SIXTH EDITION

CHILDREN'S THINKING

Cognitive Development and Individual Differences

DAVID F. BJORKLUND / KAYLA B. CAUSEY

Children's Thinking

Sixth Edition

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CONTENTS

PREFACE

There has been both continuity and change in the 6th edition of *Children's Thinking*. Concerning continuity, we continue to see cognitive development as a dynamic field. Theories and research findings from a variety of areas combine to produce a picture of a developing child who is born prepared to make some sense of the world but whose mind is also shaped by forces in the physical and social environment. This theme, of the continuous transaction between an embodied child embedded in a social world, continues to serve as the focus of the 6th edition. Throughout this book we attempt to present cognitive development not as a series of separate accomplishments (e.g., memory, language, theory of mind, executive function) but as a process that involves the dynamic interaction between an active organism with a changing environment. As such, we strive to integrate biological (e.g., genetics, brain functioning) with sociocultural and evolutionary factors to describe and explain human cognitive development.

In addition, as in past editions, we emphasize not only the typical patterns of change in thinking observed over time (cognitive development) but also individual differences in children's thinking in infancy, childhood, and adolescence. Moreover, children use their developing cognition to solve real-world problems, and many of those problems are related to acquiring the skills necessary for success in a highly technological world. Research and theory in cognitive development should do more than inform researchers: They should also provide insights, both for parents and teachers, in how best to deal with children. Although this new edition is in no way a "how to" book for educating children, as in previous editions, we describe research that has implications for education, making it useful for students training to be teachers as well as psychologists.

Concerning changes, there are two big ones and many smaller ones. The big changes include a new publisher, SAGE, that recognizes the importance of a book like this for the field of developmental psychology, and a new coauthor, Kayla Causey. Kayla is a lecturer in the Departments of Environmental Studies and Psychology at California State University, Fullerton. Trained as a cognitive developmentalist and well versed in the latest statistical techniques, theories, and methodologies of cognitive development, she brings a fresh perspective and lively pen to the book, especially important for a discipline that is being influenced by innovations in related fields, such as neuroscience and quantitative analyses.

Somewhat smaller changes in the book include the integration of several contemporary themes in cognitive development, including the neoconstructivist approach, the Goldilocks effect, Bayesian probabilistic reasoning, "hot" and "cold" executive functioning, perceptual narrowing, and causal representation, among others. We also expanded discussion of sociocultural perspectives in several key areas, including gender cognition, language, and the effects of media on the development of attention.

This edition also extends a trend begun in earlier editions of including more research from developmental cognitive neuroscience. There has been a "biologizing" of cognitive development in recent years, and this is most reflected in research looking at how the brains of infants and children change over time and are associated with different patterns of cognitive functioning. We firmly believe that *mind* is a state of brain, and, although knowing what's happening in the brain will not, by itself, tell us what we, as psychologists, need to know, it is an essential ingredient in understanding cognitive development. However, having a developmental theory of the brain does not obviate having a developmental theory of the mind. Our job is to develop an understanding of how children's thinking changes over time and how such changes affect children's functioning in their world. Knowing something about the biology of thinking can help us achieve this goal, although it is not the goal itself. We were careful not to make this book about developmental cognitive neuroscience but to keep the focus on cognitive development, with neuroscience research supporting, rather than replacing, the psychological perspective.

Related to this biologizing of development is an increased interest in evolutionary thinking—how selective pressures in our ancient past may influence how children develop and function today. We have been proponents of the field of evolutionary developmental psychology and believe that such a perspective has much to offer the discipline of cognitive development. This perspective is outlined in Chapter 2, "Biological Bases of Cognitive Development," and found, where appropriate, in various chapters in the book.

Several pedagogical features from the earlier editions have been retained in the 6th edition. These include a glossary that has all the key terms at the end of the book and the *Key Terms and Concepts* and *Suggested Readings* sections at the end of each chapter. As in the 5th edition, we provide a *Scholarly Works* category and *Reading for Personal Interest* category in the *Suggested Readings* section, the latter including books, articles, and websites suitable for an educated lay audience. Each suggested reading is followed by a brief paragraph explaining why a particular entry is worth perusing.

Other pedagogical features are new to the 6th edition. Long end-of-chapter summaries were replaced with more concise *Section Reviews* following each major section within the chapter. The 6th edition also features *Ask Yourself . . .* questions, consecutively numbered after each *Section Review*, to engage students in reflection and critical thinking. Instructors may find it helpful to assign these questions to students as a "reading check." Boxes were omitted, with most of the information integrated within the text. Feedback we received from students and some instructors suggested that boxed material was the most likely to be skipped material in a chapter. Although textbook writers and instructors often see boxes as an opportunity to include some interesting information related to a topic, students are more apt to see them as an opportunity to reduce their reading with little fear of missing "anything important." We decided that if it's important enough to put in the book, it's important enough to be integrated in the text.

As in previous editions, the 6th edition provides up-to-date research and theory on cognitive development appropriate for graduate and upper-level undergraduate students. Although the total number of references cited in the book remains about the same as in the previous edition, approximately 30% of all references are new to the 6th edition. We aimed to make the book reader-friendly and accessible throughout, reducing discussion of some topics while adding topics that may be of greater interest to a broader range of students. Each chapter starts with a vignette illustrating some concept or phenomenon discussed in the chapter, easing students into the chapter.

The general organization of the book remains unchanged from the 5th edition—13 chapters, all with the same titles as found in the previous edition. However, continuity at the chapter level belies some substantial changes in the content of many chapters. Several chapters have been reorganized, and, throughout each chapter, recent groundbreaking research is summarized to demonstrate and support important concepts and theories in the field. The following provides specific chapter-by-chapter changes to the 6th edition.

CHAPTER-BY-CHAPTER EXAMINATION OF CHANGES BETWEEN 5TH AND 6TH EDITIONS

All chapters in the 6th edition have been substantially revised. There are many new tables and figures, sometimes replacing older research discussed in previous editions, sometimes presenting new phenomena. Here we discuss what we see as major organizational changes (and stabilities) between the 5th and 6th editions of *Children's Thinking*.

Chapter 1. Introduction to Cognitive Development

Chapter 1 has been streamlined to provide a more reader-friendly introduction to the field of cognitive development. We retained all major sections from the previous edition (*Basic Concepts of Cognitive Development*, *Six Truths of Cognitive Development*, and *Goals of Cognitive Developmentalists*) but reduced coverage of some topics that are discussed in more detail elsewhere in the book (for example, *What Does It Mean to Say Something Is Innate?* and *Dynamic Systems Approaches to Development*). This chapter now provides what we believe is a comprehensible introduction to the major concepts and issues of cognitive development, giving students the background to understand what is to come, without bogging them down in details that will make more sense to them as they read further in the book.

Chapter 2. Biological Bases of Cognitive Development

The organization of this chapter remains essentially the same between the 5th and 6th editions. The opening section *Evolution and Cognitive Development* discusses evolutionary theory and features an expanded section on evolutionary developmental psychology, including some of the material omitted from Chapter 1 of the previous edition (e.g., a discussion of the various types of constraints on development) and a new section, *Evolved Probabilistic Cognitive Mechanisms*. The remaining major sections—*Models of Gene-Environment Interaction*, *Development of the Brain*, and *Developmental Biology and Cognitive Development*—are the same in both editions, although they have been substantially updated. For example, we modified the discussion of recovery of function from brain damage to discuss the early plasticity versus early vulnerability perspectives, included a section on interactive specialization models of brain development, and eliminated sections on neural Darwinism and the evolution of the human brain.

Chapter 3. Social Construction of Mind: Sociocultural Perspectives on Cognitive Development

We made both substantial additions to and deletions from this chapter. As in the previous edition, we begin the chapter with an overview of the sociocultural perspective on cognitive development, giving special attention to Vygotsky's theory and related research. We replaced the two previous major chapter headings, *Implications for Education* and *Sociocultural Theory of Cognitive Development*, with two new ones: *Cognitive Artifacts That Support and Extend Thinking: Tools of Intellectual Adaptation* and *Social Origins of Early Cognitive Competencies*. These changes reflect mostly a reorganization of information, intended to provide an easier-to-follow organization, as well as the inclusion of new topics (for example, WEIRD—Western, educated, industrialized, rich, and democratic—societies; children as digital natives). The chapter is slightly shorter than in the 5th edition, in part because issues related to the sociocultural perspective of cognitive development are found increasingly in other chapters of the 6th edition.

