constraints suggests that linear growth models are only appropriate for modeling change within the very specific windows in which the data were observed (e.g., from Ages 3 to 6 years).

Polynomial Growth Curves

There are many ways in which the simple linear growth model can be expanded or adapted to describe more complex patterns of change over time (see also Ram & Grimm, 2007). One of the most common expansions is the addition of higher order polynomial time functions (e.g., Bryk & Raudenbush, 1992). For example, curvature in the change function might be accommodated by adding a quadratic term (e.g., *time*^{2}) and/or a cubic term (e.g., *time*^{3}) to the linear model. The linear growth model is expanded by including growth factors, g_{2i} to g_{ki}, each of which is paired with a specific function of time (e.g., *timefun*$2 =$ *time*^{2}, *timefun*$3 =$ *time*^{3}). Making use of this opportunity, many researchers turn to the quadratic growth model when a linear change model does not fit well or when a nonlinear trend is seen in the longitudinal plot (e.g., as in many of the examples in Figure 20.1). Assuming for simplicity of presentation that $c_1 = c_2 = 1$, the quadratic growth model can be written as

$$y_{it} = [g_{0i}] + [g_{1i} \cdot time_{it}] + [g_{2i} \cdot time_{it}^2] + e_{it} \qquad (20.10)$$

with the person-specific intercept g_{0i}, linear rate of change g_{1i}, and quadratic rate of change g_{2i}, and residual errors modeled as per equations (20.2) to (20.6). In the SEM framework the additional growth factors are indicated by sets of factor loadings constrained to progress in a quadratic manner (e.g., 1, 4, 9, …) as shown in Figure 20.6. This model allows for a specific type of nonlinearity in the change pattern and is particularly useful for modeling incremental change processes characterized by some convex or concave curvature.

As with the linear model, the quadratic growth model is simple to estimate because the random coefficients capturing between-person differences in specific aspects of the change pattern are *additive*. That is, the predicted score at time t for individual i, y_{it}, is the *sum* of the three components of growth that have been set within brackets in equation (20.10). As we explain later, as we get to more complex models, the ease in estimation comes from the fact that these terms are summed, rather than multiplied. A drawback, though, is that the parameters of the quadratic growth model can be difficult to interpret (see Cudeck & du Toit, 2002). The intercept g_{0i} remains the predicted score when *time* $= c_1$; but, the interpretations of the linear and quadratic slopes are more problematic. The linear slope, g_{1i}, represents the instantaneous rate of change at *time* $= c_1$, and the quadratic slope, g_{2i}, represents change in the rate of change (see Bollen & Curran, 2006). Thus, larger absolute values of g_{1i}, represent a faster rate of change at *time* $= c_1$, and larger absolute values of g_{2i} indicate that the rate of change is changing more rapidly, producing greater curvature in represented trajectories. Interpretation of results is difficult because the linear and quadratic slopes both affect the effective rate of change at each value of *time* $= 1$ to T, and may do so in different ways (e.g., one serving as a brake and the other as accelerator, see Ram & Grimm, 2007).

Furthermore, as noted with the linear model, expected trajectories of the quadratic model can be algebraically tractable, but should be interpreted only as local (in time) approximations of growth processes. Extended beyond the

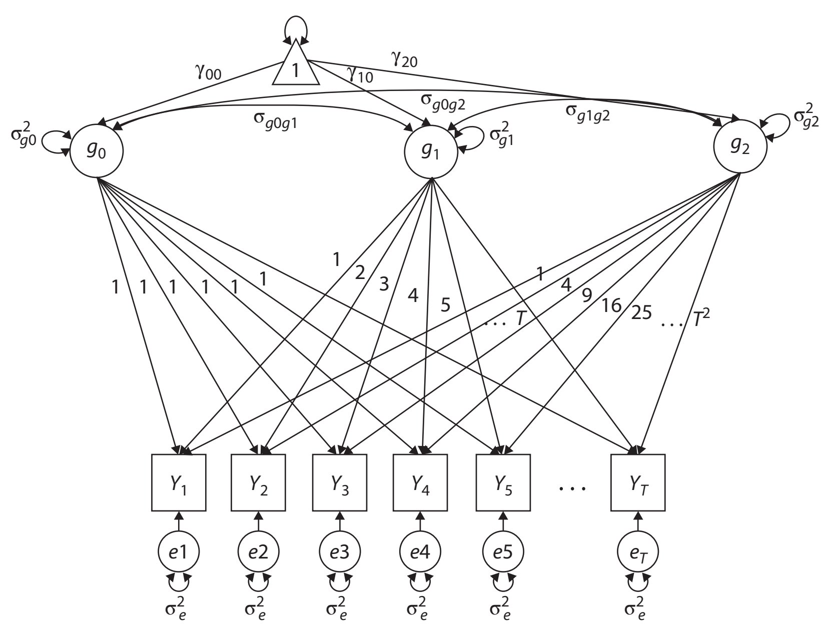


Figure 20.6 Graphical depiction of *quadratic growth model* as a SEM path diagram. Model is extended to include higher order polynomials (cubic, quartic, etc.) by inclusion of additional factors with appropriately structured factor loadings.

window of actual observation, quadratic trajectories either diverge to negative infinity when the model is concave down (i.e., $g_{2i} < 0$), or diverge to positive infinity when the model is concave up (i.e., $g_{2i} > 0$). Thus, in most cases, the parameters of the quadratic model are unlikely to provide a good representation of developmental theory because of their limited interpretability and their "forcing" of a symmetric, parabolic pattern of change (akin to "what goes up must come down"). Cudeck and du Toit (2002) presented a reparameterized quadratic model that has parameters that more easily transfer to substantive interpretation, but nonlinear constraints on the parameters are necessary, thus making estimation more computationally intense. In sum, quadratic growth models appear, on the surface, to be relatively limited for representing developmental processes, especially those that exhibit growth to an asymptotic level (Grimm & Ram, 2009; Widaman, 2007).

Free Function Latent Basis Curves

Alternative adaptations of the basic framework include the latent basis growth model (McArdle & Epstein, 1987; Meredith & Tisak, 1990), where the pattern or shape of nonlinear change is derived in an "exploratory," data-driven manner. Conceptually best explained in the SEM framework, consider again the model in Figure 20.5. The factor loadings for g_1 (e.g., elements of *timefun1* or A_1) specify the "shape" of change. Rather than constraining them to follow a linear pattern ($\lambda_1 = 0,\ \lambda_2 = 1,\ \ldots,\ \lambda_T = T - 1$) as depicted in the figure, the factor loadings are estimated freely (besides minimal constraints needed for model identification). Analytically, the time function is not defined in an a priori manner by the researcher, but derived directly from the data. The model can be written as

$$y_{it} = [g_{0i}] + [g_{1i} \cdot \lambda_t] + e_{it} \tag{20.11}$$

As before, the intercept g_{0i} is the predicted score for individual *i* when $\lambda_t = 0$, factor loadings represent *how* the within-person change process unfolds over time and can be interpreted (with appropriate scaling) as the proportion of total change that has occurred since the first measurement occasion. The individual differences in g_{1i} are literally interpreted as the expected amount of change in y for a one-unit change in λ for that individual, and conceptually interpreted as the extent to which the pattern of change has been "stretched" or "compressed" in the vertical direction (see, e.g., Fortunato, Gatzke-Kopp, & Ram, 2013).

The latent basis model is able to capture a variety of nonlinear change patterns because it does not have a specific functional form. That is, the model is *atheoretical* regarding the structure of change. The latent basis model will reproduce the mean structure of the data with the single interindividual-differences variable, g_{1i}, that controls the change process. In this sense, the latent basis model rescales time for optimal fit. Thus, the latent basis model will be the best fitting model, in terms of the SEM χ^2 fit statistics, for any growth model with one such interindividual-differences variable (e.g., will fit better than a linear model). Drawbacks of the latent basis model are that it is parameter-heavy, especially with many measurement occasions, because all but two shape factor loadings are estimated and the estimated parameters can be difficult to map onto theoretical notions of the developmental process. More generally, growth curve models and the latent basis model in particular, use the same model (i.e., factor loadings λ_t) to represent both the longitudinal mean and variance-covariance structure of the raw data. If the longitudinal means differ substantially in magnitude from the longitudinal covariances, a biased representation may emerge. Care should be taken to evaluate what aspects of the data are represented well and not so well by the model.

Given these drawbacks, researchers may also use specific mathematical functions, exponentials, sigmoids, and sinusoids, to describe nonlinear change trajectories (Browne, 1993; Browne & du Toit, 1991; Cudeck & Harring, 2007; Grimm & Ram, 2009; Ram, Chow, et al., 2005). These models were simultaneously developed in multiple fields of study for different purposes, with an important distinction being made between models with *additive* random coefficients and models with *multiplicative* random coefficients (Grimm et al., 2011). This distinction is fleshed out below; however, for clarity we note some of the alternate terminology used to describe these models. In discussions of random coefficient models (RCM), the first type is sometimes referred to as *partially nonlinear* random coefficient models (Blozis & Cudeck, 1999; Cudeck & Harring, 2007; Harring, Cudeck, & du Toit, 2006) or *nonlinear structured latent curve* models (Browne, 1993; Browne & du Toit, 1991) and the second type is discussed as *fully nonlinear* random coefficient models (Davidian & Giltinan, 1995).

A benefit of nonlinear curve models is that their functional forms are numerous, and therefore many different patterns of change can be modeled (Grimm et al., 2011; Ram & Grimm, 2007). These nonlinear models describe specific patterns of change over time, and, as such, offer developmental science a collection of models useful for testing specific (theory-based) hypotheses about change. Several models have parameters that are easy to interpret in terms of how the process unfolds and can be straightforwardly mapped onto theories regarding psychological or physical growth (a point we return to later).

Exponential Growth Curves

We first focus on the exponential model to highlight similarities and differences across types of nonlinear latent growth curves. We use an exponential model in our initial presentation because of its relative simplicity and because its utility for the study the development has been demonstrated in several domains, including learning processes, language development, and life-span cognitive development (Browne & du Toit, 1991; Burchinal & Appelbaum, 1991; Ghisletta, Kennedy, Rodrigue, Lindenberger, & Raz, 2010; McArdle, Grimm, Hamagami, Bowles, & Meredith, 2009; Ram, Rabbitt, Stollery, & Nesselroade, 2005).

Additive Model. Additive nonlinear latent curves are models that follow a specific nonlinear function and have additive random coefficients. So, similar to the models discussed thus far, predicted scores are simply the *sum* of the participant's scores on the random coefficients (e.g., intercept and slope) each multiplied by a function of time that does not vary across participants. For example, an exponential model with additive random coefficients can be written as

$$y_{it} = [g_{0i}] + [g_{1i} \cdot (1 - \exp(\alpha \cdot time_{it}))] + e_{it} \qquad (20.12)$$

where g_{0i} is the predicted score when $time = 0$, g_{1i} is the total amount of change from g_{0i} to an upper asymptote (i.e., $g_{0i} + g_{1i}$), and α is the rate of approach to the upper asymptote. In this model, α is a fixed parameter and does not vary across participants whereas g_{0i} and g_{1i} are random coefficients that vary across participants. Between-person differences, sample-level means, and covariances of the deviations and residual errors follow the setup in equations (20.2) to (20.6).

Additive nonlinear latent curves are estimated relatively easily using most SEM and multilevel modeling software (see Blozis, 2004; Blozis & Cudeck, 1999; Grimm & Ram, 2009; Ram & Grimm, 2007; Harring et al., 2006) because the random coefficients are additive. For example, in this exponential model, g_{1i} is a random coefficient that multiplies a nonlinear function of time that does not contain another random coefficient $((1 - \exp(\alpha \cdot time_{ti}))$. As a structural equation model, g_{1i} is easily configured as a latent variable with factor loadings equal to $(1 - \exp(\alpha \cdot time_{ti}))$. Estimation of such models in a structural modeling framework requires the ability to impose nonlinear equality constraints, and is easily accomplished in programs such as M*plus*, Lisrel, Mx, and PROC CALIS in SAS. Similarly, for multilevel modeling programs to estimate this model the required nonlinear constraints can be implemented in programs such as PROC NLMIXED in SAS, nlme in R, and HLM.

These additive nonlinear latent curves are elegant, often have interpretable parameters, and are able to model complex developmental patterns with few parameters. Furthermore, they may be able to represent the entirety of the developmental process, even if that process stretched beyond the specific window of time during which the data were collected. For example, projecting this model forward, as *time* increases, y_{it} gets closer and closer to the "natural boundary" provided by the asymptote, $g_{0i} + g_{1i}$, but will never go beyond it.

However, in this particular representation of the exponential model, participants only differ with respect to two aspects of the developmental process, the intercept, g_{0i}, and the distance to the asymptote, g_{1i}. Because g_{1i} is the only random coefficient controlling the time function, both the rate of change and the total amount of change for each person are contained within this single value, making g_{1i} a complex, potentially confounded random coefficient (just as was the case in the linear and latent basis models discussed previously).

Multiplicative Model. The additive version of the model can be extended in a straightforward way. Multiplicative nonlinear latent curves allow for additional complexity of between-person differences in the nonlinear function. An exponential model with multiplicative random coefficients can be written as

$$y_{it} = [g_{0i}] + [g_{1i} \cdot (1 - \exp(\alpha_i \cdot time_{it}))] + e_{it} \qquad (20.13)$$

where g_{0i}, g_{1i}, and α_i are interpreted in the same way, but now α_i is a random coefficient that can differ across persons. The model is considered to be multiplicative because within the function of time, $(1 - \exp(\alpha_i \cdot time_{ti}))$, there is a random coefficient (α_i). Predicted scores for y_{it} are not simply the sum of random coefficients and fixed parameters, but the multiplicative product of random coefficients because g_{1i} is a *multiplier* of α_i. Multiplicative nonlinear latent curves can be difficult to estimate because of their multiplicative random coefficients (see du Toit & Cudeck, 2009; Vonesh & Carter, 1992), particularly in the traditional structural modeling framework where the factor loadings for g_{1i} would need to vary across persons. There are at least two ways to estimate multiplicative nonlinear models. The model can be estimated directly using nonlinear mixed effects modeling programs (e.g., NLMIXED in SAS & nlme in R) or approximated using a first-order Taylor series method using nonlinear mixed effects modeling programs or structural equation modeling programs (see Browne, 1993; Browne & du Toit, 1991).

In sum, the multiplicative models are very useful because they allow for between-person differences in various aspects of a change process that may be theoretically and practically important. Much of development is characterized by differences in both rates of change and natural boundaries. Therefore, if separating variation in rates of change, timing, and total amounts of change is of theoretical importance when representing an incremental change process, a multiplicative model is *required*.

Sigmoidal Growth Curves

As noted earlier, nonlinear growth models can take many different forms (polynomials, latent basis, exponential, etc.). Here we focus on three *S-shaped* patterns of change: Logistic, Gompertz, and Richards curves. Individual change may be characterized by accelerations and decelerations of a particular form. Learning and/or population growth, for instance often consists of multiple *phases*, an initial period of adjustment where little growth occurs, a rapid growth phase, and a slowdown as ability or population approaches task or environmental capacity limits (Thieme, 2003). Such patterns of growth can be described by *sigmoid* curves that generally look like an elongated *S*. Key parameters of the mathematical functions used to describe such curves include the lower and upper asymptotes, the rate of acceleration, the location of changes, and the symmetry (or asymmetry) in the pattern of acceleration and deceleration.

Sigmoid curves have a long history of use in many areas of study, including biology, physiology, economics (e.g., Westerfeld, 1956; Winsor, 1932), where they have been used to describe change processes ranging from bacterial growth to product innovation to early life increases in brain size. Within psychology, sigmoid functions have historically been used to model probability of binary outcomes (e.g., logistic regression), item response probabilities (e.g., item response characteristic curves), neuronal function (e.g., Easton, 2005), and learning (e.g., Browne & du Toit, 1991; Ganger & Brent, 2004). Applications within the growth modeling framework, though, have been few (e.g., Marceau, Ram, Houts, Grimm, & Susman, 2011). Given the success of such functions for describing growth in many natural systems, we encourage further consideration and use of sigmoid curves to describe longitudinal panel data and investigate incremental change processes (and perhaps transformational change processes) (see also Grimm & Ram, 2009).

Logistic. The logistic function, as with all three curves covered here, is characterized by lower and upper asymptotes, and rates of change that are slowest near the asymptotes and fastest at an "inflection point" in the middle. The logistic growth model can be written as

$$y_{it} = [g_{0i}] + \left[g_{1i} \cdot \left(\frac{1}{1 + \exp\left(-\alpha_i \cdot \left(time_{it} - t0_i\right)\right)} \right) \right] + e_{it} \tag{20.14}$$

where α_i is a person-specific parameter governing the rate of change and where $t0_i$ denotes the time at which the rate of change reaches its maximum, the *inflection point*. When $\alpha_i > 0$, growth proceeds from g_{0i}, a person-specific lower asymptote, to $g_{0i} + g_{1i}$, a person-specific upper asymptote (and vice versa when $\alpha_i < 0$). The defining feature of the logistic curve is that growth is distributed equally before and after the inflection point $t0_i$. That is, there is symmetry to the growth pattern such that exactly half of the total change has occurred before the inflection point, and half occurs after.

Gompertz. Similar in form to the logistic model, the Gompertz function is also characterized by upper and lower asymptotes, and an inflection point. The Gompertz curve, however, is not symmetric with respect to its inflection point. Rather, growth proceeds in a manner such that roughly 37% (i.e., $1/exp[1]$) of the total growth occurs prior to the inflection point with the remainder occurring after. The model can be written as

$$y_{it} = [g_{0i}] + [g_{1i} \cdot (\exp(-\exp(-\alpha_i \cdot (time_{it} - t0_i))))] + e_{it} \tag{20.15}$$

where g_{0i} indicates the lower asymptote, $g_{0i} + g_{1i}$ is the maximum asymptotic value of the function, $t0_i$ denotes the time at which maximum growth rate occurs, and α_i governs the rate of change. Substantively, it may be noted that the Gompertz growth curve, with its specific asymmetrical structure, is often used to describe the incremental growth of populations in confined spaces with limited resources/nutrients (e.g., tumors; Laird, 1964). To the extent that the incremental change process being modeled may follow the growth patterns found in "confined" biological or social systems (e.g., economic markets) the model may provide some of the sought after links between behavioral and natural systems.

Richards. Both the logistic and the Gompertz curves have a priori defined symmetry or asymmetry around the inflection point. As a generalization of the logistic curve, the Richards Curve (Richards, 1959) allows for flexibility in the asymmetry by including an additional parameter, τ, that controls to which asymptote the inflection point is nearest. This model can be written as

$$y_{it} = [g_{0i}] + \left[g_{1i} \cdot \left(\frac{1}{\left(1 + \tau_i \cdot \exp\left(-\alpha_i \cdot \left(time_{it} - t0_i\right)\right)\right)^{\frac{1}{\tau_i}}} \right) \right] + e_{it} \tag{20.16}$$

where $t0_i$ denotes the time at which the rate of change reaches its maximum, and τ_i controls whether this point of inflection is closer to the lower or upper asymptote. Together, these parameters allow for substantial flexibility in the shape of the S curve. Although it is necessary to spend additional time understanding how differences in the parameters relate to different "S" shapes, some general observations may be useful. When the coefficient governing the growth rate, α_i, is lower, indicating that the rate of change is slower throughout the curve, the upper part of the "S" would appear to be pulled to the right and the lower part of the "S" pulled to the left. When τ_i, which controls the asymmetry of change, is higher, a greater proportion of change occurs prior to the inflection point, $t0_i$. More specifically, when $\tau_i < 1$, less than half the change occurs before $t0_i$ (e.g., as in the Gompertz curve). When $\tau_i = 1$, half the change occurs before $t0_i$ and half after (i.e., as in the logistic curve). When $\tau_i > 1$, more than half the change occurs before $t0_i$.

Sinusoidal Growth Curves

Many aspects of human functioning (e.g., physiological rhythms) have been found to display some regular, periodic changes over time. These include circadian rhythms, menstrual cycles, and seasonal changes in mood (e.g., Larsen & Kasimatis, 1990; Murray, Allen, Trinder, & Burgess, 2002; Reid, Towell, & Golding, 2000; Rusting & Larsen, 1998), all of which might generally be thought of as driven by stability-maintenance processes. One basic model of nonlinear change that may be useful when describing cycles is the sinusoidal function used as the visual icon in Figure 20.2. Cyclic change is usually examined using frequency-domain time-series methods (Box & Jenkins, 1976; Koopmans, 1995; Warner, 1998). In short, this class of methods can be used to extract and represent the cycles or oscillations present in single-subject multioccasion data. As a whole, frequency-domain analysis techniques range from the more *exploratory* spectral analysis to the more *confirmatory* fitting of a particular sinusoid. In the latter, a prespecified frequency (e.g., the frequency associated with a weekly cycle) is directly fitted to the data in much the same way as the other nonlinear functions given above (exponential, logistic, etc.). By assessing how well the model fits the data (e.g., the amount of variance explained), we can assess the extent to which an individual's data are characterized by, or "entrained" to the hypothesized cyclic process. Spectral analysis, in contrast, can be used to fit a collection of frequencies to each individual's data, and, in an exploratory way, identify those frequencies that are most prominent.

Within the growth modeling framework a sinusoidal curve of specific frequency can be modeled as

$$y_{it} = [g_{0i}] + [g_{1i} \cdot (\cos(\omega \cdot time_{it} + \phi_i))] + e_{it} \tag{20.17}$$

In this model g_{0i} represents a person-specific equilibrium around which the sinusoid oscillates (vertical shift), g_{1i} is the amplitude of oscillation at the specific frequency ω being modeled, and ϕ_i is the phase (horizontal) shift of the oscillation, or time elapsed between $time_{it} = 0$ and the first peak of the wave. For clarity, in the frequency-domain time-series literature the coefficient we have labeled g_{1i} is often notated as R_i, and ω, a particular frequency of oscillation in radians, can be rewritten as $\omega = 2\pi/\tau$, where τ (which is not the same τ used in our description of sigmoid models) is the period of oscillation in the units of the *time* variable (see Warner, 1998). As before, sample-level descriptions of the between-person differences are structured as in equations (20.2) to (20.6). Between-person differences in equilibrium level, amplitude, and phase can then be examined in relation to potential predictors and correlates of the sinusoidal stability-maintenance process captured in the longitudinal data. For example, applied to 7 weeks of daily data on individuals' mood, the sinusoidal growth model has been used to examine the extent of individual differences in entrainment to a regularly maintained weekly schedule (Ram, Chow, et al., 2005).

Spline Growth Curves

Thus far we have presented a selection of models that map relatively directly onto incremental change processes (e.g., linear, quadratic, exponential) or stability-maintenance processes (e.g., sinusoid). Spline models, wherein multiple phases of change are made explicit, map onto transformational change processes. In this class of methods, multiple equations and knot points are used to model change within phases and transitions between phases (Cudeck & Klebe, 2002).

Within the growth modeling framework equations, a simple spline function can be modeled as the combination of two linear growth curves that are invoked at different times. For example,

$$\text{when } time_{it} < k_i,\ y_{it} = [g_{0i}] + [g_{1i} \cdot (time_{it} - k_i)] + e_{it}, \text{ and} \tag{20.18}$$

$$\text{when } time_{it} \geq k_i,\ y_{it} = [g_{0i}] + [g_{2i} \cdot (time_{it} - k_i)] + e_{it} \tag{20.19}$$

where k_i is a person-specific *knot point* that indicates when, in time, individual i transitions from one phase of change to another. The first equation, (20.18), describes the growth function that governs change in the period prior to transition (in this case linear change at rate g_{1i}), and the second equation, (20.19), describes the growth function that governs change in the period after the transition (in this case linear change at rate g_{2i}). The common intercept, g_{0i}, in both equations serves to keep the two functions connected. As shown in the far right column of Figure 20.4, individuals may differ in intercept (Row 1), pretransition slope (Row 2), posttransition slope (Row 3), and when the transition occurs (Row 4) to produce a wide variety of possible trajectories (bottom row). The key difference of this model from the others is that it provides for explicit representation of a shift in the growth function, sometimes called a *regime switch*. For example, this model has been used to articulate notions of terminal decline, wherein individuals near the end of life transition from a preterminal phase characterized by less steep decline to a terminal phase characterized by more steep decline (see second analysis in Gerstorf et al., 2008). Although we have presented only linear models embedded within two distinct phases, both the number of phases and the complexity of models within a phase may be increased (see, e.g., Ram & Grimm, 2007).

Other Models

Growth curve modeling is an important analytic tool to help us understand and model change processes. The growth models discussed here are only the beginning, but are very useful for examining many different types of change processes and their determinants (see also Preacher, Wichman, MacCallum, & Briggs, 2008). The growth model has been extended to evaluate multiple groups (McArdle & Hamagami, 1996), complex nonlinear forms (Browne & du Toit, 1991), and lead-lag relations (McArdle & Hamagami, 2001). Excellent introductions to some of these more advanced models can be found in, Bollen and Curran (2006), Grimm and Ram (2009), Grimm et al. (2011), McArdle and Nesselroade (2003), and Ram and Grimm (2007).

Mapping Theories of Change, Change Processes, and Change Outputs

The growth curve modeling framework and the models covered above seek to describe individuals' longitudinal trajectories and the between-person differences in those trajectories. Specific mathematical functions (e.g., linear, quadratic, exponential, sigmoid, sinusoidal) are used to describe the observed *output* of a latent change process. However, the specific *change process* that is producing the observed output is often not explicit. Rather, it is embedded somewhere in the equations. In this section we review some of the ways that explicit descriptions of the underlying change process can be used to map theoretical propositions about underlying change processes to the modeling enterprise more directly. *Our hope is that a shift toward models that make the underlying theory of change explicit (e.g., differential equations) may prompt consideration and testing of a more appropriate set of hypotheses*.

Within the SEM framework, the growth model has been (re)rendered as time-ordered process in which occasion-to-occasion changes accumulate over time. In particular, McArdle and Hamagami (2001) presented a formulation of the standard latent growth curve model that is based on successive latent changes. In general form this (univariate) *latent change score model* can be written as

$$y_{it} = [g_{0i}] + \left(\sum_{t=2}^{t} \Delta y_{it}\right) + e_{it} \tag{20.20}$$

where individual i's score at occasion t, y_{it}, is the sum of an initial score, g_{0i} (interpreted as an intercept or baseline score) and all of the subsequent changes that have occurred up to that time (sum of Δy_{it} from $t = 2$ to t). Key for the shift from toward articulation of change process is that the discrete changes, Δy_{it}, which accumulate over time to produce an individual's long-term trajectory, become the focal point of inquiry.

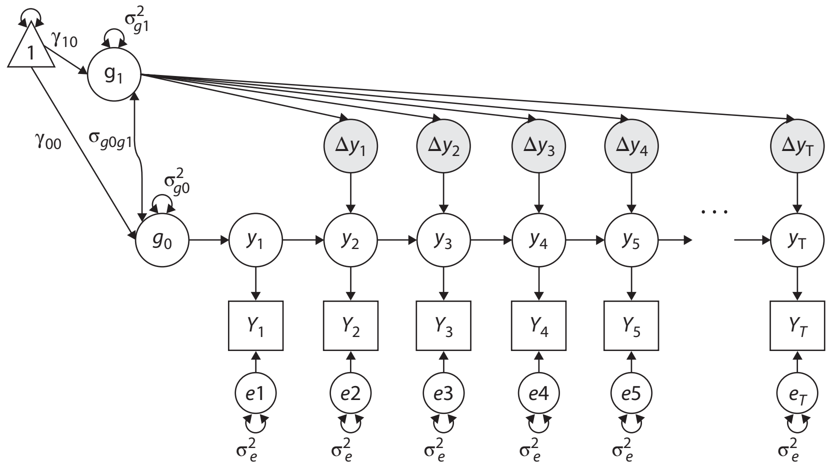


Figure 20.7 Graphical depiction of *latent change score model* as an SEM path diagram. Gray shading indicates the shift in focus to change as the outcome. Unlabeled paths are = 1.

The latent change model shown in Figure 20.7 is exactly equivalent to the traditional growth model shown in Figure 20.5, but makes the underlying process more explicit (Grimm & McArdle, 2005). In Figure 20.5, the focus is on how *time* (as a measured variable that is imposed on the factor loadings) is used to connect the latent intercept, g_0, and linear slope, g_1, variables the observed outputs, squares y_1 to y_6. In simple terms, the arrows go in the vertical direction. In Figure 20.7, the focus is on how prior states are connected to subsequent states, the change process, or in simple terms, the arrows going from left to right. Importantly, *time* (as a measured variable) *is not imposed on the model*. Instead, *the model articulates a process that evolves over time*, left to right. To make the contrast between change outputs and change process explicit, consider how the linear growth model and the latent change model are used to describe the change process at $time_t = t = 4$ for an arbitrary individual. Following from linear growth model in equation (20.7), the output of change is,

$$y_{t=4} = [g_0] + [g_1 \cdot 4] + e_{t=4} \tag{20.21}$$

the sum of some fixed quantities. "Change" (Δ) is not apparent in the mathematical model. In contrast, following the latent change model in equation (20.20), the output is the accumulation of a series of successive changes,

$$y_{t=4} = [g_0] + [\Delta y_{t=2} + \Delta y_{t=3} + \Delta y_{t=4}] + e_{t=4} \tag{20.22}$$

The mathematical model is formulated in a way that makes the cumulative change process explicit (McArdle & Grimm, 2010).

Within this framework, then, the occasion-to-occasion changes, Δy_{it}, can be produced by any number of "internal" and/or "external" factors or processes (e.g., x, y, z). That is,

$$\Delta y = f(x, y, z) \tag{20.23}$$

For example, to obtain equivalence between equations (20.21) and (20.22) (i.e., the standard linear growth curve model and the latent change rendition of the model), the latent changes are produced by the function

$$\Delta y_{it} = \frac{\Delta y_i}{\Delta t} = g_{1i} \tag{20.24}$$

This *difference equation* is an explicit rendering of the change process underlying the linear growth model—the *theory of change*. Once made explicit, the simplicity of the hypothesis is clear. The notion that the *change process* underlying cognitive, social, biological, and so on can be described entirely by a single number that does not change over time or in relation to where an individual is in the process, seems at odds with key tenets of most developmental theories.

To avoid confusion, the standard and latent change renditions of the growth model are equivalent (see Ferrer et al., 2004, for full breadth of equivalences; Grimm, Zhang, Hamagami, & Mazzocco, 2013). The difference/differential equation is an explicit, direct rendering of the hypothesized change process in mathematical language (Boker, 2001). As such it provides for direct mapping between the theory and the method (i.e., mathematical model). However, mapping the method to empirical data often requires an additional step. We must solve the equation for the specific window of observation being examined. Calculus provides all the necessary tools. For example, rewriting the change process described by equation (20.24) (a difference equation in discrete time, $t = 1, 2, 3, \ldots T$) as

$$\frac{dy}{dt} = g_1 \tag{20.25}$$

(a differential equation in continuous time) we have expressed a concise theory of change in the lingua-franca of differential equations that is used to represent change processes in many areas of science. Mapping the model to empirical data, the output series y_t for $time_t = t = 0$ to t, requires mathematical integration over the specified window,

$$\int_{t=0}^{t} \frac{dy}{dt}\, dt = \int_{t=0}^{t} g_1\, dt = g_1 \cdot t + g_0 \tag{20.26}$$

where g_0 is a constant of integration that represents the initial conditions. Rearranging, and acknowledging the presence of measurement error, e_t, we obtain the solution of the original differential equation in a form that can be fit to empirical data using ordinary least squares, maximum likelihood or other parameter estimation techniques,

$$y_t = [g_0] + [g_1 \cdot time_t] + e_t \tag{20.27}$$

and thus be used, in analytical practice, to map between the data and the model. Between-person differences are incorporated as per equations (20.2) to (20.6).

Across fields, change processes are almost always formulated as *differential equations*. Calculus provides powerful tools for describing and explaining the behavior of dynamically changing processes. As illustrated above, the differential equations are particularly useful in connecting theory to data because they provide for direct translation of theories of change into mathematical forms that may then be reformulated in ways that make them easier to fit to empirical data. Given their location in a theory to method to data research process, (process-oriented theoretical model → differential equation model of change process → growth model of change outputs → empirical observations of change outputs), their use can greatly facilitate progression of knowledge about developmental and other change processes (as apparent in physics, chemistry, biology, engineering, etc.).

Theoretically, people are dynamic systems, and the change processes that drive their development are probably not constant,

$$\frac{dy}{dt} \neq g_1 \tag{20.28}$$

A few simple extensions can illustrate how working directly with the differential equation models facilitates articulation and construction of more complex and realistic theories of change. For example, we may theorize that there is endogenous dependence in the growth process. That is, the progression of the process depends in part on the level of output already achieved,

$$\frac{dy}{dt} = \alpha \cdot y_t \tag{20.29}$$

Solving this differential equation by the method of separation of variables we obtain

$$y_t = \exp(\alpha \cdot time_t) + g_0 \tag{20.30}$$

where again g_0 is a constant of integration that represents the initial conditions. When placed in the statistical estimation framework (SEM or multilevel) with between-person differences (i subscripts) the differential is fully converted into an exponential growth model that can then be fit directly to empirical data.

Adding a bit more theory, development often occurs in the context of a limited amount of resources. That is, growth may be bounded by endogenous or exogenous constraints. Incorporating an upper bound or *carrying capacity*, g_1, into equation (20.29), we get the change process model

$$\frac{dy}{dt} = \alpha \cdot (g_1 - y_t) \tag{20.31}$$

which is solved (see Apostol, 1969, p. 143; Banks, 1994, p. 53) to obtain the model of change outputs,

$$y_t = g_0 + g_1 \cdot (1 - \exp(\alpha \cdot time_t)) \tag{20.32}$$

the negative exponential growth model in equation (20.13), where the initial condition provides $g_0 = y_0(\exp(\alpha \cdot time_0))$. Differential equations and the change output models for sigmoid and sinusoid forms are obtained following the same basic principles.

The door we hope to have opened is the idea that translating theoretical propositions into the differential equation model is much more straightforward than working directly with the analytical equations that are actually fit to the data. The "language" of differential equations provides for straightforward articulation of knowledge about change processes, highlights the simplicity and potential inadequacy of current models (e.g., linear growth), and opens up a wide range of possibilities for articulating the complexities of development. For example, our hope is that through teaching and intervention efforts we may be able to influence both an individual's *growth rate*, α, and *carrying capacity*, g_1. Acknowledging that these aspects of the change process may change over time as the individual is exposed to the curriculum, the model in equation (20.31) can be expanded to,

$$\frac{dy}{dt} = \alpha_t \cdot (g_{1t} - y_t) \tag{20.33}$$

where the now time-varying value of α_t and g_{1t} are provided by a specific function of exposure to the program (e.g., $\alpha_t = \alpha_0(1 + ct)$, where c is a constant). This very simple extension is theoretically precise and provides for a tremendous variety in the shape of the resulting trajectories (see Banks, 1994; Ratkowsky, 1989)—much more like the complex shapes we see in real data than like the straight lines obtained when using a process model of the form $dy/dt = g_1$.

Many differential equation models have been worked out in detail to describe a wide variety of change phenomena in numerous fields (e.g., physics, chemistry, engineering, biology). As has happened in these other fields, reconceptualizing developmental and change phenomena in terms of differential equations may accelerate our discovery of "laws" that govern the behavior of human systems. At the very least, such reconceptualizations allow us to take advantage of the substantial work done in other fields on the use of growth and diffusion processes to model highly complex phenomena (e.g., weather, fluid dynamics), at least some of these must have counterparts in individual development (see, e.g., Boker & Laurenceau, 2006; van der Maas et al., 2006; van Geert, 1993). Differential equations are the lingua franca for knowledge transfer—both between theory and method, and between disciplines.

Time-Series Models: Longitudinal Factor Analysis

The growth curve (and differential equation) models reviewed above are typically applied to longitudinal panel type data. That is, data on which many individuals have been measured on a few occasions (e.g., 3 to 10 waves)—*T-data* (Cattell, 1952). Applied to those data streams, that set of models has been extremely useful in describing and learning about incremental change processes that manifest on relatively slow time scales (months, years, decades). In this section we review time-series models that are typically applied to intensive longitudinal data (Walls & Schafer, 2006) where one person (or relatively few people) are measured on many occasions (e.g., >50)—*P-data*. These models are being adapted and used to more clearly understand the biological, psychological, and behavioral processes that manifest on relatively fast timescales (e.g., seconds, minutes, days).

Time-series data consist of observations obtained from the same entity on multiple occasions. Given that organisms maintain some sort of continuity over time, repeated measurements obtained from the same person are likely to be related. Thus, time-series data likely violate a key assumption required by many statistical analyses, namely that observations are independent and identically distributed. Time-series analysis emerged as a way to explicitly model and accommodate the dependencies in such data (e.g., Box & Jenkins, 1976; Jenkins & Watts, 1968). A plethora of techniques are now available for dealing with and making use of the time ordering, sequences, and dependencies inherent in time series data (Chatfield, 2004; Shumway & Stoffer, 2006). Generally, the aim of these models is to articulate and test hypotheses about how an established series of events or actions transform an entity from one state to another. Specifically, the objective is to model how an individual's current state is influenced by his or her past states and/or influences his or her future states. Of particular importance for our purposes here was the advent of *autoregression* (and moving average) *models*, wherein relations among successive occasions are modeled explicitly, and the merging of those models with *factor analysis*, a core component of both psychometrics and SEM.

P-Technique

Factor analysis is a method for investigating the structure of a set of variables. The basic principle is to represent the covariation among many observed variables in terms of linear relations among a *smaller number* of abstract or latent variables. The underlying idea is that if two or more characteristics covary in a systematic manner, they may reflect a shared underlying construct. In practice, the patterns of covariation reveal the *latent* dimensions that lie beneath the *measured qualities* (Gorsuch, 1983; Tabachnick & Fidell, 2007). P-technique factor analysis is the application of factor analysis to P-data—a multioccasions × multivariables (× single person) matrix of scores (Cattell, Cattell, & Rhymer, 1947). Applied to this multivariate time-series data, the *P-technique* factor model provides a parsimonious description of intraindividual variation and covariation. As such, the P-technique model provides a framework for examining the latent dimensions that lie beneath repeated measures for an individual. The modeling approach has been used in numerous areas to describe individual-level structures of affect, personality, psychophysiology, and other domains (see Jones & Nesselroade, 1990; Luborsky & Mintz, 1972; and Russell, Jones, & Miller, 2007, for reviews).

Technically, P-technique factor analysis is procedurally similar to the familiar between-person (R-technique) factor analysis (Cattell, 1963). What differs are the data to which the models are applied. In the usual R-technique factor analysis, the common factor model is applied to multivariate observations obtained from multiple subjects at a single measurement occasion (a persons × variables matrix of scores). In contrast, in P-technique factor analysis, the common factor model is applied to multivariate single subject time-series data (an occasions × variables matrix of scores). The model can be written as

$$\boldsymbol{y}_t = \Lambda \boldsymbol{\eta}_t + \boldsymbol{\varepsilon}_t \tag{20.34}$$

where, y_t is a p-variate time series of observations indexed by time ($t = 1, 2, \ldots, T$), $\boldsymbol{\Lambda}$ is a $p \times q$ factor loading matrix, η_t is a q-variate time series of latent factor scores, and $\varepsilon_{\mathbf{t}}$ is a p-variate residual time series interpreted as measurement noise. An example model is depicted graphically in Figure 20.8. The path model depicts how a six-variate y_t time series (squares labeled $y1$ to $y6$) is "driven" by two common factor score series (circles labeled $\eta 1$ and $\eta 2$) that are appropriately weighted by the factor loadings $\lambda 1$ to $\lambda 6$, and six residual series (circles labeled $\varepsilon 1$ to $\varepsilon 6$). From the model, and a set of identification constraints (e.g., factor loading or variance = 1), a set of covariance expectations can be developed and tested against the data to assess the viability of the model (see Brose & Ram, 2012, for implementation guide).

In P-technique factor analysis, the common factor model is used to model data obtained from one individual over many occasions under the assumption that the observations are *independent*. As seen in the Figure 20.8,

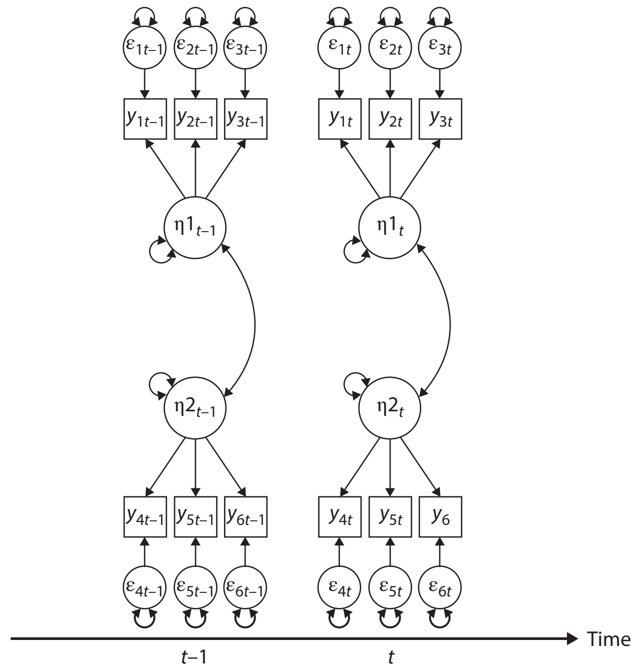


Figure 20.8 Graphical depiction of *latent change score model* as an SEM path diagram. Unlabeled paths are = 1.

there are no sequential dependencies (arrows) between the variables (latent and manifest) at occasion $t-1$ and those at t. The arrows only go in the vertical direction, not from left to right. The labels for the two occasions could be swapped, t and $t-1$, without effect on the model fit or model parameters. Given organismic continuity, this is an unlikely circumstance. Rarely would we find that repeated measures obtained from the same organism are truly independent observations in the sense that there is no relation between the states on different occasions (see Fiske & Rice, 1955, and Ram & Gerstorf, 2009a, for discussions of net intraindividual variability).

Dynamic Factor Analysis

Molenaar (1985) introduced dynamic factor analysis (DFA) as a combination of P-technique factor analysis and time-series analysis. The objective was to both deal with the independence violations and provide a framework for modeling the dynamic nature of ongoing processes (see also Nesselroade, McArdle, Aggen, & Meyers, 2002). In brief, the underlying notion of the DFA model is that the (multivariate) state of the individual at any given time is a function of both concurrent influences and past states. Events that influence an individual at one moment in time contribute not only to current levels but also carry forward for some limited amount of time. The DFA framework provides an opportunity to explicitly model such processes (Molenaar, 2010). Specifically, DFA relaxes the assumption that all observations are independent observations of an individual's states. The occasion-to-occasion dependencies of a time series with *equally spaced* observations are modeled explicitly (addressing some of the early critiques of P-technique; e.g., Anderson, 1963) and allowing for *carryover*, *spillover*, or *system memory* from one occasion to the next (Browne & Nesselroade, 2005).

Articulated in *state-space model* form, the DFA model can be written as

$$\boldsymbol{y}_t = \boldsymbol{\Lambda}\boldsymbol{\eta}_t + \boldsymbol{\varepsilon}_t \tag{20.35}$$

$$\boldsymbol{\eta}_t = \boldsymbol{B}_1\boldsymbol{\eta}_{t-1} + \boldsymbol{B}_2\boldsymbol{\eta}_{t-2} + \cdots + \boldsymbol{B}_s\boldsymbol{\eta}_{t-s} + \boldsymbol{\zeta}_t \tag{20.36}$$

where the q-variate latent state series η_t is now modeled as a function of $h = 1, 2, \ldots, s$ prior latent states, $\boldsymbol{\eta}_{t-1}$ to $\boldsymbol{\eta}_{t-s}$, that are weighted by $\boldsymbol{B_1}$ to $\boldsymbol{B}_s$. Present time "disturbances" are then introduced as a q-variate set of latent "innovations" representing process noise $\boldsymbol{\zeta}_t$, and measurement noise, $\boldsymbol{\varepsilon}_t$, the latter of which may be correlated across occasions. Figure 20.9 graphically depicts an example model. In contrast to the P-technique model, time dependencies are now explicitly incorporated at the latent factor level through a set of autoregressions and cross-regressions (and may also be incorporated at the measurement error level through between-occasion correlations, not shown in figure). Process is captured by the arrows going from left to right.

Many fields make use of DFA/state-space frameworks (Durbin & Koopman, 2001). In fact, much of the machinery that takes us from place to place (e.g., planes, trains, automobiles) depends on such frameworks to model, forecast, and help guide movements in real time. Methodological literature illustrates use of maximum likelihood, ordinary least squares, Kalman filter, and Bayesian approaches (Zhang, Hamaker, & Nesselroade, 2008), use of the model for estimations of reliability of change (Lane & Shrout, 2010), and implementations as structural equation models or as state-space models (Chow, Ho, Hamaker, & Dolan, 2010). The availability of software tools and computational power now afford the possibility to conduct DFA with relative ease and speed (see Ram, Brose, & Molenaar, 2013, for a step-by-step guide). Substantive applications in psychology include modeling of affective and psychophysiological changes (Chow, Nesselroade, Shifren, & McArdle, 2004; Ferrer & Nesselroade, 2003; Gates, Molenaar, Hillary, Ram, & Rovine, 2010; Wood & Brown, 1994), where ongoing processes (e.g., adaptation, regulation, homeostasis) can be extracted from time-series data collected on relatively fast timescales. In sum, dynamic factor analysis offers a robust framework for modeling process-oriented theory in time-series data.

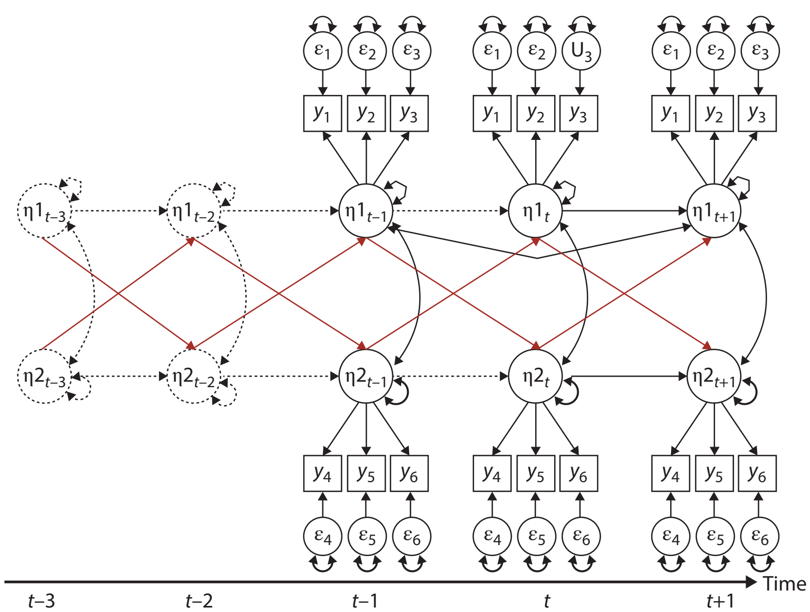


Figure 20.9 Graphical depiction of *dynamic factor model (state-space model representation),* where dependencies among the occasion-to-occasion repeated measures (i.e., the change process) are captured by auto- and cross-regressions among the latent factors.

Latent Markov Models

It may be noted that the dynamic factor model is used to describe changes that are continuous—where individual's characteristics change incrementally along a continuous latent dimension. Typically, these models describe individual change as a smooth function, evolving in little steps over time as the stability maintenance process moves forward. However, as noted earlier, not all change processes are smooth. *Transformational change processes* can be discontinuous and involve qualitative changes in behavior. For example, theoretical models posit discrete transitions between developmental stages (e.g., Mascolo & Fischer, Chapter 4, this *Handbook*, this volume; Piaget, 1977), or shorter scale changes in behavior posit transitions through discrete states of behavior (e.g., six states in the transtheoretical model of behavior change: precontemplation, contemplation, preparation, action, maintenance, and termination; Prochaska, DiClemente, & Norcross, 1992). Like dynamic factor models, Markov models provide a general framework for analyzing and interpreting time dependencies where individuals switch or transition among discrete states.

In brief, discrete-state latent Markov models can be characterized by three properties: (1) at any point in time there are a finite number of states (e.g., categorical rather than continuous latent variable depicted by the different colors within the circles in Figure 20.10); (2) shifts among states are governed by a probabilistic process (analogous to the autoregression in the DFA; and depicted by the black arrows going from left to right); and (3) the future of a Markov process depends on its past only through its current state (e.g., single-lag model). Following these principles, the latent or "hidden" Markov model (HMM; Rabiner, 1989; Visser, 2011) can be written in the same (state-space) configuration as the DFA models above as

$$\boldsymbol{y}_{t+1} = \boldsymbol{A}\boldsymbol{\eta}_t + \boldsymbol{V}_{t+1} \tag{20.37}$$

$$\boldsymbol{\eta}_{t+1} = \boldsymbol{C}\boldsymbol{\eta}_t + \boldsymbol{W}_{t+1} \tag{20.38}$$

where both the latent state process $\boldsymbol{\eta}_t$ and the observed process $\boldsymbol{y}_t$ are vectors the elements of which are all zero, save for one position which = 1. $\boldsymbol{A}$ and C are matrices of transition probabilities, the columns of which sum to = 1. The observed variables $\boldsymbol{y}_t$ are connected to the latent states $\boldsymbol{\eta}_t$ through a "measurement model"—described by the emission probabilities (also called *output probabilities*) in $\boldsymbol{A}$. How an individual progresses through the latent states over time is described by transition probabilities in C. The measurement and process noise matrices, $\boldsymbol{V}$ and $\boldsymbol{W}$ respectively, are martingale increment processes that satisfy a specific set of constraints (see Elliott, Aggoun, & Moore, 1995). Initial conditions are provided in an additional matrix, $\boldsymbol{\pi}$ that indicates the probability of being a particular latent state at $t = 0$. As before, individual differences are investigated in a subsequent step, by examining differences/similarities in the transition matrices and resulting state sequences.

The main difference between the DFA above and the HMM is that usually the observations $\boldsymbol{y}_t$ are discrete in HMM, and thus the model is particularly useful when modeling a dynamic process categorical time-series (as are collected in many observational studies of children completing laboratory tasks). However, this is not a necessity. Ordinal and continuous variables may also be used (see also Zhang et al., 2008). Key, though, here is that the latent state, $\boldsymbol{\eta}_t$, is discrete—and therefore maps to the characteristics that define stage transitions and other transformational change processes.

Implementation and the Data-Box

Ideally, the study of development is characterized by the seamless integration of well-articulated *theory of change*, statistical *models* that operationalize those theories, and

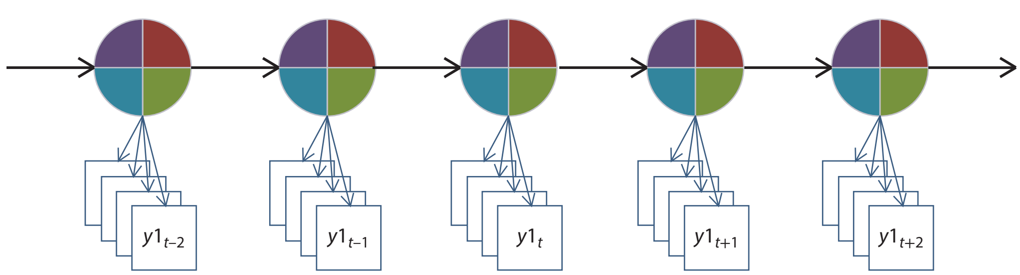


Figure 20.10 Graphical depiction of *Hidden Markov Model*. Multiple manifest indicators (squares) indicate latent factors that are categorical. Occasion-to-occasion transitions among states are represented by black arrows.

longitudinal data to which those methods can be applied (Adolph, Robinson, Young, & Alvarez, 2008; Collins, 2006). Developmental research questions focus on describing, explaining, predicting, and modifying how and when the many characteristics of an individual change over time (Baltes et al., 1977). The wide array of available analytical methods, and the increasing ease with which longitudinal data can be obtained, provide many possibilities for aligning theory, method, and data. Cattell (1952) introduced the data-box (persons × variables × occasions) as a practical schema to systematically identify and present different ways data could be organized and subsequently analyzed via covariation analysis. Given a particular research question, the data-box can be used to identify the appropriate subset of data and associated analysis (Ram & Gerstorf, 2009b). Here we use the data box heuristic to highlight three aspects of study implementation that might be considered further when using growth curve models and/or longitudinal factor analysis.

In brief, longitudinal data can be located within a three-dimensional space (persons × variables × occasions) as shown in Figure 20.11. Each little cube represents a single individual's score on a particular variable that was obtained at a specific occasion (e.g., specific time or age) and roughly correspond with cells or entries in a data file. The individual to whom the score/cube belongs is indexed by placement along the *persons* axis, with all the data associated with that person filling a distinct horizontal slice in the space. The particular variable or item to which a score pertains is indexed by column along the *variables* axis, and the time (e.g., age, grade, or other index of time) at which that observation was obtained is indexed along the *occasions* dimension.

Heuristically, the three dimensions of the data-box map onto theoretical and methodological issues that must be considered when developing theoretical models, analytical models and longitudinal study designs (see Ram & Gerstorf, 2009b). For example, selection of which columns should be included in the *variables dimension* of a study design requires precise consideration of *measurement* and if and how multiple variables are organized. Similarly, selection along the *occasions dimension* requires

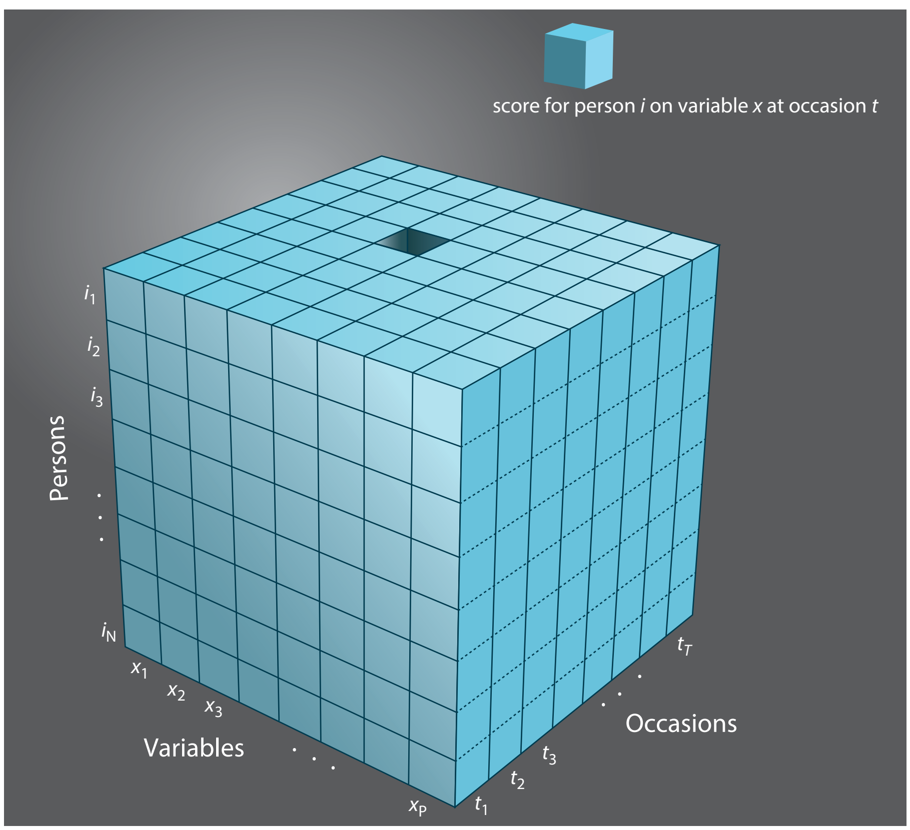


Figure 20.11 The data-box. Adaptation of Cattell's (1952) three-dimensional data-box of persons × variables × occasions to represent multivariate longitudinal data. Each small cube represents the score for a single person on a particular variable obtained at a specific occasion. The data-box serves as a heuristic for selecting study designs and appropriately aligned statistical models.

consideration as to how, when, and for how long individuals should be studied in order to capture the specific *change* processes of interest. And, organization of the *persons dimension* requires thoughtful consideration of both how individuals are expected to differ from (or be similar to) one another, *interindividual differences* (e.g., in intercept, in linear slope), and the assumptions inherent in the chosen modeling framework (e.g., individuals are deviations from an average trajectory). Precision in how research questions address the three dimensions of the data-box can make the process of formulating appropriately matched theories of change, models of change, and longitudinal study designs more straightforward.

Variables: Categorical, Count, and Continuous Measures

With the advances in estimation and numerical integration, fitting models to nonnormally distributed observed variables and using categorical latent variables has become more and more feasible. Measurement models with continuous manifest and continuous latent variables (common factor models), categorical manifest and continuous latent variables (item response theory), continuous variables and categorical latent variables (latent profile analysis), and categorical manifest and categorical latent variables (latent class analysis) are all feasible. Longitudinal extensions are straightforward (e.g., growth mixture models). Advances in the formulation of longitudinal measurement models are expanding how developmental constructs can be measured over time (e.g., Edwards & Wirth, 2009). From an analytical perspective, there is a good deal of flexibility; categorical, count, and continuous measures and latent variables can be mixed and matched as needed. No longer are we constrained to using particular types of variables for particular types of analysis. As noted earlier, just about everything fits within the generalized latent and multilevel modeling framework. This means that the focus now returns to developing theoretically precise measurement equations that map the observations to the hypothesized change processes.

Of particular importance in the use of growth curve models and longitudinal factor analysis is the sensitivity of the measures to change. Depending on the change process (incremental change, transformational change, or stability maintenance), particular types of measures may be easier to work with than others. For example, there is a natural mapping between categorical variables and transformational change processes, wherein an individual "jumps" between qualitatively different states. In contrast, continuous indices may be particularly useful when articulating incremental change processes wherein individuals are hypothesized to move up and/or down along a continuous dimension. Advances in sensor technology and machine learning are changing how individuals can be tracked and how behavioral observations are coded (e.g., machine learning routines). These innovations provide new opportunities to develop and use measured variables that map directly, or at least more closely, to the dynamic processes of interest.

Occasions: Time Scale of Change

Often a first decision when attempting to articulate and understand change processes is deciding on an appropriate timescale for tracking and modeling change (Shiyko & Ram, 2011). For example, yearly assessments obtained in a school setting may be organized along a grade in school time metric. This is not the only time metric that may be reasonable for these data. Additional, potentially meaningful time-metrics include age as well as measurement occasion. In discussing time-metrics, there are time-metrics that represent discrete time intervals, such as measurement occasion and grade in school, where the time-metric takes on discrete values (e.g., 1, 2, 3) that are more or less common to all participants. Alternatively, there are time-metrics that represent more continuous timescales, such as age, where age is measured precisely with values that are not common to multiple participants (e.g., 12.34 years). Parallel examples exist in the behavioral coding of children's behavior. For example, in a behavioral inhibition task where a child is asked to not eat an enticing cookie, behavior can be coded in discrete time units as behavior within 1- or 5-second windows, or in continuous time units as latency to behavior onset or end. Given that the different models treat time in different ways (as continuous or discrete) the choice of coding affords use of some models while constraining use of others.

It is possible for the same time-metric to be used in a discrete or continuous fashion (see Aigner, Miksch, Muller, Schumann, & Tominski, 2008). For example, age could be rounded to the nearest year or half year and grade could be measured more precisely as year in school plus number of days since the beginning of the school year. In this chapter, we have reviewed techniques for fitting growth models with a time-metric that is more or less continuous, differential equations that are based in continuous time, and longitudinal factor analysis models that are based in discrete time. In all cases, the selection of measurement intervals (e.g., seconds versus hours, or months versus years) has important implications for model implementation as well as how between-person differences in timing along the developmental sequence may be captured.

Persons: Application of Models for Sample-Level or Individual-Level Inferences

As noted earlier, growth curve models emerged from a tradition focused on analysis of longitudinal panel-type studies—*T-data*. The models are structured to describe the average trajectory and quantify in specific ways the range of individual deviations from that trajectory. That is, model parameters are descriptions of sample-level distributions (means, variances, covariances). In contrast, the time-series models emerged from a tradition focused on analysis of many-occasion longitudinal data obtained from single entities—*P-data*. The models are structured to describe individual trajectories. The model parameters are descriptions of individual-level distributions, with between-person differences only being dealt with in a subsequent step (see Ram et al., 2013). This contrast was made explicit in our notation through inclusion of subscripts for both persons and time (i and t) up through equation (20.24) for models that are typically applied to T-data, and only subscripts for time (t) thereafter for models that are typically applied to P-data. However, given that the mathematics and estimation algorithms are agnostic to the types of data they are applied to, almost all of the models covered here can be applied to either T- or P-data (Bergman et al., 2003). For example, the Latent Transition Model (see Collins & Lanza, 2010), a model typically applied to longitudinal panel data to describe transformational change processes manifesting at the sample-level, is mathematically equivalent to the latent (hidden) Markov model that, as shown in equations (20.37) and (20.38), is typically applied to single-subject time-series data. Notably, the linear, quadratic, exponential, and so on, functions used in the growth curve models to describe T-data, can all be applied to individual-level P-data, and vice versa, the P-technique, dynamic factor analysis, and hidden Markov model equations can be used to describe sample-level change in T-data. However, the level of inference, sample-level versus individual-level is different (Hamaker, Dolan, & Molenaar, 2005).

As noted at the outset, we intentionally considered longitudinal factor analysis from a time-series perspective (e.g., P-technique, see Nesselroade, 2007), rather than from the more traditional longitudinal panel, measurement invariance, perspective (see Little et al., 2007). Our intent in doing so was, in part, to establish a bridge between the longitudinal panel and time-series study designs—T-data and P-data. The speed and capacity of modern computers brings with it new possibilities for computation. As has been shown with the advent of Internet search engine data mining, we can now estimate the parameters and fit thousands of models to a given set of data in less than 1 second. This means that it is now feasible to implement person-specific approaches to data analysis. Rather than presupposing, “top-down,” that all individuals fall into a single population described by an “average” process, we can instead take a “bottom-up” approach and model *individual* change and development, one person at a time (Cattell, 1966; Lamiell, 1981; Molenaar, 2004; Nesselroade, 2007; Ram & Gerstorf, 2009a; Stern, 1911; Valsiner, 1986). Interindividual differences in the individual-level processes are studied in a subsequent step. This approach provides an opportunity to test basic assumptions of homogeneity and equivalence of within- and between-person structures that are known to be problematic (i.e., the nonergodicity of developmental processes; Molenaar, 2004), and eliminates the need to interpret sample-level findings based on T-data as though they apply to within-person processes that actually manifest in P-data (i.e., commit an *ecological fallacy*; Estes, 1956; Robinson, 1950; see also discussions in Sterba & Bauer, 2010, and associated commentaries, and von Eye et al., Chapter 21, this *Handbook*, this volume). These advances set the stage for implementation of *personalized* interventions, at population scale.

FUTURE DIRECTIONS FOR MODELING CHANGE PROCESSES

In encouraging researchers to make use of the growth curve and longitudinal factor models covered above (and their extensions), we forward three suggestions meant to enhance the tie between *theories of change* and *models of change*. As presented below, we encourage further consideration of nonlinearity, measuring more frequently (especially as we enter an increasingly data-rich world), and efforts to label parameters with theoretically meaningful names.