Chapter 4. Infant Perception and Cognition

This chapter maintains much of the organization of the previous edition, providing an introduction to methods used to study infant cognition as well as a review of the literature on perceptual and cognitive abilities during infancy. We discuss the development of many of these capacities through childhood in later chapters, and so this chapter remains focused on those abilities that are present at birth and/or come online within the first year of life. We added a section on perceptual narrowing, incorporated discussions of Bayesian learning and the neoconstructivist (or rational constructivist) approach, and omitted the former sections *Intersensory Redundancy Hypothesis* and *Category Learning*, making reference to this latter topic in the section *Habituation/Dishabituation Paradigm*.

Chapter 5. Thinking in Symbols: Development of Representation

This chapter is longer in the 6th edition, reflecting the continued interest in the important topic of the development of representation among developmental scientists. However, the basic organization of the chapter remains unchanged from the 5th edition (*Learning to Use Symbols*, *Piaget's Theory*, *Everyday Expressions of the Symbolic Function*, *Fuzzy-Trace Theory*, and *The Symbolic Species*), with the exception of the addition of a new major section, *Causal Representation*. We also added or expanded coverage of some hot topics in the development of representation, including the role of symbolic play in cognitive development and young children's difficulty distinguishing real objects from their symbolic representation, as reflected by their "scale errors," their ability to hold multiple representations in mind, and by the ease with which imaginary objects or events can be brought to mind.

Chapter 6. Development of Folk Knowledge

The general organization of Chapter 6 remains the same as the 5th edition. We begin with an overview of the *theory theory* approach to cognitive development, followed by major sections devoted to folk psychology, folk biology, and folk physics. We incorporated the neoconstructivist perspective introduced earlier in the text and included description of some relevant findings in brain imaging. We largely omitted the discussion on children's intuitive theories of the afterlife in the folk psychology section but added research describing children's theories about *prelife*, as well as a brief discussion of second-order theory of mind. We added a section on tool innovation under the folk physics section, as well as information regarding the role of executive function in children's understanding of time. We updated research on cross-cultural comparisons in multiple sections.

Chapter 7. Learning to Think on Their Own: Executive Function, Strategies, and Problem Solving

The major headings for Chapter 7 are the same in the 6th edition as in the 5th edition: *Assumptions of Information-Processing Approaches*, *Development of Basic-Level Processes: Executive Function*, *Development of Strategies*, and *Learning to Solve Problems*. We expanded coverage of executive function, reflecting the increasing importance of this area of research in cognitive development, and added two subsections: *Executive Function, Self-Control, and "Hot" EF* and *Executive Functioning and Brain Development*.

Chapter 8. Memory Development

Most of the topics examined in this chapter in the 5th edition are also examined in the current edition, as reflected by the same major headings in the two editions: *Representation of Knowledge*, *Memory Development in Infancy*, *Infantile Amnesia*, *Implicit Memory*, *Development of Event Memory*, *Children as Eyewitnesses*, and *Remembering to Remember*. While expanding coverage of research on these central topics—including developmental neuroscience studies—we omitted the section *Consistency and Stability of Memory*, believing it to be a bit esoteric for most readers, and expanded discussion of the development of prospective memory in the *Remembering to Remember* section.

Chapter 9. Language Development

The organization of Chapter 9 is the same in the 6th edition as in the 5th edition: *What Is Language?*, *Describing Children's Language Development*, *Some Theoretical Perspectives of Language Development*, *Bilingualism and Second-Language Learning*, *Sex Differences in Language Acquisition*, and *Language and Thought*, with each major section updated to reflect the most current thinking in the field. One major deletion is the previous discussion on language learning in chimpanzees (*Is Language Unique to Humans? Can Apes "Talk"?*). Although especially interesting for many people, this research topic is only tangentially related to children's language development. A major addition to this edition is a new subsection titled *Effects of Socioeconomic Status on Language Development*, focusing especially on the 30-million-word gap between the number of words children from high-income versus low-income families hear by their 3rd birthdays and its consequences.

Chapter 10. Social Cognition

Most of the same topics covered in this chapter in the 6th edition were also covered in the 5th edition (social learning, social cognitive theory, social information processing, the development of a concept of self, and cognitive bases of gender identity), although the organization has changed a bit. We incorporated discussion of most aspects of Bandura's social cognitive theory under the *Social Learning* main heading, with self-efficacy now discussed in the section *Development of a Concept of Self*. The subsection *Age Differences in Social Learning* was substantially expanded, including new research on overimitation. We deleted the former section *Social Learning in Chimpanzees*, although some research discussed in this former section, as well as more recent research, was integrated in other subsections in the chapter. We deleted the section *Gender Knowledge and Sex-Typed Behavior: Possible Predispositions*, replacing it with the section *Gender Cognition in Transgender Children*.

Chapter 11. Schooling and Cognitive Development

The same general topics are covered in the 6th as in the 5th edition of this chapter, but the organization has changed some, with some substantial additions to and deletions from the chapter. With respect to the major section *Development of Reading Skills*, we merged the former section *Emergent Literacy* with *Overview of Learning to Read*, adding a subsection titled *Stages of Learning to Read*. We reorganized the section *Cognitive Development and Reading*, including new subsections titled *Letter Knowledge* and *Rapid Automatized Naming (RAN)*, along with subsections titled *Phonemic Awareness*, *Working Memory*, and *Phonological Recoding*. We deleted the former section *How to Teach Children to Read*. We also reorganized the major section *Children's Number and Arithmetic Concepts*. The first major subsection is new, presenting Siegler and Lortie-Forgues's integrative theory of numerical development, followed by sections titled *Development of Conceptual and Procedural Mathematical Knowledge* and *Variations in Developing Mathematical Proficiency: Math Disabilities, Cultural Differences, and Sex Differences*. We deleted the former section *What Do Mathematically Gifted Females Do?* Coverage in the major section *Schooling and Cognitive Development* is much as it was in the 5th edition, although we moved the subsection *Costs and Benefits of Academic Preschools* to the section *Evolutionary Educational Psychology*. This latter section was modified quite a bit, including an expanded section contrasting discovery learning and direct instruction and the addition of a subsection titled *"Educational" DVDs and Videos for Infants*, in which we discuss the video-deficit effect reported in young children, all framed by evolutionary educational theory.

Chapter 12. Approaches to the Study of Intelligence

We cover most of the same topics in the 6th edition as in the 5th edition: *Psychometric Approach to the Study of Intelligence*, *Information-Processing Approaches to the Study of Intelligence*, *Sternberg's Theory of Successful Intelligence*, and *Gardner's Theory of Multiple Intelligences*. We made a number of minor deletions and a comparable number of additions, mostly updating research findings.

Chapter 13. Origins, Modification, and Stability of Intellectual Differences

We cover the same major topics in this chapter in the 6th edition as we did in the 5th edition:

Transactional Approach to the Study of Intelligence, *Behavioral Genetics and the Heritability of Intelligence*, *Experience and Intelligence*, and *Stability of Intelligence*, with most additions expanding important topics but also with some significant deletions. The deletions include the discussion of prenatal factors influencing estimates of heritability, the section *How Seriously Should We Take Heritability Studies of IQ?*, and the discussion of the Becker and Gersten (1982) research on the results of Project Follow Through.

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Anyone who writes a book such as this does so with much help from many people. David Bjorklund would like to express his greatest gratitude to his wife, Barbara, who provided constructive criticism on many chapters, while working on a textbook of her own—all in addition to being a supportive and understanding spouse. Kayla Causey thanks her husband, Aaron Goetz, for encouraging her to pursue this textbook. Despite his own substantial professional obligations, he always finds time to be an enthusiastic sounding board and capable parent to their son, Simon, providing her the time (and quiet) needed to write. Kayla would also like to acknowledge Simon for the anecdotes he provides and the theoretical questions he poses, just by being himself. He's an excellent pilot subject too. There is perhaps no greater joy to a cognitive developmentalist than observing what she already knows (and to a larger extent, what she's yet to understand) in the behavior of her own child.

We would like to thank our editor, Lara Parra, for her willingness to take on this project, as well as the many other specialty editors and support people at SAGE for making this book possible. We want to thank our students and colleagues for their many discussions with us over the years on issues central to this book, especially Carlos Hernández Blasi, Marc Lindberg, Wolfgang Schneider, Patrick Douglas Sellers II, Karin Machluf, and Martha Hubertz. Finally, we would like to thank the conscientious professional reviewers for their consistently constructive comments:

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One of the benefits of writing a textbook is how much you learn in the process. We hope that this book conveys the excitement we felt in discovering some of these new findings in the field of cognitive development. The book is not just about "what's new," however, but about the field as a whole, including classic studies from earlier decades. Although we have often focused on the new, we have attempted not to forget the tried and true research that still informs us about the nature of children's thinking today. And we have tried to make connections among different levels of analysis—macroprocesses and microprocesses, biology and environment, cognitive development and individual differences—to provide a synthesis of the field of cognitive development. And we enjoyed (almost) every minute while doing it.

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CHAPTER

1 INTRODUCTION TO COGNITIVE DEVELOPMENT

IN THIS CHAPTER

No one can remember what 4-year-old Jason did to get his father so upset, but whatever it was, his father wanted no more of it.

"Jason, I want you to go over to that corner and just *think* about this for a while," his father yelled.

Instead of following his father's orders, Jason stood where he was, not defiantly, but with a confused look and quivering lips, as if he were trying to say something but was afraid to.

"What's the matter now?" his father asked, his irritation showing.

"But Daddy," Jason said, "I don't know *how* to think."

Jason did know how to think, of course. He just didn't know that he did. In fact, Jason had been "thinking" all his life, although in a very different way when he was an infant, and his current thinking would not be anything like the mental gymnastics he'd be capable of in just a few years.

Intelligence is our species' most important tool for survival. Evolution has provided other animals with greater speed, coats of fur, camouflage, or antlers to help them adapt to challenging and often changing environments. Human evolution has been different. It has provided us with powers of discovery and invention by which we change the environment or develop techniques for coping with environments we cannot change. Although we are not the only thinkers in the animal kingdom, no other species has our powers of intellect. How we think and the technological and cultural innovations afforded by our intellect separate us from all other animals.

This remarkable intelligence does not arise fully formed in the infant, however. We require substantial experience to master the cognitive feats that typify adult thinking, and we spend the better part of 2 decades developing an adult nervous system. Little in the way of complex thought patterns is built into the human brain, ready to go at birth, although biology obviously predisposes us to develop the ability for complex thought. Our mental prowess develops gradually over childhood, changing in quality as it does.

In this first chapter, we introduce the topic of *cognitive development*—how thinking changes over time. In addition to describing developmental differences in cognition, scientists who study children's thinking are also concerned with the mechanisms that underlie cognition and its development. How do biological (genetic) factors interact with experiences in the physical and social world to yield a particular pattern of development? How do children of different ages represent their world? Does a 3-year-old understand the world in much the same way as a 10-year-old, or are these children qualitatively different thinkers? Once a pattern of intellectual competence is established, does it remain stable over time? Will the bright preschooler become the gifted teenager, or is it pointless to make predictions about adult intelligence from our observations of children? These and other issues are introduced in this chapter, but they are not answered until later in the book. Before delving too deeply into these issues, however, we need to define some basic terms (see Table 1.1). These definitions are followed by a look at some issues that define the field of cognitive development and have been the focus of controversy during the last century.

TABLE 1.1 **Basic concepts in cognitive development.**

Cognition
The processes or faculties by which knowledge is acquired and manipulated. Cognition is usually thought of as being mental. That is, cognition is a reflection of a mind. It is not directly observable but must be inferred.

Development
Changes in structure or function over time. Structure refers to some substrate of the organism, such as nervous tissue, muscle, or limbs, or—in cognitive psychology—the mental knowledge that underlies intelligence. Function denotes actions related to a structure and can include actions external to the structure being studied, such as neurochemical or hormonal secretions and other exogenous factors that can best be described as "experience"—that is, external sources of stimulation. Development is characteristic of the species and has its basis in biology. Its general course, therefore, is relatively predictable. Development progresses as a result of a bidirectional, or reciprocal, relationship between structure and function and can be expressed as structure function.

Developmental function
The species-typical form that cognition takes over time.

Individual differences
Differences in patterns of intellectual aptitudes among people of a given age.

Source:

BASIC CONCEPTS IN COGNITIVE DEVELOPMENT

Cognition

Cognition refers to the processes or faculties by which knowledge is acquired and manipulated. Cognition is usually thought of as being mental. That is, cognition is a reflection of a mind. It is not directly observable. We cannot see the process whereby an 8-month-old discovers that a Mickey Mouse doll continues to exist even though it is hidden under a blanket out of her sight, nor can we directly assess the steps a 7-year-old takes to compute the answer to the problem 15 – 9 = ?. Although we cannot see or directly measure what underlies children's performance on these and other tasks, we can infer what is going on in their heads by assessing certain aspects of their behavior. That is, cognition is never measured directly. It is inferred from the behaviors we can observe.

What psychologists can observe and quantify are things such as the number of words children remember from a list of 20, the number of seconds it takes to identify well-known pictures or words, or the amount of time a 6-month-old spends looking at a picture of a familiar face relative to that of an unfamiliar one. For the most part, cognitive developmental psychologists are not really interested in these overt, countable behaviors; what they *are* interested in are the processes or skills that underlie them. What mental operations does a 6-year-old engage in that are different from those performed by a 4-year-old or an 8-year-old? How does speed in identifying words reflect how information is stored in the minds of children of different ages? What kind of mental picture has the infant formed of the familiar face of his mother that allows him to tell her face apart from all other faces? How are such mental pictures created? How are they modified?

This is not to say that cognitive psychologists are unconcerned with socially important phenomena, such as reading, mathematics, or communicating effectively; many are, and they have developed research programs aimed at improving these and other intellectual skills so critical for children's success in a high-tech society. But, for the most part, the behaviors themselves are seen as secondary. What is important and what needs to be understood are the mechanisms that underlie performance. By discovering the mental factors that govern intelligent behavior, we can better understand behavior and its development, which in turn can help us better understand children and foster their development.

Cognition includes not only our conscious and deliberate attempts at solving problems but also the unconscious and nondeliberate processes involved in routine daily tasks. We are not aware of the mental activity that occurs when we recognize a familiar tune on the radio or even when we read the back of a cereal box. Yet much in the way of cognitive processing is happening during these tasks. For most of us, reading has become nearly automatic. We can't drive by a billboard without reading it. It is something we just do without giving it any "thought." But the processes involved in reading are complex, even in the well-practiced adult.

Cognition involves mental activity of all types, including activity geared toward acquiring, understanding, and modifying information. Cognition includes such activities as developing a plan for solving a problem, executing that plan, evaluating the success of the plan, and making modifications as needed. These can be thought of as higher-order processes of cognition, which are often available to consciousness (that is, we are aware that we're doing them). Cognition also involves the initial detection, perception, and encoding of a sensory stimulus (that is, deciding how to define a physical stimulus so it can be thought about) and the classification of what kind of thing it is ("Is this a letter, a word, a picture of something familiar?"). These can be thought of as basic processes of cognition, which occur outside of consciousness (we experience the product but are generally unaware of the process).

Cognition, then, reflects knowledge and what one does with it, and the main point of this book is that cognition develops.

Development

Change Over Time

At its most basic, **development** (or **ontogeny**) refers to changes in structure or function over time within an individual. **Structure** refers to some substrate of the organism, such as nervous tissue, muscle, or limbs, or—in cognitive psychology—the mental knowledge that underlies intelligence. When speaking of cognitive development, we use *structure* to mean some hypothetical mental construct, faculty, or ability that frames knowledge and changes with age. For example, children's knowledge of terms such as *dog*, *lion*, and *zebra* could be construed as existing in some sort of mental structure (think of it as a mental dictionary), with the meanings of these words changing over time. Or we could hypothesize some form of mental organization that permits children to place objects in serial arrays according to height, shortest to tallest.