Embracing Nonlinearity

Developmental researchers are inherently interested in examining and understanding how and why individuals change in different ways. When undertaking this endeavor, it is important to consider the defining characteristics of the change process as well as the theoretical notions guiding change. Defining aspects of change include initial levels, rates of change, periods of acceleration and deceleration, timing of developmental phases, and final levels. Growth curves are often used to understand the aspects of developmental processes and nonlinear growth curves are *essential* for capturing the various aspects of change.

Many researchers consider models of linear change because of their simplicity and interpretability; however, many developmental processes are more complex and are characterized by nonlinear change. As an illustrative example, consider individual changes in height from early childhood through adulthood. Changes in height are not adequately described by straight lines or simple curves. Instead, changes in height proceed through a number of developmental phases—a period of stable growth is followed by accelerated growth during puberty, and then decelerated growth toward a final asymptote. Further, these phases occur at different ages for different individuals (Karkach, 2006; Preece & Baines, 1978; Zemel & Johnston, 1994). To model changes in height properly, a statistical model must accommodate the nonlinear developmental pattern and important individual differences in these key aspects of change.

Thus, rather than using simple linear or quadratic models to describe changes in height from early childhood through adulthood, researchers should make use of more complex models, such as the Preece and Baines (1978) model, that allow for differences in individuals' rate of growth during childhood, timing of puberty, rate of growth during puberty, and final adult height (see Grimm et al., 2011). Each feature of change is mapped to a specific parameter.

Developmental processes are complex. Representation and understanding of them often requires complex models. Researchers often limit their analyses to models of linear change, failing to consider models that allow for description and further understanding of the complexities of developmental processes and their determinants. Although these models are admittedly more difficult to use, fitting simpler change models increases the risks of misrepresenting data by averaging over existing heterogeneity and disallowing the possibility of examining determinants of potentially important individual differences in change process. We have forwarded a proposal that attempts to describe the complexity of development will be facilitated by use of *differential equations*. As illustrated earlier, the differential equations provide for direct translation of theories of change into mathematical forms. We thus encourage their use as tools for representing nonlinearity of change.

Measuring More Frequently

Statistical models (including growth curve models and longitudinal factor analysis) provide us with the opportunity to articulate and test our hypotheses against empirical data. At the same time, they offer only approximate renderings of our ideas about how and why individuals develop and change over time. Because of these constraints, special care must be taken to select and apply models that map, as directly as possible, onto the particular theory we are attempting to articulate and test. Similar cautions apply generally in the collection of longitudinal data (Boker, Molenaar, & Nesselroade, 2009). Questions may arise regarding the *size* (in terms of both number of persons and occasions) of study needed to fit the various growth models presented above with reliability, precision, and efficiency. In-depth discussion of design and size considerations reaches beyond our purposes here, but there are a number of issues to consider (see also Collins, 2006; Fitzmaurice, Laird, & Ware, 2004, pp. 403–414; Verbeke & Mollenberghs, 2000, pp. 391–404). These include (a) the expected pattern and amount (e.g., effect size) of intraindividual change and (b) the heterogeneity of intraindividual change patterns. General rules-of-thumb suggest that the more "complicated" the expected pattern of intraindividual change, the more occasions needed. For example, linear models require a minimum of two occasions of measurement (three if a within-person residual variance parameter is also wanted), quadratic models a minimum of three (although these do not necessarily need to be provided by the same person). More complex nonlinear shapes require more occasions, and ideally with the occasions being obtained during periods where curvature exists (Adolph et al., 2008; Collins, 2006). Generally, growth curve modeling is a large sample technique. To the extent that SEM and multilevel modeling frameworks are robust, "small" samples may be accommodated. However, we caution that the number of persons needed to *reliably* estimate model parameters depends more on whether the model is representative of a homogenous behavioral change phenomena (i.e., all persons follow the chosen model of change, linear, quadratic, exponential, or other), rather than simply on how many persons are sampled. For example, if the change process is heterogeneous (and we could argue that most developmental change processes probably are—e.g., *multidirectionality* and *multifinality* of development), pooling different "types" of participants may lead to faulty parameter estimates and conclusions. We, therefore, would encourage researchers to consider heterogeneity and how or when a person-specific, time-series approach may be appropriate.

Naming the "Betas"

Rather than relying on concepts such as *intercept* and *slope* or *intraindividual variability and change* the focus should shift toward precise naming and definition of the change processes (expanding and making more precise the taxonomy forwarded at the outset of this chapter). Models of change should, ideally, provide for adequate representations of developmental theory (Ram & Gerstorf, 2009a; Ram & Grimm, 2007; Wohlwill, 1973). A model is of little use, when its parameters do not map onto theoretical models of the underlying change processes or what is known about the relational developmental system under investigation. For example, when modeling changes in height from early childhood to adulthood, it is important consider what is known regarding the relational developmental system. Biological processes coinciding with the onset of and changes occurring during puberty, the asymptotic nature of adult height, as well as how people differ with respect to these aspects of development should inform the statistical model of change (Collins, 2006). Each feature of change can then be mapped to a specific parameter ("beta") in the model.

Models that do not include parameters that map onto specific and theoretically important aspects of development may not be helpful in understanding the process of development and its determinants. It must be acknowledged, though, that in some areas, there may not yet be strong theories regarding the nature of the developmental process. In such circumstances, it may be useful to fit a set of models that are able to adequately represent the observed change patterns and have parameters that help the researcher understand the important features of the developmental process. Here again, we encourage the use of *differential equations*. As illustrated above, when written in this form, the translation between parameters and theoretically important aspects of change becomes easier. Given the nature of knowledge discovery, there is, and should be, ongoing interplay between the analytical models and the theories. Each should inform the other as we iterate between hypothesis/model construction and hypothesis/model testing.

CONCLUSIONS

Advances in mobile and computing technology are opening new possibilities to obtain biobehavioral data, model it in real time, and remotely deploy interventions at population scale. The electronic devices many of us now carry with us as we go about our daily lives provide a wide array of opportunities to collect more and more data from more and more people and, potentially, to deliver time- and context-specific guidance to them. Such data streams have tremendous implications for how *biopsychosociocultural* development can be approached, both in principle and in practice. As the "big data" arrive it shall be possible to track, model, and guide the progression of the incremental, stability-maintenance, and transformational change processes that shape individuals' development—in real-life and in real-time. Human development progresses.

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CHAPTER 21

Person-Oriented Methodological Approaches

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Developmental science seeks to describe explain, and optimize intraindividual change and interindividual differences in intraindividual change across the life span (e.g., Baltes, Reese, & Nesselroade, 1977; Magnusson & Stattin, 2006). As such, a focus on the individual and, therefore, on person-oriented approaches to the analysis of development are the fundamental foci of developmental science (Lerner, 2012). Accordingly, this chapter is concerned with theoretical and methodological aspects of the person-oriented approach to human development. The theoretical framework emphasizes the study of *individual* development and views this development as a process with interacting components that reside inside and outside the individual. It also emphasizes considering the individual as a whole instead of separate, possibly unrelated behavioral domains. These assumptions are consistent with other chapters in this volume and in other publications that take a Relational-Developmental-Systems approach to human development (Lerner & Benson, 2013; Overton, 2013). Methodologically, the person-oriented approach uses the individual rather than the variable as the unit of analysis. This chapter begins with a discussion and examples of variation. It then proceeds to theoretical approaches to and to methodological issues of person-oriented research.

With deep sadness we note the passing of Dr. Chueh-An Hsieh prior to the publication of this chapter.

THE STUDY OF VARIATION

Humans are all different from each other. Even monozygotic twins differ from each other. Reasons for this are obvious. Nontwins share only part of their DNA and part of the environment, so they are bound to be different. Nesselroade Monozygotic twins share only part of the environment, so they differ from each other as well. For example, Charney (2012) showed that the additive genetic correlation of monozygotic twins is lower than 1. Molenaar, Smit, Boomsma, and Nesselroade (2012) showed that it is possible to compute heritability coefficients for individuals, and that these coefficients are not the same for monzygotic twins. Cochran and collaborators (Cochran, & Harpending, 2009; Hawks, Wang, Cochran, Harpending, & Moyzis, 2007) posit that human adaptive evolution has accelerated over the past 10,000 years. Assuming that this trend continues, the authors predict that humans will become even more different from each other. There is no need to go as far as some well-known poets (Wells, 1895) and daring authors in evolutionary anthropology (Curry, 2006) have ventured, and to say that the human species will split into two, the genetic haves and the genetic have-nots. However, given that humans already differ greatly from each other and given that these differences may increase and become more "significant," both researchers and practitioners have to deal with these differences in theoretical, empirical, and methodological scholarship.

When a sample is large, one can expect a certain degree of variation in the data. For example, the statement that, on average, young Dutch men in 2011 are 6 foot 3 inches tall, can be defended even if a certain percentage is even taller, and even if a percentage is rather short. One can also expect that nobody will be exactly 6 foot 3 inches tall. Still, one can ask how large the portion of the population is to which the general statement applies. One can also ask whether this portion will shrink when people become ever more different from each other, and what can validly be said about those to which the general statement does not apply. These and similar questions arise in many research contexts, and there are multiple answers. Here, in the introduction to this chapter, we discuss four answers. They concern (1) outliers, (2) the existence of multiple populations, (3) the correctness of general statements, and (4) the ecological fallacy.

First, one can suspect that those for which the general statement does not hold true are distance outliers, that is, individuals far from the expected parameter, for example, the mean (see the discussion of performance outliers in Ericsson & Charness, 1994; Gladwell, 2009; Hambrick & Meinz, 2011; for a discussion of statistical aspects of outliers, see, e.g., Kutner, Nachtsheim, Neter, & Li, 2005; Wilcox, 2005a, 2005b; see also Hettmansperger, McKean, & Sheather, 1997). Statistically, outliers are rare, by definition. They can be defined with respect to any parameter. In the literature, three types of outliers found most of the attention. The first is distance outliers. These are scores far away from the mean of all scores. The second is leverage outliers. These are scores that have more influence on such parameters as regression slopes than the rest of the population. Reestimating the parameter without these cases will change the estimate more than when other cases are removed. The third kind of extreme scores is termed *inliers* (Hettmansperger et al., 1997). Whereas outliers are relatively easily detected—most general purpose software automatically search for this kind of extreme scores—inliers are hard to detect. They are located inside the data cloud, maybe even close to the centroid, and still can have dramatic effects on parameter estimates such as regression slopes (Hettmansperger & Sheather, 1992).

Other types of outliers exist, and so do combined types. Statistical methods have been proposed and discussed for dealing with such extreme scores. Examples of such methods include retaining the extreme scores (when the assumption is made that a portion of scores can be expected to be extreme), excluding the extreme scores (when the assumption is made that the extreme scores are invalid and cannot be replaced by valid scores), using robust methods (when the extreme scores are considered valid but the researchers do not wish them to have undue influence on the value of the parameter estimate; see also Rousseeuw & Leroy, 1987), and treating the extreme scores as missing (because it is assumed that the extreme values are caused by measurement or coding errors; the *thus missing* scores are then reestimated, and the estimates are imputed to replace the observed scores). It has also been discussed whether outliers can be identified based on the assumption that they result from mixing different distributions.

In particular, the last of these options is of interest for the present chapter. Removing and replacing proceed from the assumptions that (a) the extreme scores are invalid and that (b) the cases that provide these scores still belong to the parent population that is targeted for a study. Using robust estimation methods opens the doors to statistical analysis when the extreme scores are deemed valid. Considering mixture distributions also assumes that the scores under scrutiny are valid, but that they may result because the cases with these scores come from a different population than the one targeted for a study. This last statement lies at the heart of this chapter: Individuals may belong to populations that differ in major characteristics. In developmental research, this assumption implies that individuals may develop in ways that are specific to different populations.

This last statement is also the second answer to the question why general statements may not apply to everybody: Individuals in a sample may belong to different populations. The assumption of multiple populations differs from the outlier assumption in two important aspects. First, outliers are rare and are not expected to exist at a rate exceeding the portion of $\alpha = 0.05$. Outliers are, thus, individual cases that may or may not deliver defective scores. In either case, a substantive investigation of the reason why certain cases are extreme may not be warranted. This applies in particular when outliers are considered as reflecting measurement or coding errors. If, however, different populations are considered, the substantive study of such populations may be most interesting and important. The second aspect is that populations can differ in size and their size is unrelated to α. The systematic study of the characteristics in which populations differ is of importance for the definition and comparison of these populations. This applies even to the extreme cases in which a population is constituted by just one case or by an infinite number of cases.

The third answer to the question why a general statement may not apply to everybody may sound trivial, but it is not: The general statement may be incorrect. Ignoring the possibility of fraud or otherwise misguided research, incorrect general statements can result for a large number of reasons. Among the most important is that a generalization that is made, for instance, by way of statistical inference, fails to take into account unmeasured, *lurking variables*. The effects of such variables can manifest in spurious relations and, even more dangerous, conclusions that distort or reverse the direction of effects. Lurking variables can be variables that allow one to distinguish between individuals and subpopulations of different characteristics. Consider the example in which an educator ignores that extraverted students react differently to reinforcement than introverted students. Whereas extraverted students react more positively to positive reinforcement, introverted students react more positively to negative reinforcement. If the educator misses this distinction and designs a training program that is solely based on positive reinforcement, only a portion of the students may show the desired effect.

The fourth answer why general statements may not apply to everybody is that the assumption that an estimated parameter necessarily also describes every individual can be risky. Drawing conclusions about an individual based on population parameters can be incorrect. This error is known as the *ecological fallacy* (Freedman, 2001). The classic example of an ecological fallacy was provided by Robinson (1950). The author calculated, based on averages, that the correlation between literacy in English and the number of immigrants in the states of the United States was 0.51. This number suggests that immigrants display higher levels of literacy than the English-speaking population of the United States. Recalculated based on the data of individuals, the same correlation was 0.11. The reason for this discrepancy was that immigrants tended to move to states, which already had a population with high literacy rates. Robinson, therefore, warned against drawing conclusions about individuals based on aggregate-level, *ecological data*.

Related errors exist. For example, one commits the *fallacy of composition* (also called *fallacy of discrimination*; see Kreft, 2005) if one falsely draws conclusions about the characteristics of a population when this characteristic was found in only a small number of cases. Other fallacies have been discussed, but less extensively than the ecological fallacy. For example, one commits the *fallacy of division* if one claims the existence of separate populations that, in fact, do not exist. In this chapter, we focus on the most intensively discussed fallacy, the ecological fallacy.

This chapter is organized in three parts. In the first, we present examples in which we show that aggregate-level statements may not apply to individuals (see also Schmitz, 2000; von Eye & Bergman, 2003). In the second part of the chapter, we present theories concerning differences among individuals. We cover and compare the tenets of person-oriented research (Bergman & Andersson, 2010; Bergman & Magnusson, 1997; Bergman, von Eye, & Magnusson, 2006; von Eye & Bergman, 2003; von Eye & Bogat, 2006a, 2006b), concepts of idiographic research (Molenaar, 2004a, 2004b; Molenaar & Campbell, 2009; Molenaar & Newell, 2010), differential psychology (Galton, 1865; Stern, 1911), and concepts discussed in the context of ecological fallacy (see Gelman, Park, Shor, Batumi, & Cortina, 2008). The concepts of person-oriented, idiographic, and differential psychology are then compared.

These comparisons conclude the theoretical part of this chapter. The third part of this chapter reviews statistical methods of importance for developmental research from a person-oriented perspective. This part covers latent variable models and manifest variable models as well as models for metric and for categorical data. The chapter concludes with discussions of future directions of person-oriented research.

ON LOSING INDIVIDUAL DIFFERENCES IN DEVELOPMENTAL RESEARCH

In this section, we present four data examples that illustrate person-oriented research. The examples illustrate that research that focuses on groups of individuals can prevent researchers from noticing differences between individuals and their development (see also Bakan, 1954; Bryk & Raudenbush, 1988; Estes, 1956; Schmitz, 2000; Sidman, 1952; von Eye & Bergman, 2003; von Eye & Bogat, 2006a, 2006b). In addition, the examples demonstrate that conclusions drawn from aggregate-level data analysis can be misleading and result in descriptions of relations in data and development that are invalid at the individual level. The examples are concerned with patterns of developmental change (Example 1), the results from cross-sectional correlations in comparison with correlations from longitudinal information (Example 2), the (mis-)representation of individual characteristics in autocorrelograms at the aggregate level (Example 3), and statements that are statistically significant but miss the characteristics of the majority of the population (Example 4).

Example 1: *Individual and aggregate change patterns*. As explained by Wohlwill (1973) and Lerner (2002), different theoretical assumptions about the pace of changes associated with development may result in different aggregation of data, and thus affect the depiction of change trajectories. In the following example, adapted from Schmitz (2000; see also von Eye & Bergman, 2003) we use artificial data to illustrate that aggregate-level descriptions of change patterns can misrepresent individual change patterns. The example demonstrates problems with *temporal aggregation*. Consider four students, S1, . . . , S4, each of which shows one and only one change in level of academic performance. S1 and S2 improve, S3 and S4 disimprove. This can be seen in Figure 21.1.

Figure 21.1 shows that each of the four students shows only one shift in performance. Each of the shifts is by one scale unit. Aggregating the raw data results in the statement that, on average, the students first improve by half a scale point and then dis-improve by half a scale point (see the curve for the average, AVER). The individual change patterns show that none of the students concludes the observation period with a performance at the same level as at the

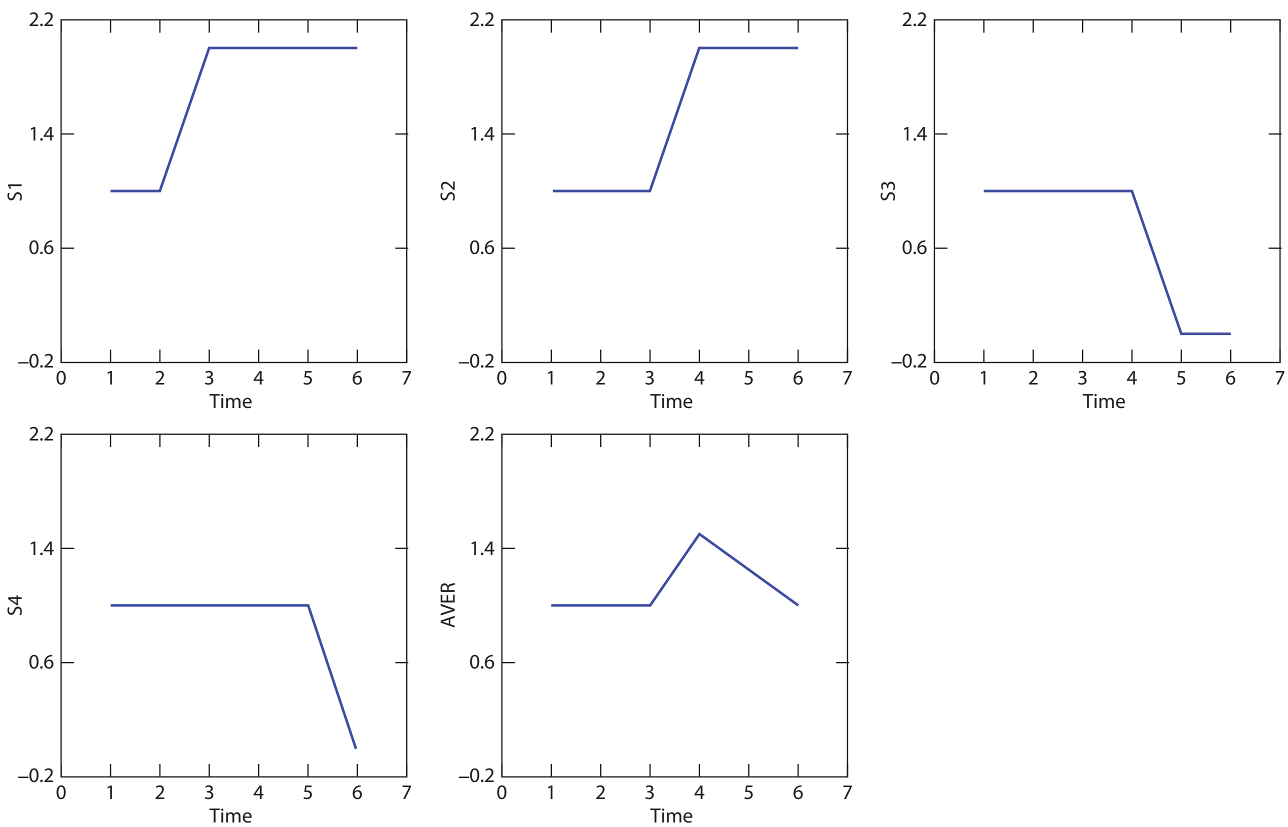

Figure 21.1 Individual-level and aggregate-level change patterns (artificial data).

beginning of the observations. In contrast, the aggregate change pattern suggests that this is the case. Evidently, none of the individuals is properly represented by the aggregate change pattern that results from averaging the raw data.

Example 2: Individual and aggregate correlations. To presage our discussion later in this chapter (pertinent to the concept of ergodicity) about the distinctions between assessing the correlations among variables across people within one time point versus assessing the relations among variables across time within one person (e.g., see, Nesselroade & Ford, 1985; Nesselroade & Molenaar, 1999), our second example goes back to a discussion by Asendorpf (1995). In an imaginary longitudinal study on the relation between effort invested in homework and internal locus of control, the scores for four students were measured (Table 21.1; see also Table 1 in Schmitz, 2000).

Table 21.1 shows a very disconcerting pattern of results. First, the correlation between effort and locus of control is, for each individual, $r = -1.0$. However, if one averages the effort scores and the locus of control scores, and calculates the association between the averages, one finds $r = +1.0$ (note that the average effort and locus of control profiles are time-invariant and have zero variation; therefore, the cross-correlation is not defined). In this example, the estimate that is based on the averaged scores suggests exactly the opposite conclusion as the estimate that is based on the individual scores. This result corresponds to the one in the ecological fallacy example, but without a lurking variable.

Second, the data in Table 21.1 suggest that neither of these estimates is related to the estimates one obtains cross-sectionally. The cross-sectional correlation between effort and locus of control is, for each of the four observation points, zero.

We conclude that, based on exactly the same data, one can present the result that the correlation between effort and locus of control is

- −1.0 (when individual-level data are used).
- 0.0 (when cross-sectional data are used).
- +1.0 (when aggregated longitudinal data are used).

TABLE 21.1 Effort Invested in Homework and Internal Locus of Control in Four Students

		Observation Point					
Student	Variable	1	2	3	4	Average	Correlation
1	Effort	120	120	101	99	110	−1.0
	Locus of Control	101	99	120	120	110	
2	Effort	120	120	99	101	110	−1.0
	Locus of Control	99	101	120	120	111	
3	Effort	80	80	99	101	90	−1.0
	Locus of Control	99	101	80	80	90	
4	Effort	80	80	101	99	90	−1.0
	Locus of Control	101	99	80	80	90	
		Average of All Students					
	Effort	100	100	100	100	100	
	Locus of Control	100	100	100	100	100	
Correlation per Point in Time		0.0	0.0	0.0	0.0	0.0	

Example 3: Individual and aggregate autocorrelations. Our third example builds on the issues associated with Examples 1 and 2. However, here we use data from a study on the development of alcoholism (Perrine, 1995). A sample of 52 male adults who had identified themselves as alcoholics indicated daily in automated interviews how much alcohol they had consumed the day prior to the interview. The participants provided this information over a span of 3 years. In the following analyses, we analyze the numbers of beer consumed by four randomly selected respondents (von Eye & Bergman, 2003, analyzed the first four respondents in the data file; here, we use the data from different respondents, specifically cases 3008, 3009, 3010, and 3011). We performed analyses at two levels. First, each individual's series of responses was transformed into an autocorrelogram. An autocorrelogram indicates the correlation of the information provided on day k with the information provided on day $k + i$ with $i >$ 0. The variable i is called the *lag*. When $i = 1$, correlations relate one day to the next. For $i = 7$, correlations relate one day of the week to the corresponding day in the following week, for example, the Wednesday in one week and the Wednesday of the following week. Results are stated in units of correlation coefficients. For the example, we use lags i from 1 to 50. Figure 21.2 presents the results for respondents 3008, 3009, 3010, and 3011, as well as the aggregate of these four respondents. The aggregate results from calculating the autocorrelogram for the sums of the four respondents' reported numbers of beers consumed each day. The five panels in Figure 21.2 are comparable because each respondent began providing information on a Sunday. The bars in the plots represent the magnitude of the autocorrelations. The solid lines that accompany the

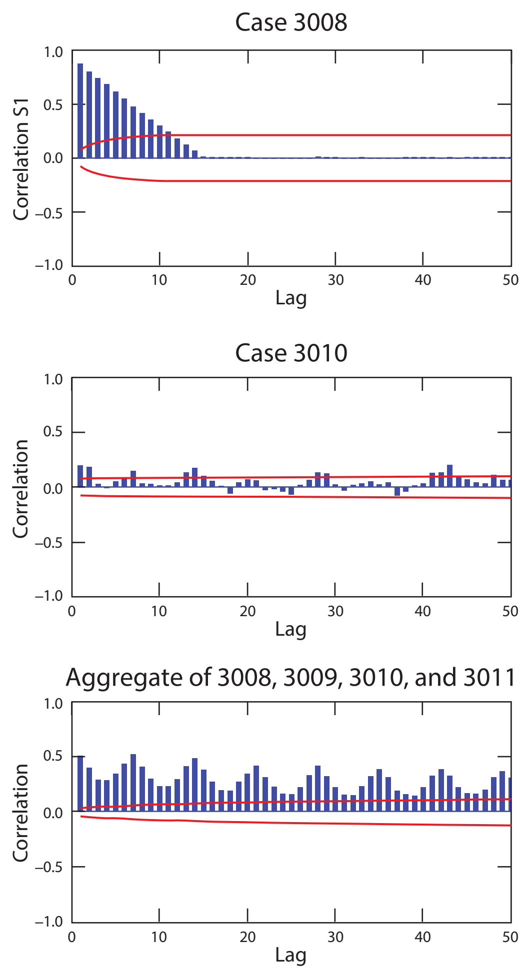

Figure 21.2 Autocorrelation plots of four individuals and their aggregate.

bars represent the significance thresholds. Bars that exceed these lines indicate significant autocorrelations.

The five autocorrelation plots in Figure 21.2 can be described as follows. Participant 3008 is highly predictable, over the short term. The correlations for this individual are extremely high for short lags. As the lags increase, however, correlations decrease and approach zero. It is well known that autocorrelations tend to decrease as the distance in time (lag) increases. In this case, however, there is a substantive reason for this strong decline. Participant 3008 changed his drinking habits. During the first 9 months of the observation period, he consumed mostly beer and no other alcoholic drinks. During the rest of the 3-year observation period, however, he mostly consumed hard liquor. This lowers the correlations for beer consumption, for the longer lags.

In contrast, Case 3009 displays extremely stable beer consumption. Specifically, higher consumption over the weekends (positive bars) corresponds with reduced consumption during the work days of the week (negative bars). This behavior is so stable that the correlation cutoff line is almost parallel to the x-axis (usually, the cutoff lines become wider as the lags increase).

Case 3010 is far less predictable in his beer consumption than the other three cases. The number of significant correlations is smaller than for the other three cases, and the correlations are low. In addition, this participant drinks smaller amounts (this is not visible in the autocorrelation plots; we state this from inspecting the raw data), and his drinking pattern shows only a weak relation with the weekdays, if any.

Case 3011 is different again. His drinking pattern is also only weakly related to the weekdays. However, it is significantly correlated up to a lag of $i = 27$. For longer lags, there is no strong autocorrelation. For this participant, we also see high correlations early, but they are neither as extreme as for Case 3008 nor do they decrease as rapidly.

The aggregate autocorrelation is displayed in the fifth panel. This autocorrelogram suggests that, on average, there is a strong pattern such that the correlations indicate that, from weekend to weekend, the amount of beer consumed is highly correlated. For the workdays of the week, correlations are weaker because drinking behavior is less consistent. The significance threshold suggests that the correlations are significant for every lag *i*.

The comparison of the individual autocorrelograms with the aggregate-level result shows that none of the individuals is properly represented. Specifically, the limited long-term stability of the correlations for Case 3008 that is caused by his switch from beer to hard liquor is not reflected at all. The negative correlations for Case 3009's working day drinking are not reflected either. The lack of sizeable correlations that result from Case 3010's relatively low and unstable beer drinking habits does not surface at all. Finally, the lack of a weekday rhythm in combination with reduction in significant correlations for lags greater than 27 that is characteristic for Case 3011 is not part of the aggregate-level pattern either. In sum, although the pattern displayed by the aggregate-level autocorrelogram may look interpretable and plausible, it fails to describe the characteristics of every single case. Please note again that these are not systematically selected participants but simply the four that follow the four used by von Eye and Bergman (2003).

Example 4: Significance statements can miss the majority of the population. The fourth example illustrates some of the errors that can be introduced into developmental science by a focus on the group (the aggregate level) to the exclusion of the individuals comprising the group. In the example, we demonstrate that effects can be significant but still miss the most important data characteristics. In a data analysis by von Eye, Bogat, and Rhodes (2006), hypotheses were tested that concern the effects of parental attitudes toward the consumption of alcohol on adolescent drinking. Data from 3,558 adolescents who were members of the control group in the National Cross-Site Evaluation of High Risk Youth Programs were analyzed. The youth indicated over a 3-month period the amount of alcohol they consumed and the degree to which they believed their parents would be upset by the adolescents' drinking.

The authors analyzed these data both from a variable-oriented and a person-oriented perspective. The variable-oriented analysis was a repeated measures ANOVA with orthogonal polynomial contrasts. Results suggested that all between and within effects are significant—not a surprise considering the solid sample size. Specifically, there was a significant effect of parental attitudes on the amount of alcohol consumed by the respondents. Adolescents with parents whose attitudes are viewed as more negative drink less. Overall, girls drink less than boys. There is a Time by Gender interaction in that boys reduce their drinking over the 3-month observation span more than girls, and there is a Gender by Attitude interaction indicating that boys respond more than girls when parental attitudes are viewed as negative.

Although these results seem plausible and were as expected, the effect sizes were all very small. The authors, therefore, concluded that there may be unmeasured heterogeneity in the adolescents' responses that is not captured by the ANOVAs. To identify the location of such heterogeneity, the authors performed two steps. First, they inspected the means. Second, they performed a Configural Frequency Analysis (CFA; Lienert & Krauth, 1975; von Eye, Mair, & Mun, 2010).

The inspection of the means revealed two interesting patterns that ANOVA failed to identify. First, a very large group of adolescents indicated that they did not consume alcohol at all. This portion is larger in female (63.5%) than in male respondents (57.0%). Evidently, the significant ANOVA result according to which, over the 3-month observation period, adolescents reduced their drinking, describes less than 50% of the respondents. Even more dramatic is that the inspection of the means revealed that some of the adolescents behaved counter the general trend and increased their drinking. Relatively more girls than boys can be found in the group that increased their drinking.

Using CFA, the authors then identified 9 types and 10 antitypes. CFA types are patterns that are observed more often than expected under a statistical base model. Conversely, antitypes are patterns that are observed less often than expected (more detail on CFA follows in the section on statistical methods for person-oriented research). Here, we briefly review and interpret a selection of the CFA results (for the complete results see von Eye et al., 2006).

- CFA types (these are typical longitudinal drinking patterns).
- 63.5% of the female respondents indicate that they do not drink over the entire observation span; this is significantly more than expected.
- Significantly more girls than expected keep their drinking rates unchanged (albeit at a low level) although they assume that their parents are very upset.

- Significantly more boys than expected (but less than 1% of the target population) reduce their drinking rates from larger amounts to nothing when they assume that their parents are very upset.
- *CFA antitypes* (these are *atypical* developmental patterns).
- Although significantly fewer girls than expected reduced their drinking over the 3-month observation span, this portion still amounts to 4.77% of the target population.
- Significantly fewer girls than expected indicate that they do not drink although they assume that their parents would not be upset at all or just a little.
- Significantly fewer boys than expected reduce their drinking from small amounts to nothing at all when they assume that their parents are upset about their drinking.

The four examples depict key problems that may arise in the analysis of developmental data when intraindividual change is not given appropriate attention. The examples illustrate (a) how the variable-oriented approach can suggest invalid conclusions and (b) the relation between variable-oriented and person-oriented research. Even if the former results in valid conclusions, the latter is, in most applications, capable of enriching results and in identifying patterns that are particularly atypical (antitypes) or observed more often than one would expect (types). In the next sections, we present the main tenets of person-oriented research and a comparison with idiographic and with differential psychology.

THE TENETS OF PERSON-ORIENTED RESEARCH

The person orientation in social and behavioral science research has been traced to Block (1971; see Bergman, Magnusson, & El-Khouri, 2003), although the role of the actions of the individually distinct organism as a source of his or her own development has roots in both comparative psychology (e.g., Schneirla, 1957) and action theoretical accounts of human development across the life span (e.g., Brandtstädter, 1998). To provide a theoretical underpinning for the application of the Q-Sort method, Block proposed distinguishing between two approaches to developmental research, the *variable* and the *person* approach. Magnusson (2000) interprets this distinction with reference to *measurement models*. If a measurement model is established in the context of variable-oriented research, data points of individuals on latent dimensions are interpreted with reference to the data points provided by other individuals. In the context of person-oriented research the same data point is interpreted with respect to the same individual's position on other latent dimensions, that is, as part of an individual's profile.

Similarly, the inferential conclusions and generalizations that can be made in the two approaches differ. Variable-oriented research results in conclusions about relations among variables. In developmental research, these conclusions focus on constancy and change of such relations. In contrast, person-oriented research makes conclusions in terms of the patterns that describe individuals or groups of individuals. Again, in developmental research, the conclusions focus on constancy and change of such patterns, their relations to other events in the system under study, and their relations to patterns of other individuals. The random element in variable-oriented research is the individual. The random element in person-oriented research is the measure.

Person-oriented research is often presented in tandem with a holistic perspective (Bergman & Magnusson, 1997; Magnusson, 1985, 1999, 2000; Magnusson & Allen, 1983). According to Bergman et al. (2006), person-oriented research considers the individual as an integrated, biological and social entity. This entity is the unit of analysis, and it constitutes the *organizing principle* of scientific inquiry, which implies a holistic perspective. (For discussions of relevant holistic perspectives see, Bateson, Chapter 6, this *Handbook*, this volume; Cummings & Valentino, Chapter 15, this *Handbook*, this volume; Kuczynski & De Mol, Chapter 9, this *Handbook*, this volume; Lerner, Lerner, Bowers & Geldhof, Chapter 16, this *Handbook*, this volume; Lickliter & Honeycutt, Chapter 5, this *Handbook*, this volume; Overton, Chapter 2, this *Handbook*, this volume; Witherington, Chapter 3, this *Handbook*, this volume.) Developmental processes possess, therefore, three fundamental characteristics:

1. The individual organism can be thoroughly understood only as a whole, not as a sum of fragmented elements.
2. The unit of person-oriented analysis is indivisible and can, thus, be studied most fruitfully taking a holistic perspective.
3. The key principle of functioning and development of an integrated individual is that of *functional interaction*.

Functional interaction is person-oriented and leads immediately to the first of the seven main tenets of person-oriented research. The first five of the tenets have been proposed by Bergman and Magnusson (1997), and have, since, gone through a number of iterations. Other tenets have been proposed and the concept of person-oriented research has been applied in many domains of research. To give just two examples, Bogat (2009) has discussed person-oriented research in the context of community psychology, and von Eye and Bergman (2009) have discussed person-oriented research on personality. Here, we focus on the seven tenets discussed by von Eye and Bergman (2003).

1. Functioning, process, and development of behavior are, at least in part, specific and unique to the individual.
2. Because of its complexity, the study of functioning, process, and development necessitates taking many factors and their interrelations into consideration.
3. There is lawfulness and structure both in intraindividual constancy and change in functioning, process, and development, and in interindividual differences in functioning, process, and development.
4. Processes occur in a lawful way and can be described as *patterns* of the involved factors; development can be described by constancy and change in these patterns; the meaning of the involved factors is determined by the factors' interactions with other factors.
5. The number of differences in process characteristics and patterns is, in theory, infinite. The number of observed differences, however, will be small and finite.
6. Some patterns occur more frequently than other patterns, or more frequently than expected based on prior knowledge, assumptions, and estimates. These patterns can be termed *common types*. Von Eye, Indurkhya, and Kreppner (2000) proposed that, accordingly, there will also be patterns that occur less often than other patterns or less often than expected. These patterns can be termed *common antitypes*. (Note that this terminology was chosen with Configural Frequency Analysis [CFA] in mind, a method suitable for person-oriented research; see the section on CFA.)
7. For a quantitative comparison of individuals on the same scale and over time, *dimensional identity* is required; for the qualitative comparison of individuals, dimensional identity is not a prerequisite.

The first of the tenets of person-oriented research is based on Bergman and Magnusson's (1997) holistic perspective. It posits that individuals can differ from each other in systematic ways that are not classified as measurement error. These differences can exist synchronously and diachronously. Most important for the person-oriented approach as well as for the following discussion of the idiographic approach is that it is not assumed that a general, all-encompassing population always exists. It is possible that single cases (i.e., individuals) differ systematically from all other individuals. It is also possible that groups of individuals exist that constitute subpopulations, or separate populations. Person-oriented research focuses on such differences. As was indicated above, it may be needed to estimate parameters first at the level of the individual. Grouping can then be based on these parameters (see Estes, 1956; Molenaar & Campbell, 2009). The outliers that were discussed in the introduction may, therefore, not really be outliers. Assuming their scores are valid, they may belong to different populations, or, individual outliers may constitute their own unit of analysis that cannot be fused with other units. Sterba and Bauer (2010) identify the first tenet as carried by the *individual specificity principle*.

The second tenet of person-oriented research is that of *multiply determined outcomes*. Only rarely, if ever, will a psychological outcome be determined by just one cause. In most cases, more than one cause exists. Naturally, these causes can differ in their importance. Some causes will be necessary for an outcome, others will be sufficient, and some will be both necessary and sufficient. Still, each causal agent will make a unique contribution to the observed outcome.

The second tenet also proposes that the factors interact. The same factor will have effects that vary depending on which other factors are present and active, and which other factors have been present and active before. This proposition has major implications for the design of empirical studies. Designs that allow one to estimate only main effects, or designs in which interactions are confounded (see von Eye, 2008; von Eye et al., 2010; Wu & Hamada, 2009) are, under the second tenet, rarely of interest to the person-oriented researcher. Considering that higher order interactions rarely explain as much variability as lower order interactions or main effects, one might consider fractional factorial designs with a resolution that allows one to estimate interactions up an order that is considered interesting and, thus, omit higher-order interactions. An example of the strategy of omitting the highest order interaction can be found in standard applications of GLM software for repeated measures analysis of variance. In these applications, the highest interaction between subjects and time is routinely used as the portion of variance to test against. In other words, the parameters for this effect are not estimated and statistically evaluated, but used as residual, that is, unexplained variance.

One should keep in mind, however, that omitting higher-order interactions does come with the risk of missing strong effects. One example in which the highest order effect explains all of the variability in a table is known as Meehl's paradox (Krauth & Lienert, 1973; Meehl, 1950). This paradox can be explained using the following (artificial) data situation. There are two groups of individuals. One is diagnosed with schizophrenia (=1), the other is without diagnosis (=2). A psychiatrist asks whether two items, I1 and I2, allow one to discriminate between these two groups. The items are formulated such that they can be answered with Yes (=1) and No (=2). Table 21.2 displays the frequency distribution.

Table 21.2 shows that respondents diagnosed with schizophrenia respond either with Yes or with No to both items, with no exception. In contrast, respondents without diagnosis respond either with Yes to the first item and No to the second or vice versa, also with no exception. Based on this result, the two items are perfectly capable of separating the two respondent groups. In contrast, based on the interitem correlation and the correlation of each item with the diagnosis, one would conclude that these two items are useless. Each of these correlations is exactly zero.

One might say that this frequency pattern is rather artificial, but there are instances in which it was found in empirical data. Well known are the results of Lienert's (1962) experimental study of psychoses in which he found that application of LSD50 results in what he called the *Leuner syndrome*. This syndrome shows a frequency distribution parallel to the one in Table 21.2. It is characterized by a three-way interaction among disturbed consciousness, thinking problems, and affective problems that exists in the absence of main effects or two-way interactions. Focusing on these lower-order effects would lead one to miss the important effect in this three-way table. Sterba and Bauer (2010) identify the second tenet as carried by the *complex interactions principle*.

TABLE 21.2 Frequency Distribution for Meehl's Paradox

	Variables		
Diagnosis	**Item 1**	**Item 2**	**Frequency**
1	1	1	15
1	1	2	0
1	2	1	0
1	2	2	15
2	1	1	0
2	1	2	15
2	2	1	15
2	2	2	0

The third tenet of person-oriented research, particularly important in developmental research, proposes that interindividual differences exist in intraindividual constancy and change. More concretely, the third tenet posits that developmental parameters are not universal. Not everybody goes through the same developmental steps. Even if individuals take the same developmental steps, they can still differ in timing, speed, intensity, and other parameters. In addition, some individuals may continue to develop when others have reached a stage of (relative) constancy. Examples of such differences include the timing of pubertal development, Kohlberg's (1973) stages of moral development (not everybody reaches the highest stages), and cognitive development after Piaget's (1932) formal operations (not everybody develops to exhibit post-formal operations). Sterba and Bauer (2010) identify the third tenet as that of the *principle of interindividual differences in intraindividual change* (see also Baltes et al., 1977).

The fourth tenet of person-oriented research is closely related to the holistic viewpoint discussed earlier. It proposes that development, constancy, and change must be described in terms of patterns of the involved factors instead of constancy and change in individual variables. In addition, the substantive meaning of the involved factors is not only defined by the meaning of these factors. Instead, a definition of the meaning of these factors also necessitates a description of their relations with other factors (see also Noble, 1951). As for the second tenet, this necessity has important implications for research design. A design that enables researchers to test hypotheses that are compatible with the fourth tenet of person-oriented research must reach a resolution level that allows one to estimate the hypothesized interactions among the factors on (a) the *x*-side of a model, (b) the *y*-side of a model, and (c) the interactions that link factors on the *x*- and *y*-sides of a model. When the distinction between the *x*- and the *y*-sides of a model is not made, the design must nevertheless allow one to estimate all hypothesized interactions.

It should be noted that this desideratum does not imply that a design needs to always be completely crossed. In many cases in nonexperimental research (the Meehl paradox representing the very few exceptions), theories do not require that all interactions be estimated. The highest order interactions in particular are rarely interesting. Therefore, fractional factorial designs are almost always a parsimonious option, even in categorical data analysis (see von Eye, 2008; von Eye & Bogat, 2006b).

Unfortunately, these parsimonious designs are rarely employed in the social and behavioral sciences.

Sterba and Bauer (2010) identify the fourth tenet as that of the *principle of pattern summary*. This label may be somewhat misleading. Person-oriented research is unlikely to result in summary statements. We, therefore, propose labeling this tenet as following the *principle of patterns as units of analysis*.

The fifth tenet of person-oriented research, only partly considered by Sterba and Bauer (2010), has two facets. First, one has to consider that, numerically, the number of differences can be extreme to the extent that no two individuals could be considered identical. Naturally, this number varies with the number of variables under consideration. When two individuals are compared using a 5-point Likert scale, the probability that they are equal is 0.04. When they are compared using five such scales, the probability that they have the same score on all five scales is 0.00032. Now, when many individuals are compared on many continuous scales, the probability that they are equal approaches zero rather rapidly.

Still, individuals often are grouped into clusters of "same" cases, clinical diagnoses are "the same" for everybody in the same nosological unit, or one group of individuals is compared with another without consideration of within-group differences. The reason for lumping individuals together is that certain numerical differences may not be interpretable (take, for example, the difference between the IQs of 125 and 126), not matter (when comparing women with men, it may not matter that one man is 5′3″ tall and the other 6′2″), or of no implication for the aims of a study (differences in hair color may have no implication for the effects of cognitive training in adolescents). Equally important is that virtually all measures come with measurement error, thus rendering small numerical differences irrelevant.

All this has the consequence that the number of meaningful patterns is finite. Bergman and collaborators (Bergman et al., 2003) give recommendations as to the number of clusters to aim for in a cluster analysis. This number is relatively small (it is about 4 to 10 clusters), and will vary with the number of variables considered (more variables result in more clusters) as well as the size of the available sample (larger samples can result in more clusters). Still, person-oriented research leaves the door open for many groups or populations to exist, and for individuals to constitute their own class. Sterba and Bauer (2010) identify the fifth tenet as that of the *principle of pattern parsimony*.

The second facet of the fifth tenet of person-oriented research concerns strategies of data analysis. Groups are formed (if Estes', 1956, criteria or Molenaar's ergodicity criteria are fulfilled; see Loken, 2010; Molenaar & Campbell, 2009; Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume), differences are calculated, patterns and profiles are created. Inferential methods of analysis are used, for instance, when clusters are compared. This comparison is to be performed using variables not included in the grouping step. For the group-forming phase, von Eye and Bergman (2003) propose taking information about the expected size of groups into account. This information stems from mainly two sources. The first is prior knowledge such as known effect sizes, known duration of effects of medicinal drugs, or known differential effects of intervention measures. The second source is a statistical base model that, specified from theory and prior knowledge, posits which effects may exist or not exist. Examples of such effects are the well-known main effects and interactions, but they can also be the effects of measured or unmeasured covariates.

Based on this kind of information, hypotheses can be tested that are compatible with theories about the existence, magnitude, or direction of effects. Person-oriented researchers will typically entertain such hypotheses when they propose statements about similarities or differences between individuals and groups of individuals. In developmental research—as posited in the sixth tenet of person-oriented research, patterns of development can be identified as constituting trajectories of development, age-specific covariance structures, or common *types of development* (patterns observed more often than expected), *antitypes of development* (patterns observed less often than expected; *atypical* development), and conform with the null hypothesis (observed as often as expected).

The seventh tenet of person-oriented research, not considered by Sterba and Bauer (2010), provides the basis for the comparison of groups or individuals. *Dimensional identity* requires that, for a numerical comparison, the same scales be used (i.e., commensurate), and that factorial equivalence be established. This is routinely the case, for example, in scales that are constructed using item response theory (IRT; Fischer & Molenaar, 1995; Lord, 1980; Reckase, 2009; see the section on the IRT, later).

An example that shows that scales are not always equally valid in comparison groups can be seen in the widely used Child Behavior Checklist (CBCL; Achenbach, 1991; Achenbach & Edelbrock, 1981). This instrument is routinely employed in the assessment of behavioral and emotional problems in children and adolescents. The instrument exists in forms filled by parents, teachers, and the individual to be evaluated him- or herself. The dimensional structure of the instrument was established using exploratory principal component analysis. It consists of eight components. The original check list included 98 items. The components represent the eight narrow-band syndromes: withdrawn, somatic complaints, anxious/depressed, social problems, thought problems, attention, delinquent behavior, and aggressive behavior. A second-order principal component analysis yielded the two broad-band components of internalizing and externalizing. The first three of the narrow-band syndromes, that is, the first three components load exclusively on the internalizing component, the last two load exclusively on the externalizing component, and the remaining three load on both the internalizing and the externalizing components.

Replication studies concerning the eight first-order and the two second-order components of the CBCL have been undertaken, both in the United States and, using translated forms, in many other countries. In a number of these replication studies, the dimensional structure was replicated. For instance, in the Netherlands (De Groot, Koot, & Verhulst, 1994; Greenbaum & Dedrick, 1998), the dimensional structure of the parent form was replicated using confirmatory factor analysis. However, there also exists a number of studies in which the authors failed to replicate the dimensional structure of the CBCL. For example, Lambert et al. (2003) used data from Jamaican youth to replicate the eight-component/factor solution of the Jamaican self-report version of the CBCL, the Jamaican Youth Self Report Form (JYSR), also using confirmatory factor analysis. The sample included 625 adolescents of African descent between 11 and 18 who were being treated for behavioral and emotional problems. Results suggested that the eight-component/factor structure cannot be replicated for the Jamaican sample. The authors then employed exploratory principal axis analysis to obtain a description of the factor structure of the JYSR. Results suggest four factors that can be labeled anxious/depressed, delinquency, somatic, and cognitive slippage. A confirmatory factor analysis in a cross-validation sample led to the conclusion that the four-factor solution describes the data very well, in samples of both boys and girls.

Evidently, Lambert et al.'s (2003) results suggest that the JYSR can be used to describe Jamaican adolescents' behavioral and emotional problems, but fails to show dimensional identity with the CBCL. It has been discussed whether the meaning of items in Jamaica differs from the meaning of the same items in the United States, and whether such differences lead to different covariance structures. Implications of this result include that application of the original U.S. form of the CBCL to Jamaican children can lead to classifications of problem behavior that may be unrelated to the factor/component structure found for White children in the United States. Accordingly, interventions to Jamaican youth that are based on the U.S. version of the instrument may turn out to be ineffective. In addition, the classifications that can result from the eight- and the four-factor structures can be different. Therefore, CBCL-based and JYSR-based descriptions of adolescents' behavior and emotional problems in the United States and in Jamaica may not be directly comparable. Not even estimates of the degree of behavior and emotional problems may be comparable because they are based on discrepant factor structures.

The CBCL example shows that dimensional identity of diagnostic instruments and measures may not exist across populations. There exist examples that suggest that dimensional identity may also not exist over age. Among the more prominent examples is that of *intelligence divergence* and *convergence*. Garrett (1938) proposed that the structure of intelligence becomes more complex with age (see also Cattell, 1966). In terms of factor analysis, this hypothesis is confirmed if the intercorrelations among subscales of an intelligence test are (a) more uniform and (b) lower in higher age brackets than in lower age brackets. Wewetzer (1958) extended this hypothesis and proposed that in populations of higher intelligence, the number of factors needed to validly describe intelligence is greater than in populations of lower intelligence. Lienert and Faber (1963) discussed the complementary concept of *intelligence convergence*, which, in other contexts, was also termed *de-differentiation* or *neointegration* (Baltes, Cornelius, Spiro, Nesselroade, & Willis, 1980). This concept implies that the number of factors needed for a valid description of intelligence in old age is smaller than in mid-age or adolescence. One major implication of these changes in the factor structure of intelligence is the same as the implications of the cross-ethnic differences in the factor structure of the CBCL: *The same score may not represent the same phenomenon, even if it comes from the same scale*.

IDIOGRAPHIC PSYCHOLOGY AND DIFFERENTIAL PSYCHOLOGY

In this section, we review two approaches that are used with goals that overlap, in part, with those of person-oriented research, psychology as *Idiographic Science* and *Differential Psychology*. The section concludes with a comparison of these three approaches.

Idiographic Psychology

Ideographic, differential, and nomothetic approaches to the study of development have occupied the attention of theorists and researchers for over a century (e.g., Emmerich, 1968; Kluckhohn & Murray, 1948; Windelband, 1894). A well-developed approach to idiographic psychology was presented in the form of a manifesto by Molenaar in 2004 (2004a; see also Loken, 2010; Molenaar & Campbell, 2009; Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume; Molenaar & Newell, 2010). Molenaar begins from two observations:

1. Current Psychology is concerned with variation between cases, that is, interindividual variability.
2. This focus operates at the expense of the study of intraindividual variability.

Molenaar's effort is interesting for many reasons. Here, we discuss the two most important ones. The first is historical. The distinction between idiographic and nomothetic psychology was introduced into the discourse of scholarly psychology already in 1894, by Windelband. This distinction has since been one of the enduring ones in psychology. It distinguishes between *people in general* (nomothetic psychology) and the *person in particular* (idiographic psychology). Later, this distinction was adopted by Allport (1937). Allport defines the goal of idiographic psychology as finding out as much as possible about individuals. Case studies were, at that time, considered prime methods suitable for idiographic research (see also Gardner, 1998). In contrast, nomothetic research aims at specifying laws or principles that are valid within a domain such as psychology or development.

In different contexts, nomothetic laws have been called *universalia* (universals). Interestingly, there is no generally accepted definition of the term *universalia*. Therefore, and without going into the details of the philosophical discussion of this term (see, e.g., Stegmüller, 1973), we use the following criteria for universals. Universals:

- Are independent of the course of time.
- Are abstract concepts (cannot be perceived by the senses).
- Have no causal effects.

None of these criteria is sufficient to identify universals. However, these criteria can be used to identify psychological concepts as universals. General terms such as *extraversion, intelligence, motive strength*, and developmental terms such as *intelligence divergence* or *puberty* qualify as universals. It should be noted that universals are not a-developmental. Developmental pathways can be universals, also, and they can change of the course of historical time. Considering that general psychology as well as person-oriented and idiographic psychology aim at general statements (Molenaar, 2004b), one can ask how research can arrive at statements that are generally true, as are universalia. Before we use this question to differentiate between the person-oriented and idiographic approaches, we describe the idiographic approach in more detail.

The second reason why Molenaar's approach is important concerns the assumptions that need to be made in psychological research (see also Brandtstädter, 1985). As was mentioned above, Molenaar (2004a) notes that current psychology focuses on interindividual variability, at the expense of intraindividual variability. This focus requires the strong assumption that conclusions that are based on data that describe interindividual variability are the same as conclusions that are based on data that describe intraindividual variability. Molenaar (2004a) shows that this assumption holds only under rare conditions. Therefore, idiographic psychology aims at correcting this imbalance by first focusing on the individual. Each individual is considered a possibly unique system of interacting dynamic processes. The development of these processes results in a high-dimensional life course, a trajectory that is specific to the individual.

A key term of idiographic psychology is that of *ergodicity*. A process is considered *ergodic* if its statistical characteristics (e.g., its moments) can be derived from a single, sufficiently long sample of the process (an example of an ergodic factor model is given below). This definition can be translated in another, equivalent one: A process is ergodic if the structure of intraindividual variation is asymptotically equal to the structure of interindividual variation. Therefore, if a psychological process is ergodic, a large sample of cases will be sufficient for the description of this process. This applies to both cross-sectional and longitudinal samples. Molenaar states that most psychological processes, for example, all developmental processes, learning, adaptive processes, regime change, and the development of behavioral disorders, are *nonergodic*. By implication, the focus on interindividual variability will not enable researchers to make conclusions about intraindividual variability. The examples given in the introduction to this chapter can be used as illustrations.

The fundamental issue to be clarified is, thus, the relation between structures that are based on interindividual variability and structures that are based on intraindividual variability. To illustrate, we give three examples. The first example (from Loken, 2010) illustrates the lack of correspondence between individual-level and group-level variability. Specifically, it shows problems one encounters when using aggregate-level, group data to make inferences about individual behavior. Imagine a campus map on which the current distribution of the location of individuals is indicated. From this map, we know how many individuals can be found in the cafeteria, in an office building, in a lecture hall, or on the soccer field. This map has snapshot characteristics. Now imagine the campus map again, but, this time, the path taken by an individual is indicated who maneuvers about campus. With great probability, these two maps will differ from each other. We can conclude that the characteristics of a sample, at any given point in time, may not allow us to describe an individual over time.

Now, interestingly, this discrepancy can still not be resolved when the time series of the individual is made longer. Over time, the individual may visit many points on campus, some points more often, some points rarely, and others not at all. Based on these data, one can also create a map on which a distribution is depicted. However, the assumption that this density plot resembles the density plot that was based on snap shot information is a strong one. We can conclude again that knowledge about the average behavior of a group (the density plot of the snap shot) carries little information about the behavior of the individual. This applies even to the *average individual* which may not exist. As Walls and Schafer put it, "the average may be highly atypical" (2006, p. xiv).

The second and the third examples are more technical in nature (from Molenaar, 2004a). For the second example, imagine a standard data matrix with N cases in the rows and p variables in the columns. Let factor analysis result in q factors. Each of the factors has a substantive interpretation. This solution is descriptive of interindividual variability because the covariance matrix this solution is based on describes the variances and the covariances of the variables, not the individuals. If the N individuals were identical, the variances in the diagonal of the covariance matrix would be zero. Accordingly, the covariances in the off-diagonal cells would be zero also. The reason for the effect that the covariance matrix is a zero matrix is that there is no interindividual variation. If this is the case, factor analysis which is supposed to explain the covariation among variables is pointless.

Now, in parallel with the campus map example, imagine that an individual is observed repeatedly on the same p variables. The result is a p-variate time series of score vectors. For this data set, a covariance matrix can be calculated just as for the $N \times p$ matrix for the original factor analysis, and a factor analysis can be performed (Molenaar, 1985). Now, if this individual delivers the exact same scores at each observation point, that is, if there is no intraindividual variability, the covariance matrix will be a zero matrix again, just as in the case in which there was no interindividual variability. Factor analysis would be pointless again. We conclude that an analogous analytical situation results when there is no interindividual variability and when there is no intraindividual variability.

In the third example (Molenaar, 2004a), we describe a structure that is ergodic. Consider a longitudinal factor model of the form

$$y_i(t) = \Lambda_t \eta_i(t) + \varepsilon_i(t)$$

for $t = 1, \ldots, T$, the number of observation points, and fixed T, and $i = 1, \ldots,$ the infinitely large number of cases. In this equation, $y_i(t)$ is the vector of p manifest variables that are observed for case i, Λ_t is the $p \times q$ matrix of factor loadings at time t, $\eta_i(t)$ a longitudinal latent variable (factor) at time t, and $\varepsilon_i(t)$ the p-variate, normally distributed residual at time t. Factor η is specified to be

$$\eta_i(t) = B_{t,t-1}\eta_i(t-1) + \zeta_i(t)$$

where $B_{t,t-1}$ is the $q \times q$ matrix of regression parameters that link each latent variable, $\eta_i(t)$, to the previous one, $\eta_i(t-1)$, and $\zeta_i(t)$ is the normally distributed residual at the factor level, also called the *innovation*. For this model, we assume that the measurement errors are uncorrelated, that is, the covariance matrix of residuals, Θ, is diagonal. The model thus specified is comparable to a model that represents a first order Markov process, that is, a model in which time-adjacent observations predict each other. This model is ergodic, if restrictions apply that result in the following model

$$y_i(t) = \Lambda \eta_i(t) + \varepsilon_i(t)$$

with $\eta_i(t) = B\eta_i(t-1) + \zeta_i(t)$. More specifically, the restrictions are

- The matrix of factor loadings, Λ, does not change over time.
- $\varepsilon_i(t)$ has constant covariance.

- $\zeta_i(t)$ has constant covariance.
- The absolute value of each eigenvalue of B is less than 1.

Only if a longitudinal factor model possesses the characteristic that these restrictions apply, it is ergodic. Only if a factor model is ergodic, intraindividual variability can be concluded from interindividual variability.

We now ask what the conditions are under which a solution that is based on the interindividual variability of *N* individuals is identical to a solution that is based on the intraindividual variability from the repeated observation of a single individual. The answer to this question can be given based on statistical ergodicity theory. The structure of interindividual variability and intraindividual variability are equivalent only if the mean and the covariance function is stationary and, thus ergodic.[1] In developmental research, almost all functions of natural development and intervention processes are nonergodic. Therefore, standard statistical analysis of aggregate-level data is bound to result in descriptions of developmental structures that fail to describe the individual.

As was recommended earlier, the following research strategy is, therefore, required for valid description of intraindividual variability, from an idiographic perspective:

- Individual-level data need to be analyzed first, that is, parameters need to be estimated at the level of the individual.
- Ergodicity must be tested.
- Only if the requirement of stationarity is fulfilled, can cases be grouped because, for these cases, descriptions of interindividual and intraindividual variability will be equivalent.

One may ask whether standard aggregate-level analysis can be defended at all. Is there a situation in which such analysis is valuable in its own right? The answer to this question can be derived from the campus map example given above and from the discussion of ergodicity. There are two such situations. First, if researchers are interested in aggregate-level statements that describe a group of cases as a whole, without necessarily being applicable to the individual, then aggregate-level analysis may be defensible. The defense is much stronger in the second situation. If it is known that ergodicity applies, aggregate-level data collection and analysis may be less costly and may require less time and effort than repeated and long-term observation of individuals. In this situation, aggregate-level analysis may be the method of choice. In other cases, it is better to collect data that allow one to analyze the developmental structure of individuals first and to then identify those who can be assigned to the same group.

Implications from this definition of idiographic research are colossal. Here, we focus on two. The first concerns the construction of psychometric instruments based on classical test theory (Lord & Novick, 1968). Before an instrument is applied to individuals, practitioners (and researchers) have to demonstrate that the ergodicity theorems apply. If these theorems do not apply—and, for classical test theory, they do not apply—it is possible that the factor loadings of the individual, which characterize the individual's intraindividual variability "differ to arbitrary degrees from the fixed loadings in the standard solution," that is, the solution for the aggregate (Molenaar, 2004a, p. 213). This issue was exemplified in the introductory examples, and was also discussed in the context of the basic tenets of person-oriented research under the label of *dimensional identity*. It should be noted, that the meaning of dimensional identity goes farther. Here, we find that factor loadings can differ. If there is no dimensional identity, the entire factor structure itself may not apply to the individual.

If the loadings of the individual differ arbitrarily from the loadings found for the aggregate, and one uses the measurement model, often a common factor model, to derive statements about the reliability of the psychometric instrument, it cannot be guaranteed that the instrument does not have a reliability that is practically zero in a large subset of cases in the population. Naturally, if test scores come from tests with high reliability for the aggregate but possibly zero reliability for the individual, this situation can lead to severe doubts concerning decisions about assignment to school programs, therapy, hiring, or intervention programs.

Again, this situation applies to classical test theory. In the section on item response theory, we discuss alternative options for constructing psychometric instruments in the context of work on human development.

The second implication of the above definition of idiographic research concerns development and application of methods in general. As is evident from the conditions under which interindividual and intraindividual variability are equivalent, data collection will have to undergo major changes. In addition, such concepts as factor invariance need to be redeveloped to accommodate the results from

[1]These conditions are sufficient for Gaussian processes. They are only necessary for arbitrary measurable processes.

theoretical, idiographic research. Specifically, constructs must be represented such that:

- Irrelevant idiosyncratic information is filtered out that prevents the precise description of nomothetic relations while
- Justice is done to interpretable intraindividual development and interindividual differences in such development.

Standard factorial invariance (which is related to the concept of dimensional identity in person-oriented psychology) can be described at four hierarchical levels (for an overview, see Brown, 2006; Little & Slegers, 2005). At the first, least restrictive level, there is *configural invariance*. Here, the pattern of fixed and estimated parameters is the same across the units of comparison. The loadings themselves as well as the residual variances and covariances can differ.

At the second level of the hierarchy, already more restrictive, we find *weak factorial* invariance (also called *pattern invariance* or *metric invariance*). Here, in addition to the same loading patterns, the relative factor loadings are proportionally equal across the comparison units. More specifically, the loadings are constrained to be the same across the units of comparison, but the manifest means, the factor variances, and the residual variances and covariances are free to vary.

At the third level of the hierarchy, we find *strong factorial invariance* (also called *scalar invariance*). This concept constrains the factor loadings as well as the intercepts to be equal across the units of comparison. The variances of the latent variables and the residual variances and covariances are still unconstrained such that they can vary. In the context of constructing measurement instruments, strong factorial invariance is needed for individuals with the same ability but from different groups to obtain the same score at the instrument scale. Thus, when strong factorial invariance holds, measurement equivalence is implied in group comparisons, that is, the construct that is measured is comparable across the comparison units.