In contrast to structure, **function** denotes actions related to a structure. These include actions external to the structure being studied, such as neurochemical or hormonal secretions, and other factors external to the individual that can best be described as "experience"—that is, external sources of stimulation. Function can also be internal to the structure itself—for example, the exercise of a muscle, the firing of a nerve cell, or the activation of a cognitive process, such as retrieving from memory the name of your first-grade teacher or computing the answer to the problem $26 + 17 = ?$. With respect to cognitive development, function refers to some action by the child, such as retrieving the definition of a word from memory, making comparisons between two stimuli, or adding two numbers to arrive at a third.

Development is characteristic of the species and has its basis in biology. Its general course, therefore, is relatively predictable. By viewing development as a biological concept that is generally predictable across all members of the species, we do not mean to imply that experience and culture do not also play a role in development. During the last several decades, developmental psychologists have become increasingly aware that a child's development cannot be described or understood outside of the context in which it occurs, and we address this issue later in this and other chapters, especially Chapter 3.

Structure, Function, and Development

Development is usually conceived as a bidirectional, or reciprocal, relationship between structure and function, in which the activity of the structure itself and stimulation from the environment can contribute to changes in the structure, which in turn contribute to changes in how that structure operates. Function does more than just maintain a structure (that is, prevent it from wasting away); function is necessary for proper development to occur. Function is limited, of course, to the actions that structures are capable of performing. This bidirectional relationship between structure and function can be expressed as structure $\leftrightarrow$ function.

The **bidirectionality of structure and function** (or **structure ↔ function**) can perhaps be most easily illustrated with work in embryology. Chick embryos, for example, display spontaneous movement before muscle and skeletal development is complete. Such movement obviously stems from the maturation of the underlying structures—in this case, bones, muscle, and nervous tissue. When embryonic chicks are given a drug to temporarily paralyze them for as little as 1 to 2 days, deformations of the joints of the legs, toes, and neck develop, which in turn affect the subsequent movement of the limbs (Drachman & Coulombre, 1962). The spontaneous activity of moving the legs provides critical feedback to the genes, which in normal circumstances leads to a properly developed skeleton (Müller, 2003). In other words, the spontaneous activity (function) of the skeletal structures is necessary for the proper development and functioning of the joints (structure). Development proceeds as a result of the interaction of genes with events and agents external to the genes, including functioning of the body itself, all in feedback loops that, when all goes right, produces a species-typical body.

Let us provide an example of the bidirectional relationship between structure and function at the behavioral level. Individual differences in activity level are found in newborns and are believed to be biologically based (Phillips, King, & DuBois, 1978). A highly active toddler will make it difficult for her parents to confine her to a playpen, resulting in a child who has a greater number of experiences outside of her playpen than a less-active child has. These experiences will presumably affect the child's developing intellect (structure), which in turn will affect that child's actions (function). Thus, inherent characteristics of the child (biological structures) influence her behavior, the experiences she has, and the reactions of others to her—all of which influence the development of the child's underlying cognitive/behavioral structures, and so on.

The *functioning* of mental structures promotes changes in the structures themselves. This view is most clearly reflected in the work of Swiss psychologist Jean Piaget. He believed that the activity of the child (or of the child's cognitive structures) is a necessary condition for development to occur. That is, for structures to change, they must be active. The structure's contact with the external world is responsible, to a large extent, for its development. Such a viewpoint makes children important contributors to their own development. Intellectual growth is the result of an active interaction between acting and thinking children and their world, not simply the environment shaping children's intellect or genes dictating a particular level of cognitive ability. (More is said of Piaget's theory throughout this book, especially in Chapter 5.)

We think it is fair to say that all developmental psychologists agree there is a reciprocal, bidirectional influence between structures (be they physical, such as neurons, or abstract, such as cognitive structures) and the activity of those structures (that is, the child's behavior). There is still much room for debate concerning *how* various subsystems of the child (neuronal, behavioral, social) interact to produce development, but developmental psychologists agree that development must be viewed as a two-way street. Development is *not* simply the result of the unfolding of genetic sequences unperturbed by variations in environment (structure function), nor is it the product of "experience" on an infinitely pliable child (function structure). The concept of the bidirectionality of structure and function is central to developmental psychology and is a theme throughout this book. A more in-depth discussion of bidirectional models of development, along with more examples, is provided later in this chapter and in Chapter 2 during a discussion of the *developmental systems approach*.

Developmental Function and Individual Differences

We examine two aspects of cognitive development in this book: **developmental function**, or cognitive development, and **individual differences**. In the present context, developmental function refers to the form that cognition takes over time—to age-related differences in thinking. What are the mental abilities of infants? What is a 2-year-old's understanding of numbers, words, and family relations? What about that of a 4- or 6-year-old? How do school-age children and adolescents conceptualize cause and effect? How do they evaluate the relative worth of two products in the grocery store? People concerned with developmental function are usually interested in universals—what is generally true about the course and causes of development for all members of the species. Assessments of developmental function, then, are typically based on averages, with individual variations among children being seen as irrelevant.

We all know that at some level, however, this variation *is* important. Our impressive intellectual skills are not uniform among members of the species. Some people at every age make decisions more quickly, perceive relations among events more keenly, or think more deeply than others. How can these differences best be described and conceptualized? What is the nature of these differences? Once differences have been established, to what extent can they be modified? Will differences observed in infancy and early childhood remain stable, or are some intellectual differences limited to a particular time during development?

Substantial variability in cognitive functioning also occurs *within* any given child. A particular 4-year-old will often show a wide range of behaviors on very similar tasks, depending on the context that child is in. Increasingly, developmental psychologists have come to realize the significance of individual differences and variability in cognitive performance among and within people of a given age and to see these variations as providing interesting and important information about developmental outcomes.

Individual differences have developmental histories, making the relationship between developmental function and individual differences a dynamic one. That is, individual differences do not simply constitute genetic or "innate" characteristics of a child. They emerge as children develop, often showing different manifestations at different times in development. Several chapters in this book are devoted exclusively to examining individual differences. In other chapters, individual differences in intellectual abilities are discussed in conjunction with the developmental function of those same abilities.

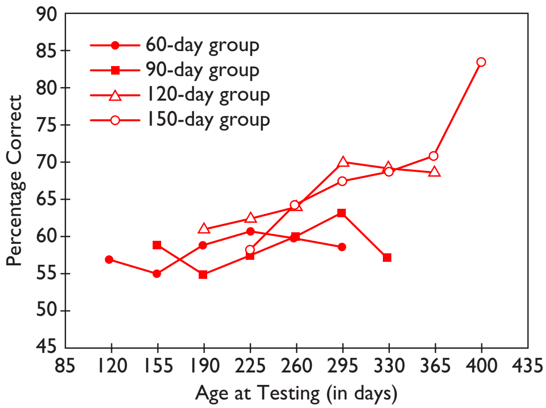
Adaptive Nature of Cognitive Immaturity

We usually think of development as something progressive—going from simple to more complex structures or behaviors, with children getting "better" or more "complete" over time. This is a wholly reasonable point of view, but such a perspective can cause us to interpret early or immature forms of cognition as merely less effective and incomplete versions of the adult model. Although this might generally be true, it is not always the case. Early or immature forms of development can serve some function of their own, adapting the infant or young child to his or her particular environment (Oppenheim, 1981). For example, young infants' relatively poor perceptual abilities protect their nervous systems from sensory overload (Turkewitz & Kenny, 1982); preschool children's tendencies to overestimate their physical and cognitive skills causes them to persist (and, thus, to improve) at difficult tasks (Shin, Bjorklund, & Beck, 2007); and infants' slow information processing seems to prevent them from establishing intellectual habits early in life that would be detrimental later on, when their life conditions are considerably different (Bjorklund & Green, 1992). The point we want to make here is that infants' and young children's cognitive and perceptual abilities might, in fact, be well suited for their particular time in life rather than incomplete versions of the more sophisticated abilities they will one day possess (Bjorklund, 1997b, 2007b; Bjorklund, Periss, & Causey, 2009). In other words, what adults often consider to be immature and ineffective styles of thought might sometimes have an adaptive value for the young child at that particular point in development and should not be viewed solely as "deficiencies."