The most restrictive concept, at the fourth level of the hierarchy, is that of *strict factorial invariance*. Here, in addition to the constraints posed at the lower three levels, the residual variances and covariances are constrained to be equal across the comparison units also. This concept is deemed too restrictive by many. However, there have been arguments in support of requiring strict factorial invariance for proper group comparisons (DeShon, 2004).

With the goals of analyzing interindividual differences in intraindividual change in mind, Zhang, Browne, and Nesselroade (2011; see also Nesselroade, Gerstorf, Hardy, & Ram, 2007) have proposed a concept of higher order factor invariance that simultaneously allows one to create an idiographic mapping of latent to manifest variables. In this approach, higher order factor invariance is defined as factor intercorrelations that are invariant across a number of cases. This type of invariance can be demonstrated in four steps:

1. Although the goal of research is that of arriving at universals, begin with estimating factor models at the level of the individual. One method that is particularly suited for this purpose is P-technique factor analysis, that is, factor analysis of multivariate series of scores that were observed for an individual; do this for multiple individuals.
2. Naturally, the loadings of the manifest variables on the factors in these models are bound to vary; by allowing this, idiosyncrasies are part of the individual-level factor solutions; please notice that this is, in part, a softening of a strict view of factor invariance.
3. Fit a factor model that has two characteristics: (1) it allows for cross-case variability of factor loadings, but (2) it constrains the factor intercorrelations among the first order factors to be invariant across the individuals.
4. If this model describes the data well, that is, if the factor correlation matrices do not vary over the individuals, one can fit a second-order factor model which then can be invariant in the traditional strict sense.

Naturally, none of the four steps comes with a guarantee that the models fit. In Steps 1 and 2, one or more cases may deliver data that resist the model. In Step 3, factor intercorrelations may resist the attempt to constrain them to be equal, and in Step 4, the higher order factor model may fail to describe the first order factor structure. Still, targeting factor intercorrelations instead of loadings in first order factor models as the defining elements of factor invariance involves a paradigmatic shift in the definition of factor invariance. This shift was proposed in response to the arguments presented by idiographic psychology, specifically, idiographic developmental researchers. Naturally, Zhang et al.'s (2011) approach requires data that allow one to estimate factor models for the individual.

The concept of higher-order factor invariance is actively being further developed. For example, Molenaar and Nesselroade (2012) show that the idiographic filter that had been introduced by Zhang et al. (2011) is always testable in state-space models.

Differential Psychology

In *differential psychology*, "we study individual differences" (Revelle, Wilt, & Condon, 2011, p. 3) or, as Anastasi (1937) put it, "the fundamental aim of differential psychology . . . is similar to that of all psychology, namely the understanding of behavior . . . through a comparative analysis of behavior under varying environmental and biological conditions" (p. 580). One of the goals of differential psychology is developmental. Researchers aim at teasing out "the relative contribution of different factors to behavior development" (Anastasi, 1937, p. 580).

Differential psychology has been in existence since the beginning of psychology. The core questions then concerned the elements that apply to all humans (universals) and the elements in which humans can differ (see Emmerich, 1968). Interestingly and importantly, differential psychology is not specific to any particular psychological subdiscipline. In departments of psychology and in scholarly journals, personality and differential psychology are often lumped together. However, as can be seen, for instance, in Anastasi's statement, development is of interest to a differential psychologist, and so are cognition, emotion, affect, education, clinical phenomena, and any other subdomain of the social and behavioral sciences. Differential psychology differs from the other subdisciplines not in content but in methods and aims. The aims of differential psychology include the explanation of differences in behavior. The methods focus on reliable differences instead of treating differences as residual or error variance. From the perspective of differential psychology, differences can be systematic and worthy of study.

According to Revelle et al. (2011), the development of differential psychology experienced a number of phases. At the beginning of the phase that was characterized by the emergence of psychology of a science, we find a first attempt at establishing the conceptual and methodological bases of the subdiscipline, by Stern (1911). To many, Stern is the founder of scholarly differential psychology. Later, in the middle of the 20th century, psychometric methods were being developed at a rapid pace, and, a few years later, computers became available to the psychological researcher. From this point on, differential psychology developed in parallel with methods of data generation and analysis. Methods of regression were complemented by exploratory factor analytic approaches. The big theories of personality that were proposed by Cattell (e.g., 1946), Eysenck (e.g., 1952), or Costa and McCrae (e.g., 1992) all use factor analytic methods.

Almost in parallel, methods of classical test theory were developed (e.g., Lord & Novick, 1968), which made it possible to create measurement instruments with comparable characteristics. As was discussed earlier, the methods of classical test theory may not be suitable for research in the new traditions of person-oriented and idiographic psychology. The methods of exploratory factor analysis were followed by methods of covariance structure modeling, aka structural equation modeling (e.g., Jöreskog & Goldberger, 1975). Classical test theory was followed and, partly, replaced by Rasch modeling (Rasch, 1961) and Item Response Theory (Lord, 1980). Differential psychology used all these and can be expected to also use methods that will be developed in the future, all for the sake of establishing reliable individual differences and, in developmental research, interindividual differences in intraindividual change.

Without going into substantive results of differential psychology, we ask whether there are characteristics that make this branch of psychology unique, and where differences from the other branches discussed here. One characteristic stands out. To the best of our knowledge, differential psychology never challenges the proposition that instruments can be created that apply to everybody in a well-defined population. In other words, dimensional identity as discussed in person-oriented research or ergodicity as discussed in idiographic research seem assumed to be given. The main aim of differential psychology is to make sure individuals can be placed on scales in a reliable, meaningful, and interpretable way.

The possibility that responses to an instrument fail to be identically distributed, that is, the possibility that a scale was created based on an improper aggregate is rarely considered, and neither is the possibility that dimensional identity may not exist. Therefore, we conclude that differential psychology is mostly interested in quantifying and studying differences between individuals (and making the strong assumptions discussed above). Differences that would manifest in violations of the tenet of dimensional identity or violations of ergodicity theorems are rarely targeted in differential psychological research. There may be exceptions, but differential psychological research seems to proceed from the assumption that it is virtually always possible to apply a scale to all members of a population.

In the following section, we expand our earlier discussion of the *Ecological Fallacy*. As noted earlier, this term is used to describe the problems that can arise when aggregate-level statements are applied to individuals. The ecological fallacy is not a research approach, and it is not a subdiscipline of any of the empirical sciences. However, the problems that arise from ecological fallacy can also arise when the strategies that are discussed in the context of person-oriented and idiographic psychology are ignored. Therefore, a further discussion of ecological fallacy is of importance, in the present context.

Ecological Fallacy

One falls into an ecological fallacy when one uses a statistical result that was found at the aggregate level to make a statement about individuals. As was said in the introduction to this chapter, the first example of an ecological fallacy was published by Robinson (1950). We used this example to introduce what is known as the *ecological correlation*, in which the unit of analysis is not the individual person but an aggregate. In another example, reported by Kreft and de Leeuw (1998), the relation between education level and income was investigated. Individuals from 12 countries provided information about their income and education. Just as in Robinson's literacy example, the correlation at the level of individuals was significant, $r = 0.12$, suggesting that individuals with more education are more likely to earn higher salaries. In contrast, the ecological correlation was $r = -0.71$, suggesting just the opposite. The authors' explanation for this seemingly contradictory result was that a lurking variable was identified that has a different distribution in the countries included in the study. This variable was the factor *type of industry*, which has the two categories private and public. In a number of jobs in the private sector, individuals can earn good salaries even without advanced education (Bill Gates walked away from Harvard, with no degree, in 1975; he received an honorary degree in 2007). In contrast, in the public sector, some "industries" like universities pay comparably low salaries but, for some academic careers, will not hire applicants without a PhD.

As before, one can ask what the conditions are under which there is no risk of ecological fallacy (see, e.g., Kreft, 2005). Following Salway and Wakefield (2005; see also Wakefield & Salway, 2001), we can use the following statistical framework, which was proposed in the context of intervention studies. Consider a geographical study area, A, that is subdivided into a set of N subareas. Subarea A_k contains n_k individuals, with $k = 1, \ldots, N$. The dependent variable Y_{ki} represents the response of Individual i in Area k, with $i = 1, \ldots, n_k$. $Y_{ki} = 1$ describes an individual with a positive response, and $Y_{ki} = 0$ describes an individual with a negative response to an intervention. In the following explanation, we consider one independent variable, X_{ki1}, and one lurking variable, X_{ki2}. Let the individual response depend on X_{ki} through the regression relation

$$E[Y_{ki} \mid X_{ki}] = p(\beta_0, \beta_1, \beta_2, X_{ki})$$

where β_0, β_1, and β_2 are unknown parameters; β_0 is the intercept, β_1 is the parameter associated with the independent variable, X_{ki1}, and β_2 the parameter associated with the lurking variable, X_{ki2}.

At the individual level, the parameters can be estimated using, for example, a logistic model,

$$p(\beta_0, \beta_1, \beta_{2,}X_{ki}) = expit(\beta_0 + \beta_1 X_{ki1} + \beta_2 X_{ki2})$$

where *expit* is an expression for the inverse of the logit function. Parameter β_1 is the parameter if interest. It represents the relation between the independent variable, X_{ki1}, and the dependent variable, Y_{ki}. Other functions can be considered, depending on the rarity of the outcome, the nature of Variable X_{ki1} as continuous or categorical, or the assumptions made on underlying distributions. Among the results from using the above function is the odds ratio $\exp(\beta_1)$. In disease studies, this odds ratio expresses how much more likely a particular outcome is under exposure versus nonexposure.

Now, in the example given earlier in which an area is subdivided into a set of N subareas, the information available to the data analyst is often incomplete. The responses for each subarea may be fully known, that is, known for each respondent. However, information on the independent variable, X_{ki1}, and the lurking variable, X_{ki2}, may be available just by their means, that is, at the aggregate level instead of the individual level. Let this information be denoted by ϕ_k. If both the dependent and the independent variables are completely available, there is no need to represent the independent variable scores by their area means. But if only the means are available, only the so-called *naïve ecological model* (Salway & Wakefield, 2005) can be employed, that is, the model

$$E[Y_k|\beta_o', \beta_1', \beta] = n_k \operatorname{expit}(\beta_o' + \beta_1'\overline{X}_{k1} + \beta_2'\overline{X}_{k2})$$

where the $'$ indicates that these parameters are estimated using information that differs from the one used above, where we assumed that the complete information for independent variable, X_{ki1}, and the lurking variable X_{ki2} is available. The bias created by only using the means instead of the individual scores on the independent variable, X_{ki1}, and the lurking variable X_{ki2}, can be expressed as the difference between the β estimates under the two conditions. Of particular interest is the relation of β_1 to β_1', that is, the difference in the effect of the independent variable that is estimated under the two data situations. We ask—in parallel to the discussion of the ergodicity theorems in the context of idiographic research—what the conditions are under which knowledge of the individual scores on the independent variable results in the same parameter estimates as using the area-specific averages.

As in the case of idiographic research, the two estimates are equivalent only under very rare and implausible conditions. Specifically, Salway and Wakefield (2005) note that there are only two conditions under which there is equivalence:

- There is a linear model that relates the independent variable, X_{ki1}, and the lurking variable, X_{ki2}, to the dependent variable, that is, a model of the form $p(\beta_0, \beta_1, \beta_{2,} X_{ki}) = \beta_0 + \beta_1 X_{ki1} + \beta_2 X_{ki2}$, a situation in which there is no interaction between the independent variable and the lurking variable. This is a situation in which the lurking variable does not play the role of a moderator variable that it is hypothesized to play.
- There is no within-area variability in the independent variable, X_{ki1}, and in the lurking variable, X_{ki2}.

However, even if the within-area variances are invariant across the subareas, there will still be bias.

To illustrate this situation in the context of a substantive example, consider a study on the effects of domestic violence on cognitive development of infants. Suppose that, in a first study, the complete information concerning the dependent variable, Y_{ki}, the independent variable, X_{ki1}, and a lurking variable, X_{ki2}, is available. Let the independent variable be the severity of domestic violence, and let the lurking variable be the living quarter of the family that is studied. In this situation, the parameters that express this effect will not be biased if the usual conditions for proper data collection are fulfilled. If, in contrast, only averages of violence are known for the living quarters, the estimates will be unbiased only if the relation between the predictors violence and living quarter and the outcome cognitive development assumes the linear form described above, and if there is no living quarter-specific variability in the independent variable severity of violence, X_{ki1}, and the lurking variable living quarter, X_{ki2}.

In sum, using aggregate-level instead of individual-level information can lead to severe bias. In other contexts, using aggregate-level information has been compared to collapsing across the categories of a variable that is not completely unrelated to all other variables. This aggregation would violate the conditions under which *collapsibility* can be defended. This issue has been discussed in detail in the context of log-linear modeling (e.g., Bishop, Fienberg, & Holland, 1975; von Eye & Mun, 2013).

Other examples of effects of unmeasured lurking variables have been discussed under the header of *statistical paradoxes*. Among the best known paradoxes is *Simpson's paradox*. This paradox describes the situation in which conclusions drawn from subtables, subareas, or data segments are in contradiction to the conclusions drawn without consideration of the lurking variable. One of the best known examples of this paradox concerns the analysis of the hypothesis of gender bias in the admissions procedures in the graduate school at U.C. Berkeley in 1973. Overall, there were 8,442 applications from male students, 44% of which were admitted. There were 4,321 applications from female students, of which 35% were admitted. These numbers look like the hypothesis of a gender bias could be supported. A closer look, however, suggests a different picture. Table 21.3 displays the number of applicants to the six biggest graduate programs at Berkeley, and the percentages of admitted students, by gender.

Table 21.3 suggests that four of the six departments are in strong contradiction to the aggregate result (the exceptions are Departments C and E). In these four departments, a higher percentage of female applicants was admitted than male applicants. The table shows also that male applicants tend to send their applications to departments that are less selective and, thus admit higher percentages of applicants (mostly Departments A and B). In contrast, female

TABLE 21.3 1973 U.C. Berkeley Graduate Applications and Admissions for the Six Largest Majors, by Gender

	Male Applicants		Female Applicants	
Major	Number of Applications	% Admitted	Number of Applications	% Admitted
A	825	62	108	82
B	560	63	25	68
C	325	37	593	34
D	417	33	375	35
E	191	28	393	24
F	373	6	341	7

Source: Adapted from "Developmental Pathways," by A. Pickles and J. W. Hill, in *Developmental Psychopathology* (2nd ed., pp. 211–243), D. Cicchetti and D. Cohen (Eds.), 2006, Hoboken, NJ: Wiley. Available from http://www.stat.berkeley.edu/~stark/SticiGui/Text/experiments.htm applicants tend to send their applications to departments that are more selective and, thus, admit smaller percentages of applications (most notably Department F). Therefore, the hypothesis of a gender bias that goes at the expense of female applications, cannot be retained (see Bickel, Hammel, & O'Connell, 1975).

In all, the discussion of the ecological fallacy shows that ignoring lurking variables or, in more general terms, ignoring variables that carry unobserved heterogeneity has the potential of distorting results to a degree that they suggest conclusions that are just the opposite to when such variables are taken into account. Ignoring lurking variables amounts to, technically, collapsing tables over variables or categories of variables when these variables are related to other variables in important ways. Substantively, ignoring such variables amounts to not including those effects in a model that help explain the data. In other words, ignoring lurking variables amounts to aggregating at the expense of validity of results.

COMPARING PERSON-ORIENTED RESEARCH, IDIOGRAPHIC RESEARCH, AND DIFFERENTIAL PSYCHOLOGY

In this section, we compare the three research strategies person-orientation, idiographic research, and differential psychology. The ecological fallacy cannot be considered a research strategy. Instead, it is a risk that researchers face in empirical research. This applies accordingly to paradoxes such as Simpson's. The three comparison research strategies take different positions on a number of issues of importance in research. These issues concern assumptions made before data collection, design, goals of analysis, and methods of analysis. In the following sections, we focus on assumptions made by the comparison approaches. In the remainder of this chapter, we discuss methods of analysis.

Assumptions Made in Person-Oriented Research, Idiographic Research, and Differential Psychology, and Their Implications

To compare person-oriented research, idiographic research, and differential psychology, we focus on the assumptions made under each of three strategies.

Assumptions Made in Person-Oriented Research

In the following paragraphs, we review assumptions made in person-oriented research concerning the number of populations, aggregation, and dimensional identity.

Number of Populations

In person-oriented research, researchers rarely assume that the sample at hand originates from just one population. To the contrary, as von Eye and Bogat (2007) have pointed out, person-oriented research typically proceeds from the explicit assumption that the sample originates from, possibly, multiple populations. These populations often overlap as in the example of the height distributions of females and males.

If the populations are known or exist by definition, and if dimensional identity has been established, research can indeed proceed as taught in standard social science statistics textbooks. One goal of analysis can be to describe the differences between the known populations. However, in many cases, the number of populations a sample was drawn from may not be known, and neither may be their sizes or, more fundamentally, their existence. In these cases, one cannot rule out that the underlying populations may include cases in which a single individual constitutes a separate population, other populations are small, and a third group of populations is large. In addition, it cannot always be a priori ruled out that groupings are constituted by cases that, otherwise, are considered members of different populations such as females and males or young and old adults. In this situation, researchers need to identify and establish the populations that data were drawn from.

In the discussion of developmental patterns and trajectories in the context of idiographic research (see also Molenaar, 2004b; von Eye, 2004), issues concerning the number of populations have been addressed. It is clear that, in principle, every individual can display his or her own and unique developmental trajectory. Some differences, however, may not be large enough to be considered nonrandom. Other differences may carry no implications for a particular question in research or practice. Therefore, individuals can, under certain conditions, be aggregated to form populations, groups, or clusters. The number of these aggregates will always be smaller than the number of individuals studied and it may be as small as the number of clusters (i.e., between 4 and 10) suggested by Bergman et al. (2003). In addition, the groupings can differ dramatically in size. Some groups may contain one case, others may contain billions of cases. The number and the size of groupings are hard to predict unless they are based on theory and prior knowledge.

Aggregation

When the underlying population(s) are known before analysis, data analysis can proceed at the standard and routine aggregate level if dimensional identity and ergodicity exist, and there are no lurking variables. When, however, populations are unknown, they first need to be identified and then, for each population, it needs to be tested whether the conditions are fulfilled. This step is superfluous only if subpopulations are created based on parameters of subsets of cases that fulfill the conditions. In other words, person-oriented research aggregates cases when defensible, rarely by definition.

Dimensional Identity

Whenever observations of whatever kind are performed (e.g., when tests are administered, coding schemes for video recordings are applied, or questionnaires are employed), one proceeds under the tacit assumption that the observational instruments are valid for each individual assessed. The doubts raised by von Eye and Bergman's (2003) examples, Molenaar's (2004a) discussion of classical test theory, and the results of applications of tests such as the CBCL (Achenbach & Edelbrock, 1981) in various populations (Lambert et al., 2003) point to the importance of such conditions as dimensional identity. This condition is exemplified in the concept of *factorial invariance*. If invariance was established and ergodicity applies, results can be considered valid for all members of the populations for which it was established. If the CBCL is valid for two individuals, the individuals' scores can be compared. If, however, as has been shown, the CBCL exhibits a different factor structure for youth from Jamaica and the United States, scores cannot be compared. As stated earlier, the same score may not be indicative of the same behavior. Similarly, if an intelligence test exhibits factorial invariance over a particular age range, intelligence scores can be compared. If, however, intelligence divergence does take place, or intelligence convergence can be observed in the advanced age groups, intelligence scores that were measured for individuals from different age brackets may no longer be comparable. Person-oriented research does not assume that dimensional identity is always a given. Instead, person-oriented research requires that researchers provide proof that it exists.

If the cognitive semantic structure of a phenomenon is represented differently in individuals and populations, dimensional identity may also be hard to establish, and comparability of scores may be problematic. This can be exemplified using the parent form of the CBCL. Parents from different cultures differ in the child and adolescent behavior that they perceive as problematic. Therefore, an instrument that is validated for one culture may be useless in another. It follows that the degree to which a child exhibits problematic behavior may be hard to compare across cultures, even if the observed scale score is the same, when the underlying semantic or factor structures differ from each other.

Assumptions Made in Idiographic Research

We now review assumptions made in idiographic research concerning the number of populations, aggregation, and dimensional identity.

Number of Populations

Of the three approaches that are compared in this section, the idiographic approach is the most extreme in terms of making assumptions about the number of populations a sample was drawn from. Idiographic research begins under the assumption that every case constitutes a separate population. Only if the theorems of ergodicity apply, cross-sectional data can be substitutes for longitudinal data that describe the individual. As discussed by Molenaar (2004a; see also Wakefield & Salway, 2001), ergodicity theorems apply only rarely and only under rather constrained, unrealistic conditions. However, if they apply, aggregate-level results will be valid for the individual. Similarly constrained and unlikely to be fulfilled are the conditions under which one can assume that a possibly lurking variable can be collapsed (Salway & Wakefield, 2005). Therefore, aggregate-level, cross-sectional data can only rarely be the substitutes for longitudinal data that describe the individual. For aggregation, parameters must be estimated at the level of the individual first, and then, cases can be aggregated based on their parameters. The differences between describing series of measures based on aggregated data and based on aggregated parameters were illustrated earlier, in the section on examples.

In idiographic research, the number of underlying populations is rarely determined before a data set is collected. This number is, in many cases, an empirical rather than a theoretical question.

Aggregation

For aggregation, idiographic research requires that each case obeys the same dynamics. That is, aggregation in idiographic research is based on the ergodicity conditions of (a) stationary processes and (b) a homogeneous population. The aggregation situation in idiographic research is comparable to the situation in person-oriented research when the number of underlying populations is unknown. In contrast to person-oriented research, however, developmental idiographic research always begins from the assumption that every case constitutes its own unit. Existing subpopulations are not considered to the same extent as in person-oriented research. Parameters are estimated at the level of the individual. Even this rule is in a state of continued development. For example, an approach has been developed to obtain a group model based on heterogeneous, replicated time series (Gates & Molenaar, 2012).

As discussed by Molenaar (2004a), it is doubtful that instruments constructed on the basis of classical test theory can guarantee validity of a test score for an individual. This applies in particular when a test was constructed for the usual standard population, at the aggregate level. Test results apply to the individual only if the theorems of ergodicity apply. If this is not the case, tests must be constructed either separately for each homogeneous group or based on a different statistical model.

Dimensional Identity

Interestingly, the discussion of dimensional identity takes a different focus in idiographic than in person-oriented research. In idiographic investigations, the question asked is whether aggregate-level parameters apply to the individual. Largely, the answer is no. Consequently, to depict development, investigators discuss the creation of multivariate, longitudinal series of measures that can be used to estimate parameters for the individual. However, what remains to be discussed is the possibility that psychometric instruments may suffer in validity for at least two reasons. First, the instrument can be differentially valid for different individuals and groups of individuals. This is one of the reasons why idiographic investigators strongly recommend estimating parameters at the level of the individual. Second, and this issue has been raised both in classical developmental (Baltes et al., 1977) and in discussions of person-oriented research (von Eye & Bergman, 2003), psychometric instruments can change their characteristics over the course of a longitudinal study. In particular when a study involves large numbers of observation points in time, respondents may tire of responding to the same questions again and again. As a consequence, respondents may reinterpret questions; there may be changes in response tendencies over time; and there may be experimenter effects. In one word, the validity of an instrument may change over time, and these changes can differ across individuals. Dimensional identity of psychometric instruments is likely to be jeopardized in longitudinal research.

A lack of dimensional identity may be less of a problem when physiological information is collected. Measures of blood pressure, cholesterol, or brain waves are unlikely to change their meaning over the course of repeated observations. The same applies to measures of income, marriage status, or employment status. These measures can change, but their validity is likely to stay the same.

However, when psychometric instruments are considered for longitudinal work, researchers need to establish that these instruments can be used longitudinally and that their validity will not change over time. This applies both to changes in validity that reflect development and changes that reflect respondents' reactions to repeated applications of the same instrument. Tests that are based on classical test theory are known to have shortcomings when they are repeatedly applied. For example, differences between scores from such tests over time are not necessarily interpretable as indicating change. Therefore, in this chapter, we present a section on IRT which creates test scores that can be interpreted as indicating change.

Assumptions Made in Differential Psychology

We now review assumptions made in differential psychology concerning the number of populations, aggregation, and dimensional identity.

Number of Populations

Considering the long history and tradition that differential psychology has enjoyed, it does not come as a surprise that this branch of psychology uses standard definitions of samples and populations. Unless specifically designed for subpopulations (e.g., age groups), psychometric instruments are assumed to be valid for the entire population, and test scores are assumed to validly describe the individual, even if a test was created based on classical test theory. Based on these assumptions, test scores are used to compare individuals.

For developmental researchers, it is important to note that many instruments target particular age brackets. Most personality inventories target adult populations. The same applies to instruments used to assess behavior problems. However, child and adolescent forms exist for many purposes, for example the CBCL discussed above. It is the main goal of differential psychology to place individuals validly on scales. This goal is reached in a most parsimonious way if there is only one reference population, not many. For example, an adult's IQ score is typically interpreted in comparison with the entire adult population (although many IQ scores result from age-specific norms), and the same applies to an individual's score on a depression scale, a posttraumatic stress disorder (PTSD) scale, or a spacial performance scale.

Aggregation

When an entire population (or a well-defined subpopulation) is used for reference, aggregation also has a particular meaning. Individuals are aggregated based on their raw data on scales. For example, individuals are aggregated because their scores are close to each other, or their scores correlate highly. In the process of instrument development, items that suggest group differences are often removed from an instrument. This applies in particular in the context of establishing retest reliability. Items to which individuals give different responses in subsequent observations (here, the time interval between two observations is typically short) are often removed because they are not considered stable over time. This strategy can have the effect that behavior is labeled as time-stable only because change-sensitive items are no longer part of an instrument. Using this type of instrument makes it particularly difficult to depict differential development. Groups that display specific patterns and courses of development are, based on this methodology, difficult to find, and cannot be built by way of aggregation.

Dimensional Identity

When an entire population or a large population such as all adolescents is used for reference, it is necessary that dimensional identity exists in this population. Comparability of test scores requires that the scale used has the same factor structure, and is equally valid and reliable for all cases that are compared. Great efforts have been taken to devise strategies to ensure that this is the case. Examples of such efforts can be found in contexts of *test fairness*. Among the criteria for the quality of a test, test fairness ensures that no participant is systematically discriminated because of ethnic, sociocultural, or gender-related characteristics. If a test is fair, it is more likely to be valid for everybody. Only fair tests can exhibit dimensional identity.

Goals of Analysis

In the following sections, we discuss goals of analysis that are characteristic of the three comparison approaches. The approaches share the general goal of generalization. Whenever researchers employ methods of inferential statistics, generalization to a superordinate population is intended. This population includes individuals, behavior of individuals, patterns of behavior in the comparison of populations, or any unit of analysis.

Person-oriented developmental research pursues multiple goals of analysis. First, it usually attempts to identify aggregates of individuals with similar profiles. Defensible groupings are either given a priori (but still need to be confirmed empirically) or created from data. However, defensible groupings may also be constituted by isolates that are not lumped with any of the other groupings. The second goal of analysis concerns the establishment of dimensional identity. For each of the groupings, dimensional identity is established for the instruments that will be used. Third, statements are made about the groupings and their development.

The first goal pursued with *idiographic research* concerns the estimation of parameters at the level of the individual. Only under conditions that are defined by ergodicity theory, cross-sectional sample data can replace longitudinal individual data. The second goal concerns generalization. Based on individual-level parameters, decisions are made about groupings.

The main goal of *differential psychology* is to make reliable and valid statements about differences between scores. To this end, dimensional identity is required. It is established using methods of classical or modern test theory, with populations in mind that are as encompassing as possible.

Required Data Structure

The data structure that is required for developmental research under the three approaches can be derived from the assumptions made about valid statements and the population(s) under study. When populations have been defined or found, and dimensional identity has been established, *person-oriented* research requires data structures that are no different than in standard developmental research. Person-orientation, however, keeps the arguments of idiographic research in mind and substitutes longitudinal individual data with aggregate-level cross-sectional data only of the conditions are fulfilled that are based on statistical ergodicity theory (Molenaar, 2004a; Molenaar & Campbell, 2009).

In contrast, and considering how unlikely it is that these conditions are fulfilled, *idiographic research* requires long multivariate series of repeated measurements. The number of observations is parallel to the number of cases needed for factor analysis. For example, if, for a standard R-factor analysis, a multivariate data matrix with at least 100 cases is required, then, in order to perform a P-factor analysis on the same number for variables, for one individual, at least 100 observations are needed. The resulting data structure is the same for each individual.

For developmental research under the paradigm of *differential psychology*, data are required as described by Cattell's data-box (1988; see Molenaar & Nesselroade, Chapter 17, this *Handbook*, this volume), which has the three dimensions individuals, variables, and occasions. The number of individuals typically is large, the number of variables is smaller, and the number of occasions is smaller yet.

We conclude that the three approaches to developmental research, the person-oriented, the idiographic, and the approach guided by differential psychology, require data that differ greatly in structure. One the one extreme, there is differential psychology which requires data as usually found in social and behavioral science research. On the other extreme, there is idiographic research that requires a long series of repeated observations for each case. The data structure required for person-oriented developmental research depends on the assumptions made and the results created with regard to dimensional identity. If there are many groups for which dimensional identity must be established and the theorems followed by the idiographic approach are used, the data that need to be collected are as intensive as in idiographic research. If, however, only one homogeneous group or population is investigated, the data structure can be similar to the one used for differential psychology.

TABLE 21.4 Assumptions, Goals of Analysis, and Data Needed for the Person-Oriented, Idiographic, and Differential Psychology Approaches

Argument of Comparison	Approach to Developmental Research		
	Person-Oriented	Idiographic	Differential
	Assumptions		
Number of Populations	Possibly multiple; $n = 1$ is possible	Begins from treating each case as separate population	As few as possible; maybe only one
Aggregation	Based on individual parameters; a priori groups may exist	Based on individual parameters	Not needed if number of populations is small
Dimensional Identity	Must be established	Assumed, even when there are many repetitions (see, however, Molenaar et al., 2009)	Assumed; considered characteristic of instrument
	Goals of Analysis		
Targeted unit	Aggregates or individuals	Individuals; aggregates if groups can be created	Differences among individuals
	Required Data Structure in Developmental Research		
	—Standard sampling if groups exist a priori —Individual series if grouping is a priori unknown	Individual series	Standard sampling

Summary of Comparison

Table 21.4 presents a summary of the comparison of the person-oriented approach, the idiographic approach, and differential psychology. We now discuss the links between the conceptual and methodological issues we have raised in regard to the person-oriented approach and the methods that may be used to pursue this orientation to the analysis of developmental data.

METHODS OF PERSON-ORIENTED RESEARCH

In the following sections, we discuss and exemplify methods of person-oriented research. We begin with a discussion of the *method-problem* match and present implications of the person-oriented approach for design and sampling. The larger part of the discussion concerns methods of analysis. This section covers a selection of methods and data examples of interest for developmental researchers.

The Method-Problem Match

The selection of the method one uses in one's empirical work should be derived from, or legitimated by, the theory-predicated question one asks. Simply stated, method derives from theory. To this point, we have introduced the theoretical features of the person-oriented approach, the ideographic approach, and differential psychology. We have presented and discussed key assumptions made by each approach. However, we argue that it is *the scientific* problem under study that is of decisive importance for the selection of a theoretical framework, measures, research design, and statistical methods of analysis. Given this argument, we need to turn here to a discussion of the relation between the problem under study and the methods employed to solve the problem, which is referred to as the *method-problem match* issue.

Bergman and Vargha (2013) have discussed the method-problem match with respect to the match or lack of match between problems that entail the individual as point of focus and various research methods. This match/mismatch has implications for measurement, design, and selection of statistical methods, and, from our perspective, the most important of these implications—discussed by Bergman and Vargha (2013)—include:

- In developmental science, a method-problem mismatch can arise from combining a person-oriented theoretical framework with statistical methods that do not correspond with assumptions about the studied process that can be derived from the theory (e.g., a theoretical dynamic process view is taken but standard linear models are used). For instance, in the presence of strong higher-order interactions, which can often be expected from a person-oriented theoretical standpoint, a standard linear model that is based on a covariance matrix, that is, exclusively bivariate relations, can give incomplete or misleading results.
- Sometimes, when the problem calls for intensive measurements (e.g., to understand a process characterized by discontinuities around transition points), only a few measurement points are used.
- When individual development is at focus in a causality context, measurements with limited reliability are often used that preclude interpretation at the level of the individual (e.g., it cannot be ascertained whether a given individual has benefited from a therapy due to measurement errors, which can result in large standard errors of the parameter estimates that represent change). This often forces researchers to concentrate on reporting only group statistics (e.g., means and correlations), instead of interpreting scores for individuals. Carlson (1971) lamented, after surveying a large selection of articles published in major personality journals, "Where is the person in personality research?" He could not find a single article where the information said something about the individual (see also Schmitz, 2000; von Eye & Bergman, 2003).

Number and Spacing of Observation Points

In this section, we discuss the issue of making decisions concerning the number and spacing of observation points to be covered by longitudinal studies. In theoretical considerations, the number of observation points is either not considered in detail (Baltes et al., 1977), or discussed from the perspectives of (a) information gained with the increase in the number of observations (e.g., Willet, Singer, & Martin, 1998), (b) the increase in funding needed for repeated observation (Donnellan & Conger, 2007), (c) the requirements for idiographic research (Molenaar, 2004a), or (d) the timing of observation points (see Nesselroade's, 1991, *burst designs*; see also Salthouse & Nesselroade, 2010). The conclusions that can be drawn from longitudinal data can depend on the amount of information provided by series that differ in length and timing of observation points. We point to the issue that these conclusions can be inconsistent and confounded with characteristics of the series. For issues concerning patterns in timing of assessments, time structures, and considering time an outcome variable, see, for example, King et al. (2006).

Here, we argue that (a) extrapolation from short-term studies may not be valid, (b) selecting inappropriate numbers of observation points can distort the description of developmental pathways, and (c) classifications of the same cases that are based on different numbers of observation points may not be in strong agreement. Distortion can come in two forms. First, existing pathways may not be unearthed. Second, predictors of pathways can change their characteristics and predictive power depending on the length of time over which observations are conducted.

These issues can be illustrated using the pathways in developmental psychopathology discussed by Pickles and Hill (2006). Consider the various pathways and risk types for depression in adulthood that Pickles and Hill depict in the form of a decision tree (2006, p. 213, Figure 7.1). This tree, reproduced in Figure 21.3, is based on dichotomous decisions, made at developmental turning points. It covers the age span from early childhood to young adulthood. The outcome is a statement about the probability of depressive episodes in the age bracket of 21 to 30. If the number of observation points is unrelated to the conclusions drawn from a study, the examination of any time slice of this tree should lead to the description of the same picture of precursors and consequences as looking at the complete tree. For example, if researchers begin their observations when participants are about Age 15 instead of Age 4, the predicted probabilities should be the same. However, beginning at Age 15 makes the researchers miss the first decision steps. Therefore, they may not be able to distinguish between all possible developmental outcome patterns, because the number of patterns may be just half or

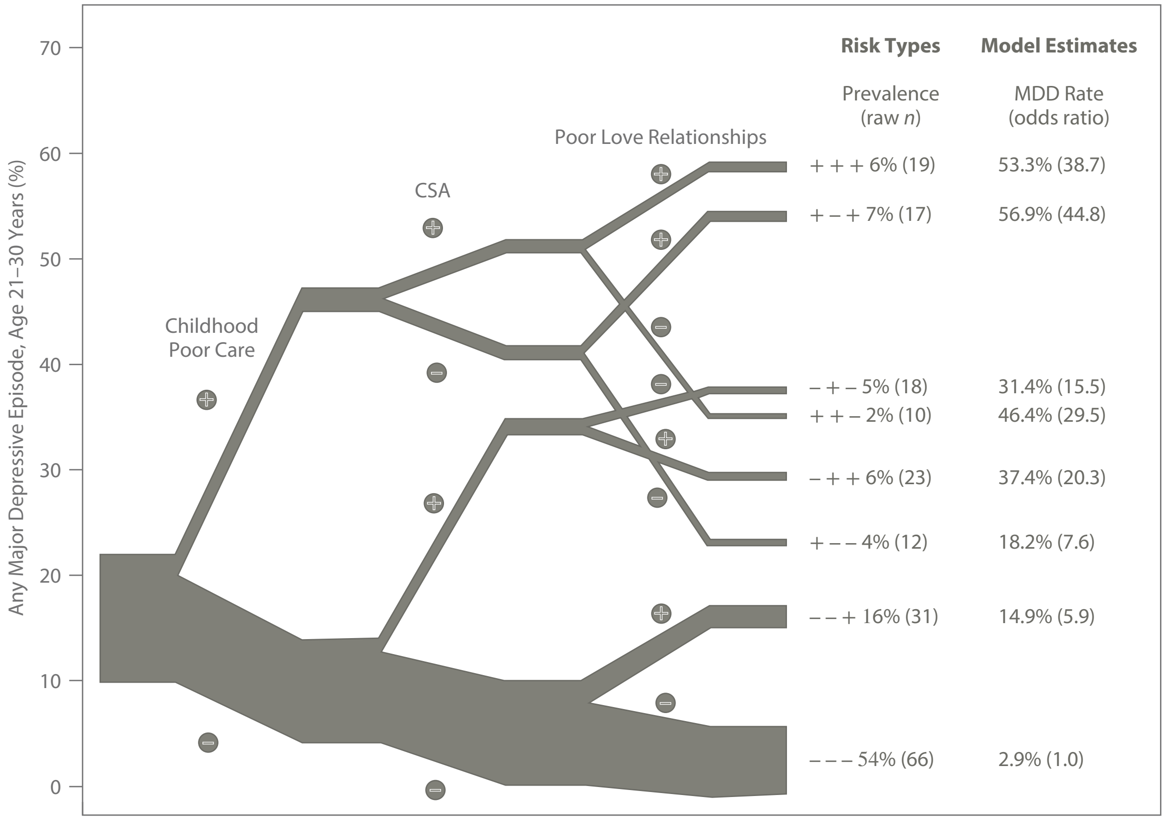

Figure 21.3 Decision tree for study of developmental turning points.

Source: Adapted from "Developmental Pathways" (pp. 211–243), by A. Pickles and J. W. Hill, in *Developmental Psychopathology*, 2nd ed., D. Cicchetti and D. Cohen (Eds.), 2006, Hoboken, NJ: Wiley.

even less than had the first two decisions been made also. Similarly, completing the study before young adulthood will also lead to fewer discernible patterns.

For categorical variables, a similar picture arises as for continuous variables. Shortening the series of observation points will create a situation in which only a selection of the cross-time relations among variables can be observed.

The question we ask has even broader implications. Specifically, we suggest that trajectories can be qualitatively different, depending on the segment of time that is selected for study. It has been demonstrated that the number of clusters and participants' cluster membership can vary with the length of the time segment used for clustering (Eggleston, Laub, & Sampson, 2004).

Donnellan and Conger (2007) propose that researchers make four decisions when they plan a longitudinal study: Decide (1) on what to measure and how to measure it; decide (2) on the number and timing of measurements; decide (3) on sources of data (e.g., self-reports, parent reports); and decide (4) on a sample and sample size. Donnellan and Conger (2007) note that determining the number and timing of assessments is one of the biggest obstacles in designing a well-crafted longitudinal study. The authors suggest that a rudimentary understanding of the underlying dynamics of interest can guide such decisions. However, the need for such understanding is often the underlying motivation for the research in the first place. In such instances, Donnellan and Conger (2007) suggest that more frequent assessments would provide useful descriptive information (see also Adolph, Robinson, Young, & Gill-Alvarez, 2008).

METHODS OF DATA ANALYSIS

In this section, we discuss a selection of methods of analysis as they can be used in the context of person-oriented research. This selection is limited as there are, as we point out, additional methods available. Our discussion centers around metric and categorical data, and manifest and latent variable models. Each of these methods can be applied to cross-sectional and longitudinal data. Here, we focus on longitudinal data.

Before discussing this selection of methods in detail, we provide an overview of other methods that are of interest in person-oriented data analysis. This overview is selective as well, because virtually any method of data analysis can be employed in person-oriented research, if the conditions are fulfilled that were outlined and discussed in the theory section above. Each of the methods reviewed in the following section approaches the issue of individuals differing from one another and the grand mean in a specific way.

Methods of Data Analysis in Person-Oriented Research: A Selection

We begin the selective overview of methods of particular interest for person-oriented developmental research with hierarchical linear modeling. Then, we review of methods for the analysis of individual series of scores.

Hierarchical Linear Modeling

The first method to be reviewed is *multilevel modeling*, also known as *random coefficient modeling*, *hierarchical linear modeling* or, brief, HLM (Goldstein, 2003; Jöreskog, Sörbom, du Toit, & du Toit, 2000; Kreft & de Leeuw, 1998; Raudenbush & Bryk, 2002). The explanation of systematic variability in parameters such as regression slopes is among the main goals of HLM application. To accomplish this goal, variables are grouped hierarchically. Measurements at lower levels of the hierarchy are nested within the categories of variables at higher levels of the hierarchy. The classical example is that students are nested within classrooms which are nested within schools, districts, and so on.

There are several reasons why, from the perspective of person-oriented research, HLM is important. Here, we discuss two central reasons. First, the basic nesting structure is considered common to all cases included in an analysis. For example, in a longitudinal study, the outcome measures are considered the first level of the hierarchy, and are nested within the experimental units (cases, respondents) which constitute the units of the second level of a hierarchy. Regression parameters and variance components can be estimated for each level of analysis.

A second reason HLM is important is that, ignoring the hierarchical structure of measures can result in serious problems. For example, aggregation and disaggregation based on variables on different levels can have the effect that predictors become collinear and standard errors can become large or biased. In addition, standard regression models with fixed parameters do not allow examination of the variation that is caused by grouping variables. This variation may be of particular interest to the person-oriented researcher or the researcher in differential psychology.

HLM methods do allow examination of variation that is specific to the levels of the hierarchy. The degree of dependence of regression parameters on variables that are higher up in the hierarchy can be estimated for the various levels of the hierarchy. In addition, the serial dependence of repeated observations can be taken into account. One advantage of HLM methods is that designs do not need to be orthogonal (balanced). For example, the number of scores per person in a longitudinal study can vary, and individuals for which only limited amount of information is available can be included in an analysis.

To briefly give an illustration of HLM, consider a series of m scores, y, that were obtained for n individuals, for example, a time series. These data are analyzed to discover whether a linear slope can explain these series. For individual i, the regression equation then is

$$y_{ij} = x'_{ij}\beta_i + e_{ij}$$

where x'_{ij} is the design matrix that contains the scores of the intercept and the linear function, for example, the observation points, β_i is the parameter vector, and e_{ij} is the residual vector. Now, let the data structure be hierarchical. For the simplest hierarchical structure, a Level-2 model is appropriate in which cases are the Level-2 units, and the repeated observations the Level-1 units. The Level-1 units are nested within the Level-2 units. Under the assumptions that the regression parameter estimates are a random sample and the residual vectors (one per case) are independently and identically distributed, the expectancy of the observed scores is $E(y_i) = X\beta$, where β is the mean of the random β_i. Now, if a classification variable such as gender is taken into account, the regression parameter estimates can be considered gender-specific. That is, they vary across the gender groups. In other words, HLM attempts to explain the variation of the regression estimates by including information about the gender of the respondents. In general, Level-2 variables are used to explain the variability of Level-1 parameter estimates. This is done using regression models again. We obtain for the intercept of the Level-1 model

$$b_{0\mathrm{i}} = g_{00} + g_{01}w_{1\mathrm{i}} + u_{0\mathrm{i}}$$

and for the slope

$$b_{1i} = g_{10} + g_{11}w_{1i} + u_{1i}$$

where $g_{.0}$ are the Level-2 intercepts of the prediction of the Level-1 intercept, the $g_{.1}$ are the Level-2 slopes for the prediction of the Level-1 slopes, the w are the Level-2 variables, and the $u_{.i}$ are residuals for these two regression equations. Here, we consider the Level-1 parameters, that is, the $b_{.i}$, random variables. The Level-2 parameters are fixed (unless they are predicted from Level-3 variables, etc.). This applies accordingly when levels higher than second are incorporated in a model.

Multilevel models have been developed for a good number of statistical models, including, for instance, manifest variable models, latent variable models, Rasch models, and generalized linear models (see also Skrondal & Rabe-Hesketh, 2004). Methodologists have shown that multilevel models can be recast as special cases of other well-known statistical models. For example, Rovine and Molenaar (2000) related HLM to structural modeling, and Hox (2000) showed that the two-level model of repeated observations is equivalent to repeated measures ANOVA. That is, HLM has been embedded into more general concepts (e.g., structural equation models, see Bauer, 2003; Curran, 2003), and the study of interindividual differences in intraindividual change can be cast in terms of structural models alone (McArdle, 2012). Nevertheless, HLM is worth considering in person-oriented research when groupings are known a priori, and can be used as Level-2 or higher variables.

Analyzing Individual Series of Scores

Key to the analysis of longitudinal developmental data is the possibility of analyzing individual series of scores (Molenaar & Newell, 2010). Whenever aggregation of raw data is deemed risky or whenever individual series are of interest in their own right, researchers make statements about the individual. As was discussed earlier, aggregation of individuals can then be based on parameter estimates. The result of this aggregation are statements at the level of groups, even populations, that are more likely to be defensible than statements that are based on the aggregation of raw data.

As discussed earlier, in the description of the idiographic approach, the ergodicity conditions that must be fulfilled by a dynamic process to guarantee that a structure of interindividual variation can be generalized are (a) that the process under study is stationary, and (b) the cases that are described stem from a homogeneous population (Molenaar, 2004a). For a normally distributed process, stationarity has two implications. First, the mean of a process is time-invariant (i.e., there are no trends or cycles that imply changes in mean over the observation period). Second, serial dependence is also time-invariant, which implies that the variance is time-invariant and the correlation between measures over time depends only on the distance between these points in time. Ergodic processes possess these characteristics.

Most developmental processes are not stationary (see also Molenaar et al., 2009). Therefore, analysis of these processes (e.g., learning, the course of therapy, the development of psychopathological phenomena) or, in general, the nomothetic analysis of processes must begin from the analysis of processes that describe intraindividual variation.

Development has presented statistical latent and manifest variable models that allow one to address a large number of hypotheses concerning the development of the individual (Molenaar & Newell, 2010). Bartholomew and Knott (1999) classify latent variable methods of analysis based on whether the manifest and the latent variables in a model are metrical or categorical. Table 21.5 displays the resulting groups of methods.

For each of the four groups in Table 21.5, new methods and extensions of existing methods have been proposed and are being developed. Here, we briefly provide examples. For more detail and application examples, we refer the reader to Molenaar and Newell (2010). We begin with longitudinal factor regression models (both the manifest and the latent variables are metrical).

Longitudinal Factor Regression Models

The longitudinal factor model was introduced earlier in this chapter in the section on Molenaar's approach to idiographic psychology; here, we discuss special cases.

TABLE 21.5 Latent Variable Methods of Analysis

		Manifest Variables	
		Metrical	**Categorical**
Latent Variables	**Metrical**	Factor analysis	Latent trait analysis
	Categorical	Latent profile analysis	Latent class analysis

Source: Adapted from *Kendall's Library of Statistics, 7: Latent Variable Models and Factor Analysis* (2nd ed., p. 3), by D. J. Bartholomew and M. Knott, 1999, New York, NY, Oxford University Press.

With reference to McArdle and Anderson (1990), Sliwinski, Hoffman, and Hofer (2010) propose adding elements of occasion in processes of learning or development to the general model in which an outcome is predicted from age. The standard model is

$$y_{ti} = b_{0i} + b_{1i}(age_{ti}) + e_{ti}$$

where y_{ti} is the outcome of case i at time t, b_{0i} is the intercept of case i, b_{1i} is the linear age slope, and e_{ti} is the residual for case i at time t. This model is enriched by partialing out retest effects. One obtains

$$y_{ti} = b_{0i} + b_{1i}(age_{ti}) + b_{2i}(occasion) + e_{ti}$$

where b_{2i} represents the retest (or occasion, learning trial, etc.) effect. Given that the intervals between occasions are not always constant, this model allows one to decompose age and occasion effects, for example in a training study. Several variants of this model have been discussed (Sliwinski et al., 2010). When the outcome variable is response time (RT), one can hypothesize that (a) performance improves during bursts of occasions (rapid training sessions; see Nesselroade, 1991), but (b) performance dis-improves during the intervals between such bursts. One model that allows one to test this hypothesis is

$$RT_{ti} = a_i + g_i \exp[-r_i(occasion_{ti})] + e_{ti}$$

where the intercept, a_i, can be scaled to represent asymptotic response time of case i, that is, the fastest response time, or the case's latent potential. The term g_i exp[$-r_i$(occasion$_{ti}$)] reflects the portion of a case's performance that is explained by this case's experience, where parameter r_i is the rate of learning during the occasions (training sessions). Parameter g_i, termed the *gain* parameter, represents the difference between a case's initial performance (before training) and the estimate of the asymptotic performance. This notion implies that g_i is positive. As far as we are aware, negative g_i values have not been discussed, so far.

Another extension of the model considers recovery effects. It allows one to test the hypothesis that rate of improvement in subsequent bursts is subject to recovery effects. If this is the case, a simple exponential curve will have difficulties modeling this trajectory. Models have been specified that take an interaction between number of burst and improvement into account (Sliwinski et al., 2010). These and models with additional complications have been proposed to model development over time that is dependent on age, type of training, training schedule, and other characteristics of developmental processes. From the perspective of this chapter, it is most important that these models have been used to describe individuals. The parameters that were estimated for individual cases can be compared using *t*-tests. When groups of individuals are analyzed and compared, group-specific parameters can be estimated and interactions that test hypotheses compatible with group differences.

Latent Trait Models

Using latent trait models, researchers create metric latent variables from categorical manifest variables such as test items, the answers to which can be correct or incorrect. An example of an approach in this domain is item response theory (IRT; Lord & Novick, 1968; Reckase, 2009). Because of the particular importance of IRT for developmental research from a person-oriented perspective, this methodology will be discussed in more detail later. At this point, it is sufficient to say that scales created based on IRT methods apply to every case in a population. This means that dimensional identity is a characteristic of the model. In addition, change can be validly assessed, person parameters can be incorporated, and variation within the individual can be modeled (Bowles, 2010; Hsieh & von Eye, 2010; Hsieh, von Eye, & Maier, 2010; Hsieh, von Eye, Maier, Hsieh, & Chen, 2012; van Rijn, Dolan, & Molenaar, 2010).

Latent Class Analysis (LCA)

LCA (Goodman, 1974; Lazarsfeld & Henry, 1968) is of interest in person-oriented research because it allows one to ask questions that are specific to the nature of categorical (e.g., nominal-level variables). LCA is used to explain the interactions among categorical variables. To accomplish the explanation, latent variables are identified. The interactions are modeled to differ across the categories of the latent variables. If a latent variable explains the interactions, they are zero within each latent class (this is called *conditional independence*). The latent classes are groups of cases. To illustrate, consider a binary outcome variable, X. The probability of obtaining the value of 1 in the ith latent class is

$$Pr(x_{ij} = 1 \mid class_i) = \theta_{ij}$$

where x_{ij} is the value for the jth variable that is observed in the ith latent class. Now, based on conditional independence, the probability that a particular response vector is observed for the ith latent class is given by

$$Pr(x \mid class_i) = \prod_{j=1}^{q} \theta_{ij}^{x_{ij}} (1 - \theta_{ij})^{1-x_{ij}}$$

where q is the number of observed variables.

LCA is important for person-oriented research because it identifies a priori unknown groups that differ in the interactions among the observed variables. For proper application, dimensional identity must be assumed.

LCA is a special case of finite mixture distribution decomposition methods (Erdfelder, 1990; Everitt & Hand, 1981). Special cases of LCA are *latent transition models*. These models are, in part, latent class models with specific Markovian restrictions. In most applications, these restrictions reflect a first-order Markov process. Particular states are predicted only from the prior, time-adjacent state, not from states farther apart. Collins and Wugalter (1992; see also Collins & Lanza, 2010) demonstrated how to model the assumptions that (a) learning goes through stages and (b) no learner regresses to an earlier stage. This set of hypotheses can be modeled by setting particular transition probabilities to zero. The model takes measurement error into account, for example, misclassifications of cases into variable categories. Joint and marginal restrictions can also be incorporated in latent transition models.

Developmental applications of hidden Markov chain models have been proposed by Rovine, Sinclair, and Stifter (2010). The authors proposed a six-state model for mother-infant interactions. It is important to realize that these models can be applied in the context of person-oriented, idiographic, and differential psychological research. The transition probabilities can be estimated separately for each unit of analysis (the mother-infant pair is the unit of analysis in Rovine et al.'s study). For an application of latent transition analysis in comparison with cluster analysis, see DiStefano (2012).

Latent Profile Analysis

When the observed variables are continuous and the latent variables are categorical, one estimates models of *latent profile analysis* (LPA; Lazarsfeld & Henry, 1968; for a discussion of the relation of LPA to structural equation models, specifically linear factor analysis and developmental applications, see Halpin & Maraun, 2010). Whereas one assumes for LCA that the probability of a case's response depends on the latent class the case belongs to, for LPA, one assumes that the probability of a case's response depends on the position of the case on the continuous latent variable.

Molenaar (1999) demonstrated the formal links between methods of time series analysis and structural equation models (see also Bentler & Molenaar, 2012). The early extensions of autoregressive models that led to the *threshold autoregressive model* (TAR; Tong & Lim, 1980) and the *Markov-switching autoregressive model* (MSAR; Hamilton, 1989) have experienced exciting further developments. The new developments are in the domain of *regime-switching models* (Hamaker, 2009; Hamaker, Grasman, & Kamphuis, 2010). The term *regime* refers to a psychological state. Development and intervention often imply change from one regime to another. Both the TAR and the MSAR assume that two or more autoregressive processes exist in a series of scores. The TAR differs from the MSAR in the assumptions made about the reasons for switching from one regime to another. In the TAR, regime switching is regressed on observed, manifest variables. In the MSAR, switches are assumed to be controlled by a hidden Markov process. This process is inferred from the observed data without regressing to manifest variables other than the observed process itself. Developments extend the TAR and the MSAR methods by formulating *duration-dependence models*, in which the probability of switching also depends on the time a case spent in a particular regime.

As for the models discussed earlier, the aspect of the new latent profile models that makes them interesting from a person-oriented or an idiographic perspective is that the models can be specified and estimated for the individual. For example, Hamaker et al. (2010) modeled data from an individual that had been diagnosed with rapidly changing bipolar disorder. As discussed earlier, dimensional identity must be assumed for the entire series of observations.

Exploratory Analysis of Pattern Development

A key aspect of the person-oriented approach is its emphasis on studying patterns of information. Usually, these patterns are operationalized by individuals' profiles. A selection of model-based methods that analyze such patterns was briefly reviewed above. When metric variables are studied and an exploratory approach judged suitable, *cluster analysis-based methods* (unsupervised classification; von Eye & Gutiérrez-Peña, 2004) are also often used. They have advantages and disadvantages as compared to model-based methods. One advantage is that they tend to require less restrictive assumptions about the data model. For the most popular group of cluster analysis, the *agglomerative methods*, first (dis)similarities between patterns are estimated for all pairs of individuals, and used as input in a classification analysis that aims at forming groups of individuals (clusters). Those in the same cluster have similar value profiles. Clustering methods can also be used in developmental, longitudinal data analysis, and they can be tailored to meet demands of the person-oriented tenets. In the following paragraphs, we review two classification methods that have been proposed for use in person-oriented research.

Using *LICUR* (*Linking of Clusters after Removal of a Residue*; Bergman et al., 2003), a cluster analysis is carried out separately at each time point, based on the variables from that time point, and the resulting cluster solutions are compared to evaluate structural stability and change. Rules exist for deciding on a suitable number of clusters and an important aspect of LICUR is the formation of a residue (a set of outliers) that is analyzed separately (Bergman, 1988). Then cluster membership at Time 1 is related to cluster membership at Time 2 by cross-tabulation, cluster membership at Time 2 is related to cluster membership at Time 3, and so on. This informs of cluster membership combinations that occur more often or less often than expected by chance (so called developmental types/antitypes; see Configural Frequency Analysis, later). Results are examined with regard to individual stability (subjects belong to similar clusters at adjacent time points) and individual change (subjects belong to different clusters at adjacent time points; the clusters themselves are assumed to be invariant over the short periods of time considered for LICUR application). LICUR can be extended to situations where different variables are measured at different time points or several domains are studied. Instead of studying stability and change, the study is then of pattern connections over time. For instance, consider a first set of variables that measure various aspects of psychological stress, resulting in a psychological stress profile, and a second set of variables that measure physiological stress, resulting in a physiological stress profile. Following the LICUR rationale, a cluster analysis of the psychological stress profiles is carried out followed by one of the physiological stress profiles. The two cluster solutions are then cross-tabulated, looking for cluster combinations that are types, each such combination indicating that a specific psychological stress cluster is connected to a specific physiological stress cluster.

ISOA (*I-States-as-Objects-Analysis*; Bergman, Nurmi, & von Eye, 2012) is tailored to study short-term development in situations for which it is assumed that the same classification structure holds at all time points (although the proportion of the sample that belongs to the different classes might change with time). A key concept is the *i-state*, defined as a person's pattern of variable values at a specific time point. All i-states, regardless of the time they refer to, are first subjected to a classification analysis that results in a time-invariant classification characterized by a number of *typical i-states*. These are interpreted to understand the classification structure. Time changes in the frequency of belonging to the different typical i-states are studied and are easily interpreted due to the invariant classification system. Then, individual stability and change in typical i-state membership is studied and illustrated by stream charts. An ISOA application is given by Nurmi and Aunola (2005) who studied patterns of task-motivation during the first school years. ISOA has been extended in various ways: (a) methods for checking the assumption of a time-invariant classification have been developed; (b) based on multidimensional scaling, information about the degree of dissimilarity between typical i-states is used as an aid in interpreting typical i-state change; and (c) attention is given to *closed paths* (i.e., i-state sequences that are nonexistent).

In the following sections, we discuss two methods in more detail. The first method is *Configural Frequency Analysis* (CFA; Lienert & Krauth, 1975; von Eye & Gutiérrez-Peña, 2004; von Eye et al., 2010). CFA can be applied to group data and to data of the individual. It is deemed a main method of person-oriented research (Bergman et al., 2003). The second method is *Item Response Theory* (Lord & Novick, 1968; Reckase, 2009). In spite of its enormous potential, it has not been discussed extensively in the context of person-oriented research (see, however, van Rijn et al., 2010).

Configural Frequency Analysis (CFA) and Log-Linear Modeling

The generalized linear model has the form $f(y) = X\beta + \varepsilon$, where $f(y)$ is the link function, X is the design matrix, β is the parameter vector, and ϵ is the vector of residuals. For ANOVA and regression models, which analyze continuous outcome variables, the link function is the identity function. That is, $f(y) = y$, and $X\beta = \mu$, where μ is the expected value, the mean. When counts are on the outcome side, that is, when the outcome variable is categorical, the link function of choice often is nonlinear. One selects the logarithmic function, and obtains $X\beta = \log(\mu)$, where log indicates the natural logarithm (base e). Models that use the logarithmic link function are known as *log-linear models* (Agresti, 2002; Bishop et al., 1975; von Eye & Mun, 2013).

In other respects, the models for continuous and categorical outcome variables are equivalent. Hypotheses concerning main effects and interactions as well as covariates and special effects can be entertained. Model fit can be estimated, and residuals can be analyzed. Manifest and latent variable models can be estimated.

In this section, we change our approach to the analysis of longitudinal data in person-oriented developmental research in two respects. First, we look at categorical variables. Second, we look at naturally occurring groups. Parameters and their significance are less of an interest in CFA, but they reside in the center of interest in log-linear modeling. The naturally occurring groups are cases that display the same pattern of categorical variable categories. These cases can be found in the cells of the multivariate cross-classification of the categorical variables under study. The questions that we ask in CFA no longer concern parameter significance, variable relations, or model fit. Instead, we ask whether the frequency with which cases with a particular profile are observed differs from the frequency that was estimated by using a base model (defined in the following section). If a profile is observed more often than expected, it is said to constitute a *CFA type*. Conversely, if a profile is observed less often than expected, it is said to constitute a *CFA antitype*.

This section is structured as follows. First, we provide an overview of CFA by introducing and explaining the five steps involved when applying this method. Then, we discuss a number of CFA models, all for longitudinal research from a person-oriented perspective.

The Five Steps of CFA

CFA proceeds in five steps (von Eye, 2002; von Eye et al., 2010).

1. *Selection of a base model and estimation of expected frequencies*. A *CFA base model* is a chance model that provides an estimate of the probability with which a pattern of variable categories (a configuration, a cell in a cross-classification) is expected to occur. A base model takes into account those effects that are *not* of interest to the researcher. If deviations between the expected and the observed cell frequencies are significant, they reflect, by necessity, the effects that are of interest to the researcher. Most CFA base models are log-linear models. An often employed base model is that of Prediction CFA. This model proposes independence between predictor variables and criterion variables, and takes all possible interactions into account both within the group of predictors and within the group of criteria. Types (antitypes) from this model indicate which patterns of predictor categories allow one to predict the patterns of criterion categories that occur more often (less often) than expected with reference to the base model.
2. *Selection of a concept of deviation from independence*. Deviation from a base model can come in many forms. Typically, when the base model proposes variable independence, deviation from independence can be assessed using measures that take into account marginal frequencies. However, there exist concepts and measures that do not take into account marginal frequencies. The corresponding deviation measures are termed *marginal-dependent* versus *marginal-free* (Goodman, 1991; von Eye & Mun, 2003; von Eye, Spiel, & Rovine, 1995). Marginal-dependent and marginal-free measures can give different appraisals of deviation from a base model. Most CFA applications use marginal-dependent measures of deviation from a model. The well-known chi-squared statistics are examples of marginal-dependent measures. In contrast, the odds ratio is marginal-free.
3. *Selection of a significance test*. A large number of significance tests of the null hypothesis that CFA types or antitypes do not exist has been proposed (see also von Eye, 2002). Simulation studies have shown that none of these tests outperforms all other tests under all of the examined conditions (Indurkhya & von Eye, 2000; von Eye & Mun, 2003; von Weber, von Eye, & Lautsch, 2004). Tests that perform well under many conditions include, under any sampling scheme, Pearson's X^2, the z-test, and the binomial test.
4. *Significance testing under protection of* α. In the typical application of CFA, many tests are performed. Therefore, the significance level, α, must be protected. The classical method for α protection is the *Bonferroni procedure*. This method can suggest rather conservative decisions about the existence of types and antitypes. Therefore, beginning with Holm's (1979) procedure, less prohibitive methods have been proposed (von Eye, 2002).