Consider the case of learning. Learning is good, of course, but is early learning always beneficial? Might providing an infant with too much stimulation or learning tasks too soon in development have a negative effect? There is little research on this issue. In one study, Harry Harlow (1959) began giving infant monkeys training on a discrimination-learning task at different ages, ranging from 60 to 366 days. For example, monkeys were to choose which of several stimuli that varied in several dimensions (size, shape, color, and so on) was associated with a reward. Beginning at 120 days of age, monkeys were given a more complicated learning task. Monkeys' performance on these more complicated problems is shown in Figure 1.1 as a function of the age at which they began training. Chance performance for these problems was 50%. As can be seen, monkeys who began training early in life (at 60 and 90 days) seldom solved more than 60% of the problems and soon fell behind the monkeys who began training later (at 120 and 150 days of age). That is, despite having more experience with the problems, the early trained monkeys performed more poorly than the later-trained monkeys. Harlow (1959) concluded, "There is a tendency to think of learning or training as intrinsically good and necessarily valuable to the organism. It is entirely possible, however, that training can be either helpful or harmful, depending upon the nature of the training and the organism's stage of development" (p. 472).

Might this relate to our species as well? In one of the few such experiments with humans, Hanus Papousek (1977) conditioned infants to turn their heads to a buzzer or a bell. Training

FIGURE 1.1 **Discrimination learning set performance.** Discrimination learning set performance for monkeys as a function of age at which testing was begun.



Source: H. Harlow (1959, December). The development of learning in the Rhesus monkey. *American Scientist*, 459–479. Reprinted with permission.

began either at birth or at 31 or 44 days of age. Infants who began training at birth took many more trials (814) and days (128) before they learned the task than did infants who began later (278 and 224 trials and 71 and 72 days for the 31- and 44-day-old infants, respectively), causing Papousek to write that "beginning too early with difficult learning tasks, at a time when the organism is not able to master them, results in prolongation of the learning process."

Infants need stimulation—interesting objects and, especially, responsive people to speak to and interact with. However, if stimulation is excessive, then it can distract infants and young children from other tasks and may replace activities, such as social interaction, that are vital to their development. We are in no way advocating a "hands-off" policy on educating infants and young children. We are advocating a recognition that infants' limited cognitive abilities may afford them some benefits. We have more to say about "educating" infants in Chapter 11 where we discuss the pros and cons of educational DVDs and videos for infants.

Children's immature cognition can be seen as having an integrity and, possibly, a function of its own rather than being seen only as something that must be overcome. Such a perspective can have important consequences not only for how we view development but also for education and remediation. Expecting children who are developmentally delayed or have learning deficits to master "age-appropriate" skills might be counterproductive, even if possible. Young and delayed children's immature cognition might suit them for mastering certain skills. Attempting to "educate" them beyond their present cognitive abilities could result in advanced surface behavior; however, the general effectiveness of that behavior might be minimally, or even detrimentally, influenced despite considerable effort expended (Bjorklund & Schwartz, 1996; J. F. Goodman, 1992).

Section Review

Cognitive development involves changes in children's knowledge and thinking over time.

Cognition

- *Cognition* refers to the processes or faculties by which knowledge is acquired and manipulated.
- Cognition reflects knowledge and what one does with it, and cognition develops.

Development

- *Development* (or *ontogeny*) refers to changes in structure or function over time within an individual.
- *Structure* refers to some substrate of the organism, such as nervous tissue, muscle, or limbs, or—in cognitive psychology—the mental knowledge that underlies intelligence.
- *Function* denotes actions related to a structure, including actions external to the structure being studied, such as neurochemical or hormonal secretions, and other factors external to the individual that can best be described as "experience."
- The *bidirectionality of structure and function* (or structure ↔ function) refers to the bidirectional, or reciprocal, relationship between structure and function, in which the activity of the structure itself and stimulation from the environment can contribute to changes in the structure, which in turn contribute to changes in how that structure operates.
- *Developmental function* refers to the form that cognition takes over time (that is, to age-related differences in thinking).
- Individual differences in cognitive function exist both between children and within the same child for different tasks.

- Some aspects of infants' and young children's immature cognition may be adaptive in their own right and not viewed as handicaps that must be overcome.

Ask Yourself . . .

1. What is cognition? What does it mean to study the *developmental function* of cognition?
2. What is the bidirectional relationship between structure and function during development?
3. What is meant by individual differences in cognitive development?
4. What are some examples of cognitive immaturity that are adaptive?

SIX TRUTHS OF COGNITIVE DEVELOPMENT

The field of cognitive development encompasses a broad range of topics. Moreover, cognitive developmentalists can be a contentious lot, disagreeing on the best way to conceptualize how thought changes from infancy to adulthood. Nonetheless, we believe there are some truths that typify the study of cognitive development—actually generalizations that we think most developmentalists believe are true about cognitive development and around which controversy and differences of opinion swirl. In the following sections, we examine six truths:

1. Cognitive development proceeds as a result of the dynamic and reciprocal transaction of internal and external factors;
2. Cognitive development is constructed within a social context;
3. Cognitive development involves both stability and plasticity over time;
4. Cognitive development involves changes in the way information is represented;
5. Children develop increasing intentional control over their behavior and cognition; and
6. Cognitive development involves changes in both domain-general and domain-specific abilities.

Cognitive Development Proceeds as a Result of the Dynamic and Reciprocal Transaction of Internal and External Factors

This truth follows from the way we define development as the result of the bidirectional relationship between structure and function over time. In essence, this is modern developmental science's answer to the classic nature/nurture issue, which has been the granddaddy of controversies for developmental psychology over its history. How do we explain how biological factors, in particular genetics, interact with environmental factors, especially learning and the broader effects of culture, to produce human beings? At the extremes are two philosophical camps. Proponents of **nativism** hold, essentially, that human intellectual abilities are innate. The opposing philosophical position is **empiricism**, which holds that nature provides only species-general learning mechanisms, with cognition arising as a result of experience. As stated, each of these two extreme positions is clearly wrong. In fact, as far as developmental psychologists are concerned, there is no nature/nurture dichotomy. Biological factors are inseparable from experiential factors, with the two continuously interacting. This makes it impossible to identify any purely biological or experiential effects. It is often convenient, however, to speak of biological and experiential factors, and when psychologists do, there is always the implicit assumption of the bidirectional interaction of these factors, as discussed earlier in this chapter (that is, structure ↔ function).

At one level, it is trivial to state that biology and experience interact. There is really no other alternative. It's *how* they interact to yield a particular pattern of development that is significant. For example, one currently popular view holds that children's genetic constitutions influence how they experience the environment. A sickly and lethargic child seeks and receives less attention from others than a more active, healthy child does, resulting in slower or less advanced levels of cognitive development. A child who processes language easily might be more apt to take advantage of the reading material that surrounds him than will a child whose inherent talents lie in other areas, such as the ability to comprehend spatial relations. Environment is thus seen as very important from this perspective, but one's biology influences which environments are most likely to be experienced and, possibly, how those experiences will be interpreted. These issues are discussed in greater detail in the chapters devoted to individual differences, particularly Chapter 13, in which the heritability of intelligence and the role of experience in individual differences in intelligence is explored.

What Does It Mean to Say Something Is Innate?

In defining nativism we used the term *innate*. This term can be contentious, and many developmental psychologists would prefer not to see it used at all. The primary reason for many developmental psychologists' discomfort with the concept of innateness is that this term implies **genetic determinism**—the idea that one's genes *determine* one's behavior—which is the antithesis of a truly developmental (that is, bidirectional) perspective. If, in contrast, by innate we simply mean based in genetics, then surely just about every human behavior can be deemed innate at some level, and the term is meaningless. If, however, we mean that a specific type of behavior or knowledge (of grammar, for example) is determined by genetics, with little or no input needed from the environment, then the term has a more specific meaning, but again, it is still not very useful, for, as we'll see more clearly in our discussions in Chapter 2, all genetic effects are mediated by environment, broadly defined.

Some people equate innateness with instinct. The problem here is that instinct is not easily defined. This is made clear by Patrick Bateson (2002), who wrote:

> Apart from its colloquial uses, the term instinct has at least nine scientific meanings: present at birth (or at a particular stage of development), not learned, developed before it can be used, unchanged once developed, shared by all members of the species (or at least of the same sex and age), organized into a distinct behavioral system (such as foraging), served by a distinct neural module, adapted during evolution, and differences among individuals that are due to their possession of different genes. One does not necessarily imply another even though people often assume, without evidence, that it does. (p. 2212)

Many developmental psychologists are just as uncomfortable (or more so) with the term *instinct* as they are with the term *innate*, and for the same reason—its association with genetic determinism. And, as Bateson's quote illustrates, it is not always clear which definition of instinct one is talking about.

Yet some behaviors, or aspects of cognition, do seem to have a strong biological basis and to typify all (or nearly all) members of a species at some time in their development. Rather than referring to such behaviors as being "innate" or as "instincts," we refer to them as *species-typical behaviors*, or *species-typical patterns of cognition*. These are more descriptive terms and do not carry with them any implications about genetic determinism.

Nature/Nurture and Developmental Contextualism

During the past decades, we have noticed two shifts in emphasis in the field of cognitive development that at first glance might seem contradictory. The first is a greater emphasis given to the role of context (including cultural context) in development. The second is a greater acknowledgment of the role of biological factors in development. In a field where nature and nurture have traditionally occupied opposite scientific, philosophical, and often political poles, seeing an increasing emphasis on both seems a contradiction, perhaps reflecting a field composed of mutual antagonists, each taking an extreme perspective to counterbalance the other (much like the U.S. Congress seems to function in recent years). This is not the case, however. The current perspective on the dynamic transaction of nature and nurture is one in which biological and environmental factors not only can peacefully coexist but also are intricately intertwined (Goldhaber, 2012; Gottlieb, 2007).

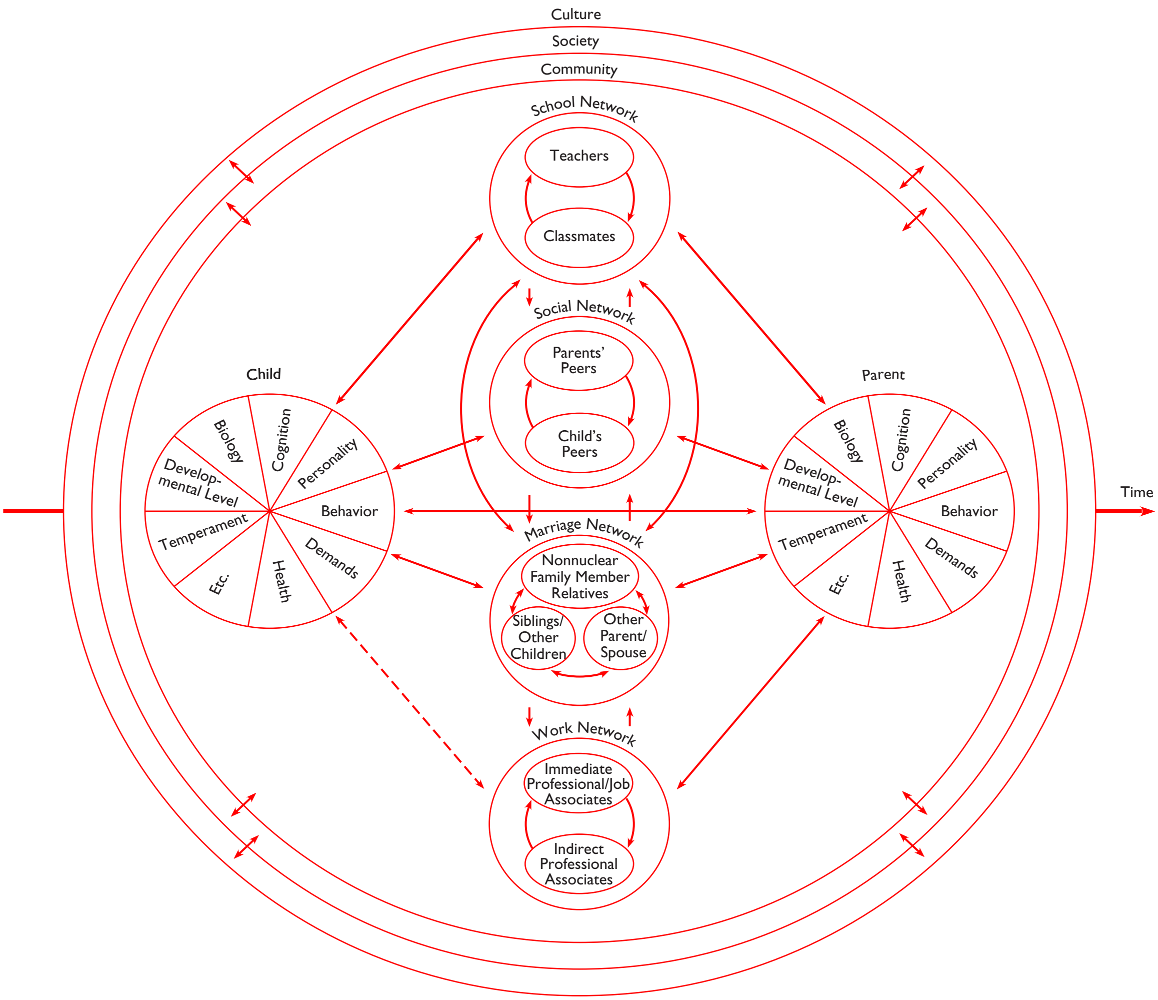
Let us provide one brief illustration of how biology and environment are viewed as separate, interacting components of a larger system. Richard Lerner (1991, 2006) has been a proponent of the **developmental contextual model**. The basic contention of this model is that all parts of the organism (such as genes, cells, tissues, and organs), as well as the whole organism itself, interact dynamically with "the contexts within which the organism is embedded" (Lerner, 1991, p. 27). This means that one must always consider the organism context as a unit and that there are multiple levels of the organism and multiple levels of the context. Figure 1.2 graphically presents the developmental contextual model, showing the many bidirectional influences between children, who are born with biological propensities and dispositions, and the contexts in which they find themselves. Perhaps more than anything else, this figure demonstrates the complexity of development. Of equal importance, however, it demonstrates the interactions that occur between the many levels of life, from genes and hormones to family and culture, and the fact that cultural effects cannot be meaningfully separated from their biological influences, and vice versa. The dynamic nature of development, which results from the interaction of a child at many different levels (genetic, hormonal, physical environment, social environment, self-produced activity, and so on), is a theme that runs through most contemporary theories of development.

Cognitive Development Is Constructed Within a Social Context

As we've presented the developmental contextual model, it should be clear that the social environment plays a central role in determining a child's development. A child's biology interacts with a child's social environment to influence a child's developmental trajectory. However, the social environment is not simply the place, so to speak, where development occurs. The culture in which children grow up also shapes, or constructs, their intellects.

We are a social species, and human development can only be properly understood when the influences of social relations and the broader social/cultural environment are considered. Development always occurs within a social

FIGURE 1.2 A developmental contextual model of person-context interaction.



Source: R. M. Lerner. (1991). Changing organism-context relations as the basic process of development: A developmental contextual perspective. *Developmental Psychology, 27*, 27–32. Copyright © 1991 American Psychological Association. Reprinted with permission.

context, culturally shaped and historically conditioned, although the specific details of a child's social environment can vary widely. From this perspective, one's culture not only tells children *what* to think but also *how* to think (Gauvain & Perez, 2015; Rogoff, 2003; Vygotsky, 1978).