5. *Interpretation of types and antitypes*. The interpretation of types and antitypes uses five sources of information.
   - The substantive meaning of the configuration which is determined by the meaning of the categories that define a configuration.
   - The base model.
   - The concept of deviation from expectation.
   - The sampling scheme (e.g., multinomial versus product-multinomial).
   - External information that can be used to discriminate among types and antitypes (from each other and from the configurations that constitute neither types nor antitypes). This information and the discrimination are not part of CFA itself. Instead, this information is used in follow-up tests that are intended, for example, to establish the external valiity of CFA types and antitypes (von Eye et al., 2010).

An additional type of information has been discussed, concerning the selection of frequentist CFA (the version described here) or Bayesian CFA (Gutiérrez-Peña, 2012). The latter tends to have more power, and additional information such as new samples can naturally be taken into account.

In general, CFA results differ from results of standard statistical analysis in a number of respects. Specifically, CFA tables are interpreted only after the base model is rejected. Rejection of a base model does not guarantee that types and antitypes will result. However, if a base model describes the data well, the search for types and antitypes that indicate the location of significant model-data discrepancies is pointless.

Only a selection of cells (configurations) emerges as type—and antitype—constituting. The remaining cells do not deviate from the base model.

The largest cell does not necessarily constitute a type and the smallest cell does not necessarily constitute an antitype. The main reason for this observation is that CFA focuses on the magnitude of *discrepancies from expectation* instead of sheer size (the model of zero-order CFA is the only exception; von Eye, 2002). Even relatively small cells can contain more cases than expected, and relatively large cells can contain fewer cases than expected.

In the following sections, we discuss and illustrate two sample models of longitudinal CFA, *lag analysis* and *configural analysis of interindividual differences in intraindividual change*. These models were selected because they allow one to analyze and compare individuals, that is, they are of particular interest for person-oriented and idiographic research.

Configural Lag Analysis

In time series analysis, one of the often-asked questions concerns the relations among elements within a series. For example, one can ask how to predict later elements from earlier ones. For practical purposes, a lag is defined as an interval in a series of scores that are equidistant in time. When cases are observed every day, a lag of 1 is used to relate, for example, information from one day to information from the next. Using CFA of lags (von Eye et al., 2010), one can find types and antitypes that indicate whether configurations are more (or less) likely to be observed than expected over a predefined number of lags, for example, over a predefined number of days apart.

To analyze a series of data from a lag perspective, one shifts the series by k time units in the direction of the lag, that is forward or backward. To illustrate, consider shifts by k =1, 2, and 3. Table 21.6 displays the resulting series of data, along with the original series.

For log-linear analysis or for CFA purposes, the resulting strings can be crossed. The resulting cross-classification can be analyzed as usual.

The questions asked when performing lag analysis depend on the approach taken, person- or variable-oriented. In variable-oriented research, one can ask, for example, whether behavior is predictable over a given lag, k, whether this relation changes systematically as k increases or decreases, or whether this relation covaries with other time-changing or time-invariant variables. In person-oriented research, one can ask, for example, whether particular patterns of constancy and change exist that occur at rates that differ from base rates, whether the (non-) occurrence of these patterns can be predicted from other

TABLE 21.6 Series With Lag 1, Lag 2, and Lag 3

Time	Original Series	Series With Lag 1	Series With Lag 2	Series With Lag 3
1	x_1	—	—	—
2	x_2	x_1	—	—
3	x_3	x_2	x_1	—
4	x_4	x_3	x_2	x_1
5	x_5	x_4	x_2	x_2
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
$n-1$	x_{n-1}	x_{n-2}	x_{n-3}	x_{n-4}
n	x_n	x_{n-1}	x_{n-2}	x_{n-3}

variables or patterns, or whether cases differ in the patterns that differ in occurrence rates from expectancy.

Data example. For the following illustration of lag analysis, we resume the alcoholism data example used earlier (Example 3). The data were collected in the context of a study on the development of alcoholism over 3 years (Perrine, 1995). In the following examples, we analyze the daily stress ratings of the first two respondents, 3000 and 3004. Both respondents provided data on 750 consecutive days. We perform analyses at both the variable- and the person-oriented levels.

Two sets of analyses are performed. First, we present a lag analysis with a lag of $k = 7$. This analysis allows us to relate stress ratings to each other that are 7 days apart, that is, from Sunday to Sunday, Monday to Monday, and so forth. At the variable-oriented level, we present a simple chi-square analysis. This analysis allows us to test the null hypothesis that the stress ratings are unrelated, in general. Second, we perform a CFA. This analysis allows us to identify the patterns that stand out.

Before performing these analyses, we recode the data. The amount of stress experienced by the respondents of the alcohol development study was indicated on a scale from 0 to 10, with zero indicating no stress at all. Because the extreme scores on this scale were so rarely used that estimation problems would result, we collapsed the scores from 0 through 3 under the value of 3, and the scores of 8 and up under the value of 8.

For respondent 3000, we calculated a likelihood ratio chi-square = 345.70, which, for $df = 25$, suggests an overall strong association between the stress levels reported on corresponding days of the week ($p < 0.01$). To identify the patterns that stand out, we follow up with a CFA. The base model for this analysis is the same as for the chi-square analysis. It is the independence model. It proposes that the stress levels on corresponding days of the week are unrelated to each other. Table 21.7 presents the results of this CFA. To test the null hypotheses that each cell frequency is the same as its expectancy, we used the z-test, along with the Holland-Copenhaver (1987) procedure of α protection.

Table 21.7 shows that CFA identified four types and five antitypes. Instead of interpreting each of these in detail, we highlight the two types and the two antitypes with the largest z-values. The most extreme types are constituted by Configurations 3 3 and 4 4. Both of these (and one of the remaining two types) indicate day of the week-related stability. Specifically, Type 3 3 suggests that when Respondent 3000 experienced relatively low stress on one day of the week, he also experienced relatively low stress on the corresponding day, 1 week later. The same applies to average stress (Type 4 4), and slightly elevated stress (Type 6 6). The two most extreme antitypes, constituted by Configurations 4 6 and 6 3, suggest that shifts in stress level by more than one rank are rather unlikely. Specifically, Antitype 4 6 suggests that an increase from moderate stress to elevated stress over corresponding days of the week is extremely unlikely to occur. Similarly, Antitype 6 3 suggests that, over a span of 7 days, a reduction in stress from elevated to mild is extremely unlikely also. In all, each antitype suggests that shifts in stress level by two or more scale points are rather unlikely.

For Respondent 3004 (data not shown here), a very similar picture emerges. Five of the six diagonal cells constitute

TABLE 21.7 First-Order CFA of the Cross-Classification of the Stress Ratings of Case 3000; Lag $k = 7$

Configuration					
Stress × Stress with a lag of 7 days	m	$\hat{m}$	z	p	
33	91.00	37.640	8.6976	.000000	Type
34	23.00	23.846	−.1733	.431217	
35	13.00	28.288	−2.8744	.002024	
36	17.00	43.952	−4.0654	.000024	Antitype
37	9.00	17.768	−2.0800	.018761	
38	2.00	3.507	−.8046	.210516	
43	32.00	25.498	1.2877	.098926	
44	56.00	16.154	9.9140	.000000	Type
45	10.00	19.163	−2.0932	.018167	
46	3.00	29.774	−4.9067	.000000	Antitype
47	3.00	12.036	−2.6046	.004599	
48	1.00	2.376	−.8925	.186068	
53	14.00	28.655	−2.7376	.003094	
54	12.00	18.154	−1.4443	.074325	
55	32.00	21.535	2.2550	.012067	
56	41.00	33.460	1.3035	.096204	
57	16.00	13.526	.6726	.250610	
58	3.00	2.670	.2022	.419895	
63	15.00	46.867	−4.6549	.000002	Antitype
64	8.00	29.692	−3.9809	.000034	Antitype
65	49.00	35.223	2.3213	.010135	
66	79.00	54.727	3.2811	.000517	Type
67	35.00	22.124	2.7376	.003095	
68	7.00	4.367	1.2603	.103786	
73	7.00	18.213	−2.6274	.004302	
74	1.00	11.538	−3.1024	.000960	Antitype
75	15.00	13.688	.3547	.361414	
76	39.00	21.267	3.8453	.000060	Type
77	12.00	8.597	1.1605	.122923	
78	1.00	1.697	−.5349	.296344	
83	2.00	4.128	−1.0474	.147446	
84	2.00	2.615	−.3805	.351779	
85	2.00	3.103	−.6260	.265672	
86	9.00	4.821	1.9036	.028481	
87	1.00	1.949	−.6796	.248374	
88	1.00	.385	.9923	.160531	

types, suggesting extreme day of the week–related stability of stress (Types 4 4, 5 5, 6 6, 7 7, and 8 8). Shifts in stress by one scale point are very likely in the domain of moderate stress (Types 5 4, 5 6, and 6 5). In contrast, shift by one or more scale points are very unlikely, in the domain of high stress (Antitypes 6 8, 7 8, 8 6, 8 7). For both respondents, shifts by many scale points are rare and do not deviate significantly from expectation, in the domain of low stress.

Configural Analysis of Interindividual Differences in Intraindividual Change

As discussed earlier, the third tenet of person-oriented research proposes that interindividual differences exist in intraindividual constancy and change (Sterba & Bauer, 2010; *principle of interindividual differences in intraindividual change*). In other words, the third tenet posits that patterns of development may not be universal.

CFA of interindividual differences in intraindividual change was proposed by von Eye and Mun (2012). This CFA model is an extension of lag CFA to two or more individuals or groups of individuals. Here, we discuss the comparison of two individuals. CFA of interindividual differences in intraindividual change requires a base model that cannot be rejected just because lags are related to each other within an individual. Instead, types and antitypes must reflect differences between the comparison individuals. In terms of hierarchical log-linear models, the base must be (a) saturated in each of the comparison cases and (b) propose independence of the two comparison cases. Let TA and TB be the series of observations for Individuals A and B. Let TAk and TBk be the corresponding series, with lag k. Then, the appropriate log-linear base model for CFA of interindividual differences in intraindividual change is

$$\log \hat{m} = \lambda + \lambda^{TA} + \lambda^{TB} + \lambda^{TAk} + \lambda^{TBk} + \lambda^{TA,TAk} + \lambda^{TB,TBk}$$

where the terms in the first row of the equation indicate main effects and the terms in the second row indicate first-order interactions. This model can be contradicted only if terms exist that connect variables from both cases. These are the two-way interactions, [TA, TB], [TA, TBk], [TAk, TB], and [TAk, TBk]; the three-way interactions, [TA, TAk, TB], [TA, TAk, TBk], [TA, TB, TBk], and [TAk, TB, TBk]; and the four-way interaction, [TA, TAk, TB, TBk].

If any of these interactions exist, the series from Case A and Case B are related. Types and antitypes will indicate the configurations that carry the relation.

Extensions are straightforward. For example, researchers can increase the number of lagged series of scores, restrict the base model even more (to get a picture of precisely the interactions that cause the types and antitypes; see von Eye & Mair, 2008), include covariates, include additional variables, increase the number of comparison cases, or compare a priori defined groups, for example groups of matched pairs.

Data Example. We now continue the example in which we compare the two alcoholics in their stress patterns over 3 years. We use the same data as in the previous example. However, to prevent the table for the present example from becoming overly sparse, categories needed to be collapsed. We therefore aggregated the rare low stress ratings for both respondents. Specifically, for Respondent 3000, the lowest rating of this respondent now was 4, for both series, and for Respondent 3004, it was 5. For both respondents, the highest rating now was 7. Let the four series that are being crossed be called S3000, S30007, S3004, and S30047, where S stands for stress, the following four numbers indicate the respondent, and the 7 indicates the series with lag $k = 7$. The resulting $4 \times 4 \times 3 \times 3$ cross-classification is analyzed under the two models,

$$\log \hat{m} = \lambda + \lambda^{S3000} + \lambda^{S30007} + \lambda^{S3004} + \lambda^{S30047}$$

and

$$\log \hat{m} = \lambda + \lambda^{S3000} + \lambda^{S30007} + \lambda^{S3004} + \lambda^{S30047} + \lambda^{S3000,S30007} + \lambda^{S3004,S30047}$$

The first of these models serves as reference. The second allows us to compare the lag-patterns of the two respondents.

For the first model, we obtain a likelihood chi-square of 581.40, which, for $df = 133$, comes with a tail probability $p < 0.01$. The model is, therefore rejected. The model indicated a large number of possible types and antitypes. These, however, may have resulted because of the strong relations between the original series and the series with $k = 7$. Therefore, we performed CFA under the second base model. We obtained a likelihood chi-square of 147.89, which, for $df = 120$, comes with $p = 0.04$. The model evidently also fails to describe the data well. The chi-square is substantial, and there is room for types and antitypes to emerge. We now discuss types and antitypes from the perspective of *functional* CFA. This perspective defines types and antitypes based on overall model fit. Types and antitypes are constituted by configurations that contain more (fewer) cases than expected and would, blanked out, lead to significant improvement in overall model fit (see Kieser and Victor's, 1999, and von Eye and Mair's, 2008, definitions).

Taking the perspective of functional CFA, there were 15 cells that were extreme in the sense that blanking them out would have significantly decreased the overall goodness-of-fit chi-square. Here, we interpret the two most extreme of these configurations. They are both antitype-constituting, and were found for Cells 4 4 4 5 and 4 4 7 5. The first of these Configurations suggests that it is extremely unlikely and contradicts the base model that when Case 3000 experiences stability in moderated stress from one day in a week to the corresponding day in the next, Case 3004 experiences an increase from moderate to high, that is, from 4 to 5. Configuration 4 4 7 5 suggests that it is extremely unlikely that when Case 3000 experiences stable, moderate-level stress, Case 3004 experiences a decrease, from high to moderate, that is, from 7 to 5. The first of these configurations was observed once, the second was observed twice.

It is important to note that these antitypes contradict the base model the most, and blanking them out would have improved overall model fit considerably. In fact, blanking out just the first of these two cells, 4 4 5 7, improves the overall goodness-of-fit Chi-Square to the value of 139.30, which, for $df = 119$ suggests that this model fits ($p = 0.10$).

It is also important to note that, because of the relatively good model fit, no configurations were found that stand out under the classical definition of types and antitypes, that is, based on large residuals. This applies even to Configuration 4 4 7 7, which was the most frequent pattern. It was observed 157 times, but the base model suggests that it can be expected to occur 153.28 times. The corresponding z-score is 0.30. This configuration indicates that a subjective stability in stress at a moderate level, for Respondent 3000, is observed at the expected rate in tandem with stable high-level stress experienced by Respondent 3004.

To conclude, CFA is a method that allows researchers to explore and test hypotheses concerning profiles of scores. In particular in longitudinal research and in comparative studies, it is important that scores are valid for everybody and at each observation point in time. This follows from the person-oriented tenet of dimensional identity. In the next section, we discuss Item Response Theory. This approach to test construction results in instruments that have characteristics that render them most suitable for empirical person-oriented and idiographic research.

Item Response Theory (IRT)

Item Response Theory (IRT; see Hambleton & Zhao, 2006; Lord, 1980; Lord & Novick, 1968; Reckase, 2009; van der Linden & Hambleton, 1997) is a summary term for logistic models that differ in the number of item parameters they include. IRT can be used for modeling in general. However, it has been discussed mostly in the context of testing and test construction. In the following sections, we first review elements of IRT, and then discuss specific models with respect to person-oriented research.

The original logit model was proposed by Verhulst (1838) as a statistical model of human population growth. The idea was that growth is not linear. Instead, after a period of steep increase in the size of a population, it approximates an asymptote. The model is now used in particular in the contexts of test construction and testing, but also in modeling in general. Each of these contexts is of key interest not only to differential, but also person-oriented and idiographic developmental research. To introduce the logistic model, consider a binary test outcome (endorsed = 1; not endorsed = 0; or correct = 1; incorrect = 0). The probability function for this outcome can be expressed by

$$f(y \mid p_0) = p_0^y (1 - p_0)^{1-y}$$

If $y = 1$, that is, for correct solutions, $f(y \mid p_0) = p_0$.

If $y = 0$, that is, for incorrect solutions, $f(y \mid p_0) = 1 - p_0$.

In a test in which a participant responds to n items, the n items are considered independent, and the joint probability of the string of zeros and ones, that is, the probability of the response vector of an individual is

$$Pr[Y] = \Pi_{j=1}^{n} f(y_j \mid p_0)$$

For the individual vector $y_1, \ldots, y_n$, one obtains

$$f_n(y_1, \ldots, y_n \mid p_0) = p_0^{\Sigma_{j=1}^{n} y_j} (1 - p_0)^{n - \Sigma_{j=1}^{n} y_j}$$

Now, in a regression or modeling context, consider the two variables X and Y, and let $(X_1, Y_1), \ldots, (X_n, Y_n)$ be a random sample from a conditional logit function. Let X be an explanatory variable (predictor) and Y an outcome variable (criterion). Then, the model that describes the relation between X and Y can, for the two outcome options "correct" and "incorrect," be expressed as the *logit model*

$$Pr[Y_j = 1 \mid X_j] = \frac{1}{1 + \exp(-\alpha_0 - \beta_0 X_j)}$$

and

$$Pr[Y_j = 0 \mid X_j] = \frac{\exp(-\alpha_0 - \beta_0 X_j)}{1 + \exp(-\alpha_0 - \beta_0 X_j)}$$

or, in more general terms,

$$Pr[Y_j = 1 \mid X_j] = F(\alpha_0 + \beta_0 X_j)$$

where the distribution of the *logit function* is

$$F(x) = \frac{1}{1 + \exp(-x)} = \frac{\exp(x)}{1 + \exp(x)}$$

The form of this function is well known to be S-shaped. In testing and in modeling, the logit function is specified with a number of substantively interpretable parameters. Consider, for example, the three-parameter logistic model

$$F_j(x) = c_j + (1 - c_j)\frac{e^{Da_j(x-b_j)}}{1 + e^{Da_j(x-b_j)}}$$

for $j = 1, \ldots, n$. This model has the following interpretation:

- $F(x)$: probability that a participant provides the correct response to item j
- b_j: item difficulty
- a_j: item discrimination
- c_j: guessing
- D_j: scaling constant

Several special cases of this model have been discussed. The cases can be distinguished by the characteristics of the model parameters. For example, setting $c = 0$ results in the two-parameter logistic model; this model has been used to describe distributions of dichotomously scored items and distributions of multiple choice items; and setting $c = 0$ and $a = 1.0$ results in the one-parameter logistic model; this model is also known as the *Rasch* model (Fischer & Molenaar, 1995; Rasch, 1960, 1961).

In the following sections, we review characteristics of the Rasch model with particular reference to its use in person-oriented research. We focus on the model for dichotomous variables. For models for polytomous or ordinal variables, see, for example, Reckase (2009) or van der Linden and Hambleton (1997).

The Rasch Model

Dropping the constant and setting $c = 0$ and $a = 1.0$ results in the *Rasch* model,

$$F_j(x_i) = \frac{e^{x_{ij}(\theta_i - \beta_j)}}{1 + e^{(\theta_i - \beta_j)}}$$

where i indexes individuals, j indexes items, θ_i is the ability parameter for individual i, and β_j is the difficulty parameter for item j. This equation describes the probability that an individual with ability θ_i provides response x to an item with difficulty β_j. Main characteristics of the Rasch model include the following (Fischer & Molenaar, 1995; Koller, Alexandrowicz, & Hatzinger, 2012):

- *Item characteristic curve* (ICC). The probability $[0 \leq p \leq 1]$ that an item with a given difficulty is responded to by individual i with response x is plotted on the y-axis. The ability parameter is plotted on the x-axis $[-\infty$ to $+\infty]$. The curve is S-shaped, increases monotonically, and the discrimination of an item, that is, the capability of an item to separate individuals with high ability from individuals with low ability reaches a maximum when the probability of solving the item is 0.5. The ICCs of different items from the same scale will not cross. When curves differ in more than one parameter, they can cross. Items that cross violate the Rasch model.
- *Unidimensionality of a scale*. The key characteristic of the Rasch model is that items on the same scale are *unidimensional*. This characteristic is also called *item homogeneity*. This characteristic suggests that only one ability determines the probability of solving an item correctly (or endorsing it). Homogeneous items correlate positively. From a latent variable perspective, it can be said that the correlations among items that represent the same ability can be captured by just one latent variable.
- *Local stochastic independence* or, brief, *local independence*. When a test is administered to a sample of individuals, the participants respond to several items and the responses can be viewed as instantiations of responses in a repeated measures design. The reason for this interpretation is that the responses are given by the same individuals, and are determined by the person characteristic

(ability) targeted by the test. Therefore, the responses to the list of items are *dependent*. If, however, this characteristic is held constant—this is the case when just one individual is observed—variations in this characteristic are no longer the causes for variations in the correctness or endorsement of items, responses to different items can be considered independent. This type of independence is termed *local stochastic independence*. The qualifier *local* applies because the independence applies only for the person characteristic of this particular participant. Similarly, when several individuals with the same ability are observed, *stochastic independence* of two items indicates that the probability of a particular response to the first item is independent of the probability of a particular response to the second item. The joint probability of the two responses is, therefore, $p(f(x_1) \wedge f(x_2)) = p(f(x_1))p(f(x_2))$. It is important to note that if, for an individual with high ability, the probability of solving an item is high, the probability of solving the next item will be high also. However, under stochastic independence, the probability of solving the first item will not alter the probability of solving the next item. The correlations among items in a scale that is homogeneous thus depend only on the person characteristic (ability). Items that do not possess stochastic independence will not add independent information to the test score of individuals.

- *Specific objectivity* is an essential element of measurement. It consists of two components. First, to compare the difficulties of two items, any sample will do. In other words, the difficulty of an item compares to the difficulty of any other item in a fashion that is invariant over independent samples from the population of respondents' abilities for which the instrument was constructed.

Similarly, to compare the ability scores of two individuals, any set of items will do. Just as individuals, items are considered drawn from a pool that contains an infinite number of items. Any sample of items will lead to the same statement about the differences in ability of two individuals.

In the following sections, we discuss a selection of scale characteristics and implications that apply when a scale conforms to the Rasch model (see also de Ayala, 2009; Koller et al., 2012).

Invariance Over Subgroups. If the population to which an instrument is administered is properly defined, random subgroups from this population will not systematically differ in their ability estimates. That is, the instrument will be fair. In other words, if the true ability is invariant over subgroups, the instrument will assign the same ability estimates to individuals with the same true person score (ability). This implies that subgroup memberships will not allow one to predict person scores. Put differently, when an instrument conforms to the Rasch model, the results of a comparison of two item difficulties (or person abilities) are invariant across individuals (or items). If, however, the assumption of invariance over subgroups is violated, it may be that the instrument is, over the subgroups, differentially sensitive to abilities. This characteristic, known as *differential item functioning* is of particular importance in person-oriented research and will be discussed in more detail later. Instruments that evince differential item functioning can, in a given context, be unfair.

Sufficient Statistics

When an instrument conforms with the Rasch model, sufficient statistics exist both for the person and the item parameters. Specifically, the sum of the endorsed items for each individual (or the sum of correct solutions) contains all the information needed for this individual's score on the scale. In addition, the sum of the endorsed statements (the sum of correct solutions) contains all the information needed to determine the difficulty of an item. There will be no Item × Person interaction and, therefore, the information inside the person by item matrix carries no additional information. By implication, for the score that an individual obtains on a scale, it does not matter which item was endorsed (solved). The same applies for the items.

In the following paragraphs, we discuss characteristics of IRT models, in particular the Rasch model, with respect to the tenets of person-oriented research. In subsequent sections, we present new developments in IRT modeling and applications.

IRT and the Rasch Model in Person-Oriented Research

In this section, we discuss implications that characteristics of IRT models, in particular the Rasch model, can have from the perspective of person-oriented research. A first focus of this discussion concerns the type of statements made in developmental research, a second concerns the possibility of making statements about development.

According to the first and the third tenets of person-oriented research, development can be specific to the individual. To establish statements that allow one to compare individuals with themselves over time and with other individuals both cross-sectionally and longitudinally, the seventh tenet of person-oriented research (i.e., dimensional identity) must be fulfilled. The Rasch model has the property of *specific objectivity*. This property implies that (a) items are valid regardless of which individuals respond to them, and (b) individual scores are valid, regardless of which item from a scale is administered. Because of these characteristics, longitudinal research becomes possible as well as interindividual comparisons (for examples, see, e.g., Fischer & Formann, 1982; Fischer & Ponocny, 1994). In contrast, scores on scales that are established using classical test theory can be most problematic in longitudinal research. The reliability of difference scores from these scales can be very low.

In spite of these important benefits from using IRT models to establishing scales, a few words of caution are in order. First, dimensional stability must be assumed over time. Increases or decreases of scores on scales can be interpreted as such only when the scales possess the same characteristics at each point in time. When the characteristics of scales change, it will be difficult to interpret changes in scores. Those changes in scale characteristics may, themselves, reflect developmental changes, but scores that change over time do require temporal dimensional identity.

If dimensional identity is not given, statements about development can be made in terms that differ from statements that focus on scores on scales. Consider, for example, the well-known dispute about intelligence divergence discussed earlier (Garrett, 1938). According to this hypothesis, the portion of variance of intelligence that can be explained by a given number of latent variables decreases over the course of development. The number of latent variables needed increases with age. Similarly, the hypothesis of intelligence differentiation proposes that for individuals who exhibit higher levels of cognitive capacity, the number of factors needed to satisfactorily describe intelligence is higher than for individuals who exhibit lower levels of cognitive capacity (see also Deary et al., 1996). If these hypotheses are correct, scores from standard intelligence tests are not comparable across younger and older individuals or across individuals who exhibit different levels of intelligence. However, if tests are tailored to age groups or brackets of intelligence, scores of individuals from different brackets may not be comparable either because they differ in the reference populations to which tests can be applied.

The conclusion one can draw from this discussion is, again, that, for descriptions of intraindividual development as well as interindividual differences in intraindividual development, dimensional identity must exist. This postulate is easy to meet when such ratio scales as the physical scales of blood pressure, number of heartbeats, cholesterol level, response times, or visual acuity are used (even models based on ratio scale variables can lack measurement invariance). When this type of scale is used, researchers can often proceed as mandated in idiographic research. When development is described based on scores from tests that are repeatedly administered on the same respondents, no matter whether a test as established using classical test theory or IRT modeling, dimensional identity must be established for the comparison units. If researchers are able to establish dimensional identity, instruments that conform to the Rasch model are uniquely suited to describe developmental constancy and change, when change is defined in terms of higher and lower scores on a given scale. When, however, the dimensional characteristics of an instrument change over the course of an investigation, over the course of development, or over comparison groups, development must be described in terms that are different than ups and downs on scales. Interestingly, this has rarely been undertaken in developmental research.

This conclusion is important in the context of the comparison of the three approaches of person-oriented research, idiographic research, and differential psychology. When dimensional identity is given, the three approaches target the same type of statement, and one can ask the important question that has propelled the discussion of idiographic research: whether and when cross-sectional designs can be employed to replace time series designs. When this question is answered, one can establish the units or groups of comparison and then perform person-oriented, idiographic, or differential psychological developmental research.

Considering the unique benefits from using IRT models in developmental research, we now proceed and discuss new developments in IRT methodology. We focus on IRT modeling in the context of structural modeling. For the technical background of the material that we are presenting, see, for example, Skrondal and Rabe-Hesketh (2004). For approaches to IRT modeling in the context of multisample analysis with changing scales of measurement, see, for example, McArdle, Grimm, Hamagami, Bowles, and Meredith (2009). For IRT models for intraindividual change, see, for example, Bowles (2010). The following sections introduce readers to the unified latent growth modeling approach proposed by Hsieh and collaborators (Hsieh & von Eye, 2010; Hsieh et al., 2010; Hsieh et al., 2012).

A Unified, IRT-Based Latent Growth Curve Model

Growth models allow one to answer important research questions in domains such as social and psychological development, and processes of learning. It is well known that growth models can often be approached from several perspectives, in terms of equivalent models (e.g., Bauer, 2003; Curran, 2003; Willett & Sayer, 1994; for words of caution, see Kuljanin, Braun, & DeShon, 2011). For example, a growth curve model can be specified as a standard two-level hierarchical linear model (HLM), where the repeated measures are positioned at the lowest level, and treated as nested within the individuals. Equivalently, a model can be specified as a structural equation model (SEM), in which latent variables are used to account for the relations between the observed variables; hence, the approach was named *latent growth curve* (LGC) *analysis* (see Muthén, 2002).

This mean and covariance structure makes it possible to specify exactly the same model as an HLM or LGC, because the fixed and random effects in the HLM correspond to the mean and covariance structure of the latent variables in the LGC analysis. Differences between these two models are rapidly disappearing (Preacher, Wichman, MacCallum, & Briggs, 2008; Raykov, 2007). One of the major differences is that, whereas in HLM, time is treated as a fixed explanatory variable, it can be introduced into the LGC model via the factor loadings. This way of taking time into account makes the HLM essentially a univariate approach with time points treated as observations of the same variable. In contrast, the LGC model represents a multivariate approach with each time point treated as a separate variable (e.g., Bauer, 2003; Curran, 2003; Preacher et al., 2008; Raudenbush & Bryk, 2002; Willett & Sayer, 1994).

When measurements are discretely scaled (as are the responses analyzed using IRT models), conventional growth curve models can introduce a potentially significant bias in the analysis and subsequent inferences (Curran, Edwards, Wirth, Hussong, & Chassin, 2007). Currently, there are two major modeling strategies, which allow for the explicit incorporation of categorical repeated data in growth curve models. One strategy is to use the nonlinear multilevel model (e.g., Diggle, Heagerty, Liang, & Zeger, 2002; Raudenbush, Johnson, & Sampson, 2003), and the other is to use nonlinear structural equation models (e.g., Jöreskog, 2002; Muthén, 1983, 2002). As Curran et al. (2007) and Vermunt (2007) indicate, when fitting measurement models to empirical data of the type commonly encountered in developmental research, such as data from small samples, multiple discretely scaled items, many repeated assessments, and attrition over time, both models become quite complex and have difficulty achieving convergence.

To alleviate this difficulty, Hsieh and collaborators (Hsieh et al., 2012; Hsieh & von Eye, 2010) proposed an integrative modeling framework, integrating derivatives of the generalized linear latent and mixed model (Skrondal & Rabe-Hesketh, 2004) in a single analytic fashion. That is, using attributes of both the IRT and latent variable models, one can incorporate multiple categorical measurement models in growth curve analysis. We now describe Hsieh et al.'s (2012) model.

In the following specifications, i represents an item or question in a test and the responses are scored as correct ($x_{ij} = 1$) or incorrect ($x_{ij} = 0$). In this setting, let θ_i represent the latent ability of person i. The model is, then, parameterized as $logit[Pr(x_{ij} = 1 \mid \theta_i)] = \alpha_j(\theta_i - \beta_j)$ or $probit[Pr(x_{ij} = 1 \mid \theta_i)] = \alpha_j(\theta_i - \beta_j)$, corresponding to a unidimensional two-parameter logistic IRT model or a unidimensional two-parameter normal ogive model. Here, the abilities can be interpreted as either logits or probits of the probability of a correct response to a particular item. The item difficulty parameters β_j are defined as the location of inflection points in an item characteristics curve (ICC) along the same scale as the latent abilities θ_i. When the participant's ability equals the item difficulty, he/she will have a 50% chance of correctly answering or endorsing an item. The α_j are the slopes of ICCs at their inflection points, and can be considered the degree to which item response varies with the underlying latent construct. This helps determine how well the item discriminates between subjects with different abilities.