Sociocultural Perspectives

Several **sociocultural perspectives** on cognitive development have emerged over recent decades (Bronfenbrenner & Morris, 2006; Cole, 2006; Rogoff, 2003; see Chapter 3), stemming in large part from the rediscovery of the work of Soviet psychologist Lev Vygotsky (1978). Writing in the 1920s and 1930s, Vygotsky proposed a sociocultural view, emphasizing that development was guided by adults interacting with children, with the cultural context determining largely how, where, and when these interactions would take place. There are many cultural universals, with children around the world being reared in socially structured, language-using groups. Thus, some aspects of development are also universal. But many aspects of culture, such as the available technology and how and when children are expected to learn the survival skills of their society (for example, formal schooling versus no formal schooling), vary greatly. Such differences can have considerable influence on how cognition develops. But how do different cultures construct different experiences for their children to learn, and what consequences does this have for *how* they learn?

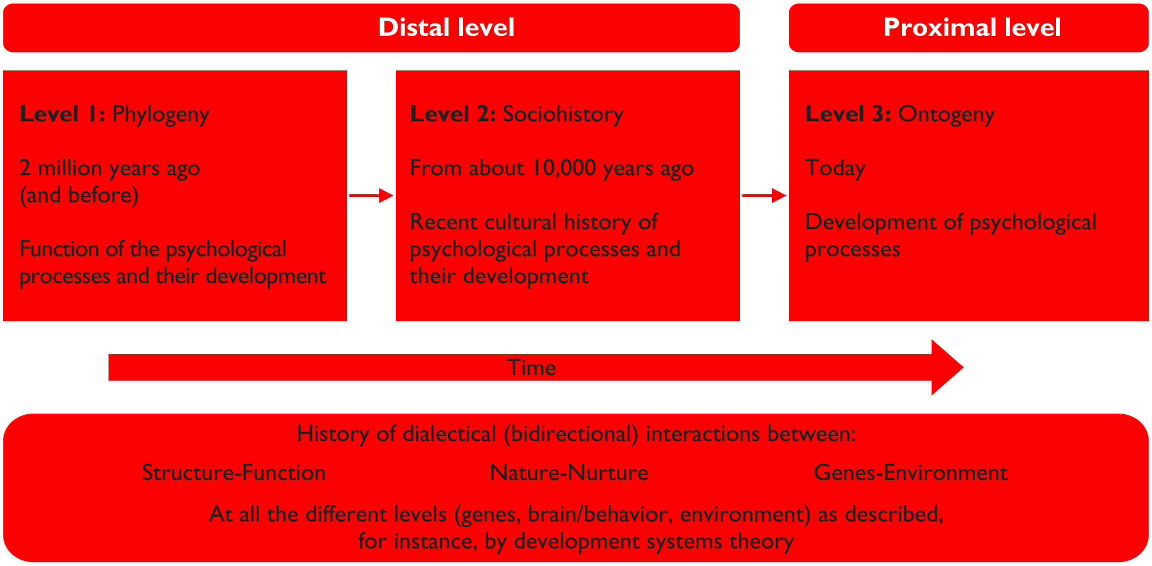
Some researchers have noted that children living in traditional societies are more attentive to what adults do and, thus, develop a keener ability to learn through observation than children from schooled societies such as ours (Lancy, 2015; Morelli, Rogoff, & Angelillo, 2003). These types of cultural experiences affect how children learn. For example, in one study, 6- to 10-year-olds observed a woman creating origami figures and were later asked to make figures of their own (Mejia-Arauz, Rogoff, & Paradise, 2005). Some of the children were of traditional Mexican heritage whose mothers had only basic schooling (on average, a seventh-grade education), and others were of Mexican or European background whose mothers had a high school education or more. The children of the more educated mothers were more likely to request information from the "Origami Lady" than the children with the traditional Mexican heritage. These findings are consistent with the observations that these "traditional" children pay more attention to the actions of the adults and learn more through observation rather than seeking instructions from adults or learning through verbal instructions (see Cole, 2006; Lancy, 2015).

Integrating Approaches

An approach that takes an even longer view of historical influences on development that we think is important for understanding children is *evolutionary theory*, which helps us better understand *why* children and adolescents behave as they do. We believe that a better understanding of the "whys" of development will help us to better understand the "hows" and the "whats" of development, as well as help us to apply knowledge of child development to everyday problems. Theodosius Dobzhansky (1964) famously said, "Nothing in biology makes sense except in the light of evolution" (p. 449). Many psychologists make the same argument for psychology, particularly for understanding the development of infants, children, and adolescents. In fact, anthropologist Melvin Konner (2010) has written that nothing in childhood makes sense except in the light of evolution. The principles of evolutionary developmental psychology are reviewed in Chapter 2.

Developmental contextual, sociocultural, and evolutionary models of development also represent three levels of analysis (see Figure 1.3). Developmental contextual models examine the development of psychological processes over an individual's lifetime, beginning before birth. Sociocultural models also look at the immediate causes of behavior but, in addition, take into account the impact of humans' 10,000-year cultural history on development. Evolutionary theory takes a truly long view of human history, examining the role that natural selection has played in shaping human development, particularly since the emergence of humans about 2 million years ago. We do not view these three approaches as

FIGURE 1.3 **Levels of analysis of developmental phenomena.**



Source: Bjorklund, D. F., & Hernández Blasi, C. (2012). *Child and adolescent development: An integrative approach*. Belmont, CA: Cengage.

competing perspectives of development but as reflecting three different, but compatible, levels of analyses, each of which is important to properly understand development. Because we believe that all of cognitive development (or at least most of it) can benefit from being examined through the lens of these three perspectives, you will find reference to them throughout the book.

Cognitive Development Involves Both Stability and Plasticity Over Time

Cognitive development is about change over time. Yet, once a level of cognitive competence is established, to what extent will it remain constant? Will a precocious infant become a bright 3-year-old and, later, a talented adult? Or is it just as likely that a below-average 5-year-old will become an above-average high school student, or a sluggish infant a whiz-kid computer jock? Once patterns have been established, what does it take to change them? Can they be modified by later experience? How plastic, or pliable, is the human intellect?

The stability and plasticity of cognition are related. **Stability** refers to the degree to which children maintain their same relative rank order over time in comparison with their peers in some aspect of cognition. Does the high-IQ 3-year-old maintain her position in the intellectual pecking order at age 8 or 18? **Plasticity** concerns the extent to which children can be shaped by experience. More specifically with respect to cognition, once a pattern of cognitive ability is established, to what extent can it be altered? Is our cognitive system highly flexible, capable of being bent and rebent, or, once a cognitive pattern has been forged, is it relatively resistant to change?

For the better part of the 20th century, psychologists believed that individual differences in intelligence, for example, were relatively stable over time and not likely to be strongly modified by subsequent environments. These views were held both by people who believed that such differences were mainly inherited and by those who believed such differences were mainly a function of environment, but for different reasons. People on the "nature" side assumed that intelligence was primarily an expression of one's genes and that this expression would be constant over one's lifetime. People on the other side of the fence emphasized the role of early experience in shaping intelligence. Experience was the important component affecting levels of intelligence, with experiences during the early years of life being most critical.

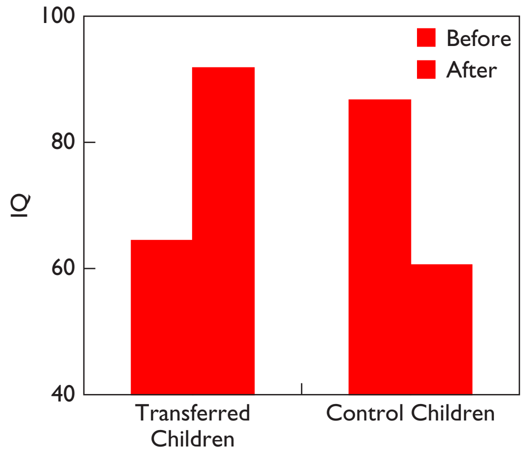
Jerome Kagan (1976) referred to this latter view as the *tape recorder model* of development. Every experience was seen as being recorded for posterity, without the opportunity to rewrite or erase something once it has been recorded. Evidence for this view was found in studies of children reared in nonstimulating institutions (Spitz, 1945). Infants receiving little in the way of social or physical stimulation showed signs of intellectual impairment as early as 3 or 4 months of age. Not only did these deleterious effects become exacerbated the longer children remained institutionalized, they were maintained long after children left the institutions (W. Dennis, 1973). The finding of long-term consequences of early experience was consistent with Freudian theory, which held that experiences during the oral and anal stages of development (from birth to about 2 years) have important effects on adult personality. (This also seems to be the opinion shared by the media and general public.)

Evidence for the permanence of the effects of early experience was also found in the animal literature. For example, Harry Harlow and his colleagues (1965) demonstrated in a series of classic studies that isolating infant rhesus monkeys from their mothers (and other monkeys) adversely affected their later social and sexual behaviors. Without steady interaction with other monkeys during infancy, young monkeys grew up lacking many of the social skills that facilitate important adaptive exchanges, such as mating, cooperation with others, and play. Furthermore, their maladaptive behaviors apparently remained stable over the life of the animals.

Exceptions were found, however, and many began to believe that these exceptions were actually the rule. In one classic study, for instance, infants believed to be intellectually impaired were moved from their overcrowded and understaffed orphanage to an institution for the intellectually impaired (Skeels, 1966). There they received lavish attention by women inmates, and within the course of several years, these children demonstrated normal levels of intelligence. Figure 1.4 shows the average IQs of these children both before they were placed in the institution for the intellectually impaired and approximately 2.5 years later. Also shown are the IQ scores of "control" children, who remained in the same orphanage the experimental children were removed from and who were tested about 4 years later. As you can see, the transferred children showed a substantial increase in IQ (27.5 points), whereas the control children showed a comparable decline (26.2 points). More recent research on the reversibility of intellectual impairment as a result of institutionalization is presented in Chapter 13. In other work, isolated monkeys were placed in therapy sessions with younger, immature monkeys on a daily basis over a 6-month period. By the end of therapy, these isolates were behaving in a reasonably normal fashion and became integrated into a laboratory monkey troop (Suomi & Harlow, 1972). Each of these studies demonstrates plasticity by a young organism and resilience concerning the negative effects of early environments.

Kagan (1976) proposed that one reason to expect resilience is that development does not proceed as a tape recorder. Rather, development is transformational, with relatively drastic

FIGURE 1.4 Average IQ scores before placement and 2.5 years after completion of program for children in the experimental and control groups.



Source: Adapted from data presented in Skeels, H. M. (1966). Adult status of children with contrasting early life experiences. *Monographs of the Society for Research in Child Development, 31* (Serial No. 105).

changes occurring between adjacent stages, or phases. During these times, the "tapes" are changed. Alternatively, methods of representing and interpreting the world change so that the codes of the earlier tapes may be "lost" to the child. The tapes of our infancy might still reside in our heads, but we've lost the ability to play them or, maybe, the ability to understand the code in which they were written. In this view, plasticity should be the rule rather than the exception, especially for the experiences of infancy and early childhood.

One important thing to remember here is that, yes, stimulation and experience are important in the early years of life, but so is later experience. Although early intellectual stimulation is important to get children off to a good start, later experiences are necessary to maintain that positive beginning. And although most children who start life in nonstimulating circumstances remain there, enhancements in intellectual skills are apt to occur for such children if their environments change for the better. This does not mean that there is infinite plasticity in cognitive development but merely that early experience is not necessarily destiny (just as biology is not) and that change is as much a characteristic of human cognition as is stability.

Cognitive Development Involves Changes in the Way Information Is Represented

One key issue that all theories of cognitive development must address concerns age differences in how children represent experience. Most psychologists believe that there is more than one way to represent a thing, and children of different ages seem to use different ways to represent their worlds. Adults, as well, use a variety of techniques to represent knowledge. While providing directions to your house to someone over the phone, for instance, you must convey the route to your home verbally, through a language code. But how is it represented in your head? What is the nature of the **representation**—that is, the mental encoding of information? You might think of the route you take by generating visual images of the buildings and landmarks you pass and then convert those into words. Or perhaps you sketch a map and then transform it into words that can be understood by your listener. What the person on the other end of the phone must do is encode the information. At one level, your friend might attend only to the sounds of the words you speak, encoding the acoustic properties of your utterances. If she does, she will probably be late for dinner. More likely, she will attend to the semantic, or meaning, features of the words. Once a basic meaning has been derived, however, she might convert the message to a mental (or perhaps a physical) map, realizing that she will be better able to find your house if the relevant information is in the form of a visual image. (Or she may just put your address into Google Maps and have Siri give her directions as she drives.)

How children represent knowledge and how they encode events in their world changes developmentally. Traditional theories have proposed that infants and toddlers much younger than 18 months are limited to knowing the world only through raw perception and through their actions on things, with little or no use of symbols. Let us provide an example from the area of memory development. Most people's earliest memories date back to their 4th and possibly their 3rd birthdays. Few people, including 6- and 7-year-old children, are able to recall anything from their earliest years of life, a phenomenon known as *infantile amnesia*. There have been a number of hypotheses about the origins of infantile amnesia, many of which we examine in Chapter 8. One prominent hypothesis is that there are differences in the way experiences are represented between infancy and later in childhood. Infants represent events in terms of sensations and action patterns, whereas preschool and older children (and adults) represent and recall information using language. Support for this position comes from research by Gabrielle Simcock and Harlene Hayne (2002), who showed children ranging in age from 27 to 39 months sequences of actions and interviewed them 6 and 12 months later, both for their verbal and nonverbal memory of the events. Despite having the verbal ability to describe their previous experience, none of the children did so spontaneously. To the extent that children did talk about these prior events, they did so only if they had the vocabulary to describe the event *at the time of the experience*. That is, children who were more verbally sophisticated at the time of initial testing tended to verbally recall some aspects of the event, but children were seemingly not able to translate earlier preverbal experiences into language. According to Simcock and Hayne (2002), "Children's verbal reports were frozen in time, reflecting their verbal skill at the time of encoding, rather than at the time of test" (p. 229).

Most cognitive developmentalists agree that there are age differences in how children represent their world and that these differences are central to age differences in thinking. Researchers disagree, however, about the nature of these differences. Can children of all ages use all types of symbols, and do they simply use them with different frequencies? Or does representation develop in a stage-like manner, with the more advanced forms of symbol use being unavailable to younger children? We believe most researchers today think that children, beginning in infancy, have multiple ways of representing information, although their ability to mentally represent people, objects, and events increases in sophistication over infancy and childhood. Research and theory pertinent to these and other issues related to changes in representation are central to the study of cognitive development, and they are discussed in the pages ahead.

Children Develop Increasing Intentional Control Over Their Behavior and Cognition

Much cognitive developmental (and educational) research is concerned with how children solve problems. And much of what interests cognitive developmental psychologists is how children go about finding solutions to complex problems that might have multiple paths to a solution. For example, how do children solve a puzzle, how do they go about remembering a grocery list, or how do they study for a history exam? Problem solving begins in infancy, but the problems children face, and their solutions, become more complicated with age.

One central concern of cognitive developmentalists has been the degree to which children of different ages can intentionally guide their problem solving. Much research on this topic has addressed the use of strategies. **Strategies** are usually defined as deliberate, goal-directed mental operations aimed at solving a problem (Harnishfeger & Bjorklund, 1990a; Pressley & Hilden, 2006). We use strategies intentionally to help us achieve a specified goal. Strategies can be seen in the behavior of infants. Six-month-olds alter how hard they swing at mobiles over their cribs to yield slightly different movements from the inanimate objects. Eighteen-month-old toddlers will deliberately stack boxes one on top of another so that they can reach the kitchen shelf and the chocolate chip cookies. These strategies are no less willful than the rhyming mnemonic the sixth-grader uses to remember how many days are in each month or the plan the 15-year-old uses as he plays all his trump cards first in a game of bridge. Yet strategies do change with development, and children seem increasingly able to carry out successful strategies as they grow older. So, one key research question in cognitive development concerns changes in the strategies children use and the situations in which they use them.

Although