In a longitudinal design, the response model can be written as $probit[Pr(x_{tij} = 1 \mid \theta_{ti})] = \alpha_{tj}(\theta_{ti} - \beta_{tj})$, where subscript t represents the occasions. Assuming that neither item difficulty nor item discrimination varies across different points in time reduces α_{tj} to α_j and β_{tj} to β_j. If the invariance of the factor structure—a key element of dimensional identity—fails to hold over time, the difference in means may be partially attributable to differences in the scale of a factor (Blozis, 2007). Thus, in the example of a unidimensional two-parameter IRT model, the estimated item characteristics curves (ICCs) in the unified modeling approach proposed by Hsieh and collaborators can be specified as $Pr(x_{tij} = 1 \mid \eta_{ti}) = \frac{\exp(v_{tij})}{1+\exp(v_{tij})} = \Phi(v_{tij})$, where v_{tij} is the linear predictor, that is, $\alpha_j(\eta_{ti} - \beta_j)$, $\Phi(.)$ is the standard normal cumulative distribution function, and, again, θ_{ti} can, in LISREL notation, be replaced by

$\mu_t + \lambda_{0t}\eta_{0i} + \lambda_{1t}\eta_{1i} + \varepsilon_{ti}$. As the model becomes more complex, for identification purposes, the intercept is typically excluded from the structural models, the first item discrimination, α_1, is fixed to the value of 1, and the mean of the latent intercept, $E(\eta_0)$, is set to 0. By doing so, other individual-level covariates (e.g., gender) can affect the response only via the latent variable. This applies in particular to the change in rate (Skrondal & Rabe-Hesketh, 2004).

As a member of the class of multilevel latent variable models, the generalized linear latent and mixed model encompasses the response model and the structural model (Skrondal & Rabe-Hesketh, 2004). Hsieh and collaborators (Hsieh et al., 2010; Hsieh et al., 2012) propose and discuss a unified modeling approach, the *IRT latent growth curve model*. In this model, the IRT part refers to the response model (i.e., the generalized linear model, GLIM), and the latent growth curve part refers to the structural model. By way of incorporating random effects in the underlying continuous latent construct(s), that is, augmenting GLIMs via the inclusion of random effects in the latent variables (the corresponding models are termed *generalized linear mixed models*), and regressing latent variables on other latent variables or covariates, this unified model becomes the generalized linear latent and mixed model. This model becomes useful in longitudinal developmental designs, when the data are of a multilevel nature with a set of categorically scored items nested within each person on each measurement occasion.

The Response Model

Standard use of a latent growth curve analysis considers a single manifest indicator at each measurement occasion. Each response is a function of time and constitutes the first level of the measurement model. However, taking such an approach fails to capitalize on one of the capacities of structural equation models (SEM), which is taking into account information about the psychometric properties of manifest variables (Sayer & Cumsille, 2001). When, in contrast, multiple indicators of discretely scaled variables are incorporated into the model, a second-order factor structure models the developmental trajectory over time. From a person-oriented perspective, this is important because this allows the researcher to evaluate factorial invariance of latent constructs across waves, and permits the separation of time-specific error and measurement error (Sayer & Cumsille, 2001).

As mentioned earlier, the multivariate random-coefficient probit regression model for dichotomous responses can be specified as $Pr(x_{tij} = 1 \mid \theta_{ti}) = \frac{\exp(v_{tij})}{1+\exp(v_{tij})} = \Phi(v_{tij})$, where v_{tij} is the linear predictor, $\Phi(.)$ is the standard normal cumulative distribution function, and θ_{ti} is the latent ability of person i on the tth occasion. Using matrix formulation, the vector of linear predictors can now be written as $v_{tij} = \theta_{ti} Z\alpha_j - X(\alpha_j\beta_j)$ (Zheng & Rabe-Hesketh, 2007), for $t = 1, \ldots, T$; $i = 1, \ldots, n$, and $j = 1, \ldots, J$, where Z and X are the design matrices, α_j and $\alpha_j\beta_j$ are the vectors associated with item parameters, and θ_{ti} represents the latent ability across the entire study span; v_{tij} represents the vector associated with the probit function of a correct response to item j, given by person i on the tth occasion, and $\theta_{ti} Z\alpha_j$ and $X(\alpha_j\beta_j)$ are the random and fixed components, respectively.

The Structural Model: The Two-Stage Formulation

Perhaps the most intuitively appealing way of specifying a growth curve model is to link it to two distinct questions about change: One concerns the beginning position (level) and the other involves the overall true change across the entire study span (shape), each arising from a specific level in a natural hierarchy; this is called the *two-stage model formulation* (Rabe-Hesketh & Skrondal, 2008; Singer & Willett, 2005).

The Level-1 Structural Model. In latent response modeling, change is modeled in the repeated latent constructs and no longer in the observed scores, in which the error in the measurement model can be further partitioned into time-specific error and measurement error. In this model, the latent variable models the time-specific error without the confounding influence of measurement error. This is because, at each point of time, a common factor is assumed to account for the dependencies among a set of categorically scored items, which allows for the decomposition of the residual variance portions not attributable to growth (i.e., time-specific error variances). Using LISREL notation, the Level-1 structural model can be expressed as

$$\theta_{ti} = \eta_{0i} + \lambda_{1t}\eta_{1i} + \varepsilon_{ti}$$

with $t = 1, \ldots, T$; $i = 1, \ldots, n$; $\lambda_{11} = 0$, and $\lambda_{1T} = 1$. In this equation, θ is the $[T, 1]$ vector of repeated observations of Case j, η is a $[2, 1]$ parameter vector with η_{0j} representing the initial status and η_{1j} representing growth or decline. Λ is the $[T, 2]$ matrix of loadings with a constant in its first column and the time-specific loadings in its second column. Notice that the first loading in the second column is fixed to zero, and the last is fixed to 1 (this is done to model a nonlinear trajectory and for identification purposes; see the suggestion of Meredith and Tisak, 1990). ϵ is the [T, 1] vector of time-specific residuals. Because the repeated measures θ_{ti} have been extracted from the item response theory model through the probit link, converting the expected response to the linear predictor, this equation is the structural model. As before, the term θ_{tj} refers to the measures of Individual j at time t, and is a function of latent variables (representing the underlying initial status η_{0i}, the relative growth or decline trajectory η_{1i}, and time-specific disturbance residuals ϵ_{ti}). The analysis can proceed in steps by adding time varying covariates to the model, as time-specific predictors of the repeated measures. Unlike the assumption typically being made in SEM (that the ϵ_{ti} are identically and independently normally distributed with mean 0 and variance θ_t), we allow disturbance residuals at the Level-1 structural model to be time-heteroskedastic and to vary across different occasions. That is, these time-specific error variances are distributed heteroskedastically over time within-person. This is one of the key characteristics that make this model interesting to person-oriented researchers.

Because the random-effect θ_{ti} can be represented by the variances of η_{0i} and η_{1i} at the second level of the structural model, the latent growth curve model is an example of a random-effect model. The variance-covariance matrix of the residuals of this model is diagonal, with the residual variances of the observed measures as its entries.

The Level-2 Structural Model. The Level-2 structural model allows us to distinguish individual change trajectories based on their specific growth parameters, for example, true initial status and change rate. This possibility is most important from a person-oriented perspective. It implies that we can examine unobserved heterogeneity in growth curves by studying interindividual variation in growth parameters. According to Singer and Willett (2005), a suitable Level-2 model possesses the following four characteristics: (1) the Level-2 outcomes are the Level-1 individual growth parameters; (2) the Level-2 model can be expressed in one equation for each Level-1 growth parameter; (3) each equation specifies a relation between the individual growth parameter and time-invariant covariates; and (4) each Level-2 equation must contain the stochastic component because those individuals who share a common predictor could still vary in their specific change trajectories; hence the name random coefficient models. The Level-2 latent growth curve model can be expressed as

$$\eta_{0\mathrm{i}} = \gamma_{00} + \gamma_{01}\omega_{1\mathrm{i}} + u_{0\mathrm{i}}$$

and

$$\eta_{1\mathrm{i}} = \gamma_{10} + \gamma_{11}\omega_{1\mathrm{i}} + u_{1\mathrm{i}}$$

with $i = 1, \ldots, n$; these two equations represent regression relations among latent variables, one for each Level-1 growth parameter. Specifically, the factors $\eta_{0\mathrm{i}}$ and $\eta_{1\mathrm{i}}$, with γ_{00} and γ_{10} as the corresponding intercepts, are explained by the predictor ω_1 and residuals u_{0i} and u_{1i}, respectively. u_{0i} and u_{1i} are usually assumed to have a bivariate normal distribution with zero mean and unstructured covariance matrix. That is, controlling for the predictor of change (e.g., ω_1), the residual variances and covariance of true initial level and shape are distributed as follows:

$$\Psi = COV(u) = \begin{bmatrix} \sigma^2_{u0} & \sigma_{u01} \\ \sigma_{u10} & \sigma^2_{u1} \end{bmatrix}$$

The Composite Model. A model formulation that is analogous to the two sets of equations used so far can be specified by substituting the two Level-2 equations into the Level-1 model. This formulation reflects the proposition that general ability simultaneously depends on: (1) the corresponding factor loadings for each Level-1 predictor, the latent growth parameters; (2) the Level-2 predictors, for example, gender, and other person-level predictors; (3) the cross-level interaction (i.e., the corresponding factor loadings associated with each Level-1 predictor multiplied by the Level-2 predictors), and (4) the composite residual variances. The model is

$$\begin{aligned}\theta_{ti} &= \eta_{0\mathrm{i}} + \lambda_{1\mathrm{t}}\eta_{1\mathrm{i}} + \varepsilon_{ti} = \\ &= \gamma_{00} + \gamma_{01}\omega_{1\mathrm{i}} + u_{0\mathrm{i}} + \lambda_{1\mathrm{t}}(\gamma_{10} + \gamma_{11}\omega_{1\mathrm{i}} + u_{1\mathrm{i}}) + \varepsilon_{ti} = \\ &= (\gamma_{00} + \lambda_{1\mathrm{t}}\gamma_{10}) + (\gamma_{01}\omega_{1\mathrm{i}} + \lambda_{1\mathrm{t}}\gamma_{11}\omega_{1\mathrm{i}}) \\ &\quad + (u_{0\mathrm{i}} + \lambda_{1\mathrm{t}}u_{1\mathrm{i}} + \varepsilon_{ti})\end{aligned}$$

with $t = 1, \ldots, T; i = 1, \ldots, n; \lambda_{11} = 0,$ and $\lambda_{1\mathrm{T}} = 1$. Thus, using the same notation as before, a unified modeling approach that combines IRT and the latent growth curve analysis can be written as follows below. The model is a derivative of the generalized linear latent and mixed model, because the model contains both fixed effects (ω_{1i}) and random effects (u_{0i} and u_{1i}), and has latent abilities (θ_{ti}), which are regressed on other factors and observed covariates.

$$probit[Pr(y_{tij} = 1 \mid \omega_{1i}, u_{0i}, u_{1i})] = \nu_{ti} = \alpha_j(\theta_{ti} - \beta_j)$$
$$= \alpha_j(\eta_{0i} + \lambda_{1t}\eta_{1i} + \varepsilon_{ti} - \beta_j) =$$
$$= \alpha_j((\gamma_{00} + \lambda_{1t}\gamma_{10}) + (\gamma_{01}\omega_{1i} + \lambda_{1t}\gamma_{11}\omega_{1i})$$
$$+ (u_{0i} + \lambda_{1t}u_{1i} + \varepsilon_{ti}) - \beta_j)$$

with $i = 1, \ldots, n; t = 1, \ldots, T; j = 1, \ldots, J; \lambda_{11} = 0$ and $\lambda_{1T} = 1$. Furthermore, with a sampling distribution assumption being imposed, $x_{tij} = 1 \mid \pi_{tij} \sim binomial(1, \pi_{tij})$, where $\pi_{tij} = Pr(x_{tij} = 1 \mid \omega_{1i}, u_{0i}, u_{1i})$. Raudenbush and Bryk (2002) note that this generalized linear latent and mixed model can be categorized into three subcomponents: (1) the Level-1 sampling model; (2) the link function; and (3) the structural model.

In brief, although many other techniques have been developed to capitalize on special features of longitudinal research, latent growth curve analysis provides a broad class of statistical methods that are highly flexible in model articulation, provide enhanced statistical power for testing hypotheses, and demonstrate greater correspondence between the statistical model and the traditional theory underpinning developmental trajectories (Preacher et al., 2008). That is, the LGC model is capable of allowing straightforward examination of intraindividual change as well as interindividual variability. The LGC can be considered as residing at the interface between variable-centered and person-centered approaches, for its ability to (a) accommodate both nomothetic (i.e., fixed-effect parameters provide an overall change profile picture) and idiographic research perspectives (i.e., random-effect parameters supply with individual variability around this mean trajectory), and (b) to establish them as complementary strategies (see Curran & Willoughby, 2003, pp. 603–604). Finally, apart from its ability to understand and discern the developmental trajectory, LGC modeling is appealing because it enables researchers to study antecedents, processes, and consequences of change (Willett & Sayer, 1994).

Extensions

The generalized linear latent and mixed model can be extended in many ways. Examples include multilevel factor structures, multilevel structural equations, discrete latent variables, additional response type, and responses of mixed types. Instead of elaborating all these models, we review two developments of the generalized linear latent and mixed model that are of particular importance for person-oriented research. The first allows one to consider the assumption that members of a sample may be drawn from more than one population. The second allows one to consider the idea that, over the course of development, dimensional identity may not hold and, therefore, the factorial structure may change.

The Mixed Rasch Model

The Rasch model is typically applied under the assumption that item parameters are valid for every individual of a population. In contrast, the *mixed Rasch model* allows researchers to test the assumption that more than one population exists, and that item parameters differ across these populations. Within each of the subpopulations, however, the specifications of the Rasch model are fulfilled. As is typical of person-oriented research, neither the number of populations nor membership in these populations are known. Taking g populations into account results in

$$F_j(x_i \mid g) = \frac{e^{x_{ig}(\theta_{ig} - \beta_{jg})}}{1 + e^{(\theta_{ig} - \beta_{jg})}}$$

or, in words, in a model in which parameters are group-specific. If the assumption of group-specific parameters can be retained, one refers to *differential item functioning*, that is, members of different populations differ in how they respond to the same item.

There are several approaches to identify such groups. One is realized in programs such as Winmira (von Davier, 2012). This program searches for items and individuals who differ in their parameters and creates groups based on the distributions of these parameters. External variables or covariates are not used for group creation. An alternative is the R program *psychomix* (Frick, Strobl, Leisch, & Zeileis, 2012). Decision rules that are based on Mantel-Haenszel and Breslow-Day test procedures have been proposed by Prieto-Marañón, Aguerri, Galibert, and Attorresi (2012).

A fourth approach, known as *Rasch trees* (see Strobl, Kopf, & Zeileis, 2010), allows researchers to specify covariates. Segments on covariate scales are identified that represent various groups. Modules in the software environment R exist that create subpopulations of differential item functioning based on covariates. To give an application example, in an attempt to create a scale that assesses knowledge about suicide, Nader et al. (2012) used age and gender of respondents to identify subpopulations. It turned out that individuals younger than 30 differed from older individuals and the gender groups differed from each other in their knowledge characteristics.

From the perspective of person-oriented research, *differential item functioning* is a violation of dimensional identity. Even if the number of dimensions of an instrument is invariant across subpopulations, the instruments may differ in how members of the various populations respond to them. Therefore, creating subgroups has, as its major benefit, the effect that the data analyst does justice to the existence of subpopulations. There exists, however, a downside to creating subpopulation-specific parameters. Individuals from different subpopulations cannot be compared to each other based on their test scores. Here, we encounter a situation that is comparable to the situation we discussed earlier using the example of the CBCL. The same test score may not indicate the same behavior.

Still, if subpopulations exist, it does not make much sense to treat respondents as if they were members of the same population. One would have to assume that item parameters apply in the same way to everyone. If one excludes all items that violate this assumption, or, equivalently, if one eliminates all cases that respond differently to particular items, one creates a situation in which test characteristics suggest that groups and group differences do not exist. From a person-oriented research perspective, these situations prevent researchers from describing interindividual differences properly.

Multidimensional IRT Models for Longitudinal Research. The following approach is useful in particular in longitudinal research. Consider a study in which the same instrument is administered to the same individuals many times (as, for example, in Lebo & Nesselroade, 1978). The magnitude of the scores of such a study can be compared over time, both intra- and interindividually only if dimensional identity exists. Now suppose an instrument that is administered in a repeated observation study has, at Time 1, $P1$ distinct dimensions. At later times, $P2$ new dimensions may have developed, so that the behavior, at a later point in time, requires $P3 = P1 + P2$ dimensions for proper description. One can say that the $P2$ new dimensions have *sprouted out* over the course of observations. An example of such a phenomenon is *intelligence divergence*, discussed repeatedly in this chapter.

To deal with a situation in which dimensional identity is not given over time, but changes systematically by extending the number of dimensions or latent variables needed to capture the developing phenomenon, *sprout models* have been developed (Roberts & Ma, 2006; te Marvelde, Glas, van Landeghem, & van Damme, 2006). These models allow one to capture change of dimensionality in items that may even display within-item multidimensionality. Earlier models focused on items that exhibited simple structure only. Models allow researchers to specify far more complex constraints.

The potential of these methods is great. Justice can be done to the possibly time-specific nature of the dimensional structure of behavior. However, not unexpectedly, these new options come with a price. The price is that there may be no way to compare the magnitude of scale scores over time because the scale changes in meaning over time. Researchers may have to develop other descriptors of development than magnitude of scores. The next section presents a data example of the application of Hsieh et al.'s (2012) unified modeling approach.

Data Example. In a simplified application of Hsieh et al.'s (Hsieh et al., 2010; Hsieh et al., 2012) unified modeling approach, we now fit the IRT-LGC to NYS data. In other words, we analyze relations among respective growth factors using data from the National Youth Survey[2] (NYS; Elliott, 1976–1987). We first present variable-oriented and then increasingly person-oriented elements of analysis.

Measures and Data Sources. As part of the investigation of the NYS, the data represent the responses to seven items concerning the likelihood that a selected panel sample of 838 youth was associated with delinquent peers during the years of 1976 through 1987. For each item, the adolescents were asked, how many of their close friends were involved in the deviant activities listed in Table 21.8, during the year before the interview. Responses were coded as 1 for "yes" and 0 otherwise.[3]

As can be seen in Table 21.8, affirmative responses (Yes) tend to have small frequencies. By implication, the data are rather sparse, and asymptotic normality of the maximum likelihood estimators may not apply. Thus, when frequentist methods are adopted, problems associated with this skewed data structure concerning statistical

[2]Data were supplied by the Inter-university Consortium for Political and Social Research (ICPSR) Data Archive. Neither the original data collectors nor the archive bear any responsibility for the present analyses.

[3]Originally, items were presented in a 5-point Likert-type scale format with higher score reflecting more severe status. Here, we dichotomize the responses by recoding scores larger than 1 as the value of 1 and 0 otherwise.

TABLE 21.8 Response Frequencies to Seven Items (Responses from the Years 1976 through 1980)

	No	Yes
NYS 1976: Exposure to delinquent peers		
(*Think of the people you listed as your close friends. During the last year, how many of these . . .*)		
1. Destroyed property	522	316
2. Stole something worth $5 or less	460	378
3. Hit someone	367	471
4. Broke into a vehicle	763	75
5. Sold hard drugs	804	34
6. Stole something worth more than $50	777	61
7. Suggested you break the law	615	223
NYS 1977: Exposure to delinquent peers		
(*Think of the people you listed as your close friends. During the last year, how many of these . . .*)	No	Yes
1. Destroyed property	526	312
2. Stole something worth $5 or less	462	462
3. Hit someone	434	404
4. Broke into a vehicle	764	74
5. Sold hard drugs	797	41
6. Stole something worth more than $50	791	47
7. Suggested you break the law	610	228
NYS 1978: Exposure to delinquent peers		
(*Think of the people you listed as your close friends. During the last year, how many of these . . .*)	No	Yes
1. Destroyed property	528	310
2. Stole something worth $5 or less	455	383
3. Hit someone	484	354
4. Broke into a vehicle	752	86
5. Sold hard drugs	779	59
6. Stole something worth more than $50	779	59
7. Suggested you break the law	605	233
NYS 1980: Exposure to delinquent peers		
(*Think of the people you listed as your close friends. During the last year, how many of these . . .*)	No	Yes
1. Destroyed property	584	254
2. Stole something worth $5 or less	490	348
3. Hit someone	546	292
4. Broke into a vehicle	742	96
5. Sold hard drugs	735	103
6. Stole something worth more than $50	747	91
7. Suggested you break the law	591	247

Source: Adapted from "Using a Multivariate Multilevel Polytomous Item Response Theory Model to Study Parallel Processes of Change: The Dynamic Association between Adolescents' Social Isolation and Engagement with Delinquent Peers in the National Youth Survey," by C.-A. Hsieh, A. von Eye, and K. Maier, 2010, *Multivariate Behavioral Research*, *45*(3), pp. 508–552.

inference and hypothesis testing should be kept in mind (see, e.g., Gutiérrez-Peña, 2006). In a first analytic step, a confirmatory factor analysis, performed to establish the underlying construct, suggested that these seven items are

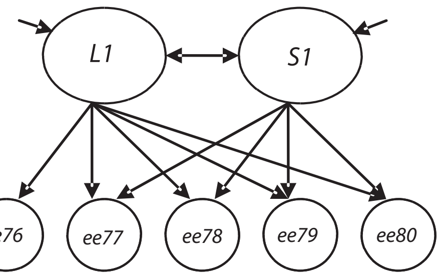

Figure 21.4 Path diagram of an unconditional latent growth model.

homogeneous. That is, a single underlying latent variable helps explain the associations among the items, and all items load on this single latent factor across the entire observation period.

We now employ Hsieh et al.'s (2012) IRT-LGC hybrid model. Specifically, we use a growth curve model. The estimation of growth profiles is represented by parameters of initial level and shape, along with other explanatory variables, such as gender. A conceptual model is depicted in Figure 21.4. An inspection of the individual responses (not shown here) suggests that both inter- and intraindividual variability over time is evident.

Results. In the *unconditional model*, we see that the estimated discrimination parameter for Item 6 is the largest, indicating that "stole something worth more than $50" is more closely related to hanging out with delinquent peers than other items. Regarding the item difficulty parameter estimates, overall, the estimated threshold parameters associated with Item 6 are rather large, implying that stealing something worth more than $50 is a difficult item to endorse. Adolescents who had endorsed this item were more likely to be associated with delinquent friends.

As for the substantive interpretation of the latent change trajectory, the model shows that without controlling any explanatory variable, we obtain a mean growth curve with significant variations around the latent means for the two growth factors. This result indicates that there remains room for individual-level covariates and contextual variables. Interestingly, the initial level has no predictive power for the change rate. Specifically, the change rate demonstrates a gradual decline pattern, regardless of the respondent's beginning level. The variation in the Level-1 residual variances—they describe measurement fallibility over time (their estimated values are 0.493, 0.451, 0.419, 0.330, and 0.588, respectively)—suggests that the existence of additional outcome variation at Level-1 may be further explained by other time-varying predictors. Finally, a segmented latent trajectory was found in the dimension of deviant peer affiliation. We, therefore, also estimated a conditional model.

Among the advantages of hierarchical IRT models is that they enable the researcher to incorporate contextual variables as auxiliary information when estimating the models, which improves not only the estimation of person abilities but also the calibration of item parameters (Mislevy, 1987). We therefore expand the model by adding Gender (0 = female; 1 = male) as a person-level covariate. Generally, we interpret the parameters within each level in a manner similar to the coefficients in regular regression. The Level-2 slope parameters that capture the effect of gender address the following research question: In terms of delinquent peer affiliation, do participants show gender-specific patterns in their change trajectories?

The results from this model suggest that the gender effects that are associated with the change rate of delinquent peer affiliation in the Level-2 structural model are statistically significant. This implies that, on average, boys had higher delinquent peer exposure than girls. Still, the Level-2 residuals, which represent the portions of the individual growth parameters unexplained by the covariate of change, gender, indicate that there remains significant between-person variability among adolescents after accounting for the effect of gender. These results suggest the need for additional time-invariant predictors. We therefore perform a second set of person-oriented analyses in which we attempt to create and use such predictors.

The models to be estimated are growth mixture models (GMM). The conceptual model appears in Figure 21.5. This model differs from the one in Figure 12.4 in that a categorical variable is now introduced that indicates latent class membership, *C*.

To complete the example in which we combine IRT, modeling, and Bayesian estimation in a context of variable- and person-oriented modeling, we use the NYS data for the analysis of growth mixture modeling (GMM). Based

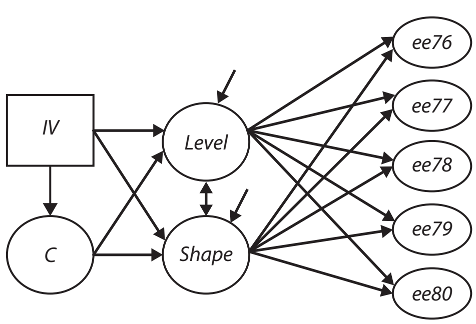

Figure 21.5 Conceptual growth curve model with time-invariant covariates.

on the path diagram in Figure 21.5, the growth mixture model consists of the following components: (1) a univariate latent growth curve with factors that represent the initial level and the shape of the growth trajectory; (2) a categorical variable for latent class (*C*); and (3) the time-invariant predictor variable(s), *IV*. Here, we adopt a two-stage analytical approach: Using Bayesian estimation, an IRT-LGC model was first used to derive the IRT scale scores across five time points; the estimation of the rate of change reflects the extent to which early adolescents engaged with delinquent peers during the assessment occasions. Second, by using maximum likelihood estimation with robust standard errors (MLR), the most probable class formation was detected by sequentially fitting the models with different numbers of classes. These models were compared based on the *Bayesian information criterion* (BIC) and entropy values (Muthén, Brown, Leuchter, & Hunter, 2008). Using the two-stage approach, we proceed with the growth mixture analysis and incorporate a time-invariant predictor, the gender of the respondents.

The results of the two-stage approach indicate that the sample comprises two latent mixture classes. Overall, 7.4% of the sample was in the first class, and 92.6% of the sample was in the second class. In addition, the results indicate that, during the assessment years, adolescents in Class 1 have a comparatively slower decreasing rate in their engagement with delinquent peers, and maintain a positive relation between the initial status and the change rate. Moreover, from the results of the multinomial logistic regression model, it appears that the odds of being classified in Class 1 are lower for male adolescents.

In sum, this example shows that IRT can fruitfully be incorporated in structural modeling. The combination of mixture distribution decomposition and structural modeling on one hand and the favorable characteristics of scales that are constructed using IRT allow researchers to capture and describe unobserved heterogeneity. This heterogeneity is caused by interindividual differences in intraindividual change that are unexplained by the variables included in a study. This variability is systematic and, when captured, allows researchers to establish profiles of individuals or groups of individuals that differ in their developmental pathways.

CONCLUSIONS

To integrate our discussion of the use of the person-oriented approach to the analysis of developmental data, and to point to future directions in theory and research that this approach may take, we couch our conclusions in the context of the perspectives of the research planner, the data analyst, and the applied developmental scientist who derives intervention measures from empirical research studies. In addition, we reflect on the question of whether variable-oriented research has become obsolete.

It is well known that statements at the level of aggregated raw data and statements about the relations among variables are almost never valid for individuals. It has been shown that such statements can be used as substitutes for statements in the developing traditions of person-oriented and idiographic research only under very restrictive and unrealistic conditions. Person-oriented approaches to psychological research are fueled by the motive of enabling and facilitating developmental scientists in their efforts of arriving at valid and accurate statements about individuals and groups of individuals. The three most prominent attempts to pursue this motive are differential, person-oriented, and quantitative idiographic psychology. These three approaches, each based on alternative assumptions in their pursuit of arriving at valid and accurate statements concerning the individual, pursue the goal of making statements about individuals based on different assumptions.

Differential developmental psychology requires the assumption that scales that allow one to establish intra- and interindividual differences are equally valid and reliable over time as well as across settings and subpopulations. If this assumption is met, the same score on a scale will have the same meaning and implications for different individuals, under all conditions and at all times. In addition, if this assumption is met, differential, person-oriented, and idiographic psychology coincide.

If, however, the *assumption of universal validity and reliability* is not met, the tenets of person-oriented psychology must be considered, especially the tenet of dimensional identity. This tenet asserts that, for comparisons to be valid, scales must have the same characteristics under all conditions and for all comparison cases. This desideratum applies to all parameters of a scale, including its dimensional structure. If subpopulations exist that differ in scale characteristics, dimensional identity needs to be established for each subpopulation. This applies accordingly to settings and points in time, and to possible changes in scale characteristics that can occur when a scale is repeatedly administered.

In longitudinal, developmental research, the issue of universal validity and reliability becomes even more complex. As Molenaar has shown (e.g., Molenaar & Campbell, 2009) aggregate-level statements can be used as substitutes for statements that are based on parameter estimates at the level of the individual only when stochastic ergodicity theorems apply or, in other words, when development does not take place. By implication, the study of development needs long series of observation, performed at the level of the individual, to create statements that can be generalized to larger groups of cases.

From the perspective of design, planning, and carrying out empirical research, taking a person-oriented perspective has major implications. Developmental scientists assume that more than one (sub)population may exist in a population, the number and relative size of which is rarely known. To have sufficient statistical power to estimate parameters validly for each of these subgroups, the subgroups must be of sufficient size. Considering the fact that a researcher may only have weak information available that can be used to estimate number and size of subpopulations, research planning can become complex.

Taking the perspective of the data analyst, adopting a person-oriented perspective first implies that different methods of analysis be used or developed than would be the case were a variable-oriented perspective to be adopted. In particular, for longitudinal research, methods need to be considered that allow one to estimate parameters at the level of the individual. In this case, aggregation employs individual-level parameters rather than raw data. Methods of statistical analysis of individual data have not as yet been as fully developed as have methods for aggregate-level data. There is ample room for creativity in this domain.

From the perspective of the applied developmental scientist, the fact that aggregate-level statements rarely apply in the individual case renders the usefulness of results that are created at the aggregate level doubtful, at best. If the client who comes for therapy is not properly described by aggregate-level results, it becomes more complicated to use such results in the search for measures of intervention. To describe a client and to derive intervention measures, the applied developmental scientists will need diagnostic tools that meet the criteria of person-oriented and idiographic research. In addition, to make interpretations at the level of the individual, the applied developmental scientist needs knowledge concerning intervention effects that is derived from person-oriented research.

From the perspective of the client—whether individual or organization—the person-oriented research approach is highly beneficial. Various interventions, ranging from individual therapy to youth development (see, e.g., Lerner et al., Chapter 16, this *Handbook*, this volume) and medical programs, will be customized to the individual case; thus increasing the likelihood of their success. This implication is not utopian as psychotherapeutic and medical intervention already follow this path of customizing interventions to the individual (e.g., person-centered cancer therapy, Cancer Center, 2012).

The summary message of this chapter is that (a) aggregate-level statements frequently miss the individual, (b) person-oriented research is needed to do justice to the characteristics of individuals, (c) research from a person-oriented perspective is highly feasible but additional creative efforts are needed, and (d) the person-oriented perspective has the potential of leading to applied programs that are more effective than programs derived from aggregate-level research measures.

In the context of this summary message concerning the value of a person-oriented approach to developmental science, it must also be noted that aggregate-level and variable-oriented research, when properly employed, remain valuable tools in addressing significant scientific questions. These questions concern the identification of what is known as the *universalia* of psychology (i.e., elements that apply to every individual) that we discussed earlier. Questions of this type are often asked at the beginning of an investigation, or when a more sociological perspective is taken. Earlier, we noted that general concepts such as *extraversion, intelligence, motive strength*, and developmental concepts such as *intelligence divergence* or *puberty* qualify as universals. Every individual can be described by profiles whose elements are constituted by universals. However, it is the task of person-oriented research (a) to establish that such elements, indeed, are universals, (b) to identify instruments that are not applicable to all members of a population, (c) to identify developmental pathways that are unique or specific to groups of individuals, and (d) to apply methods of sampling, data collection, and data analysis that result in correct generalizations that apply to individuals.

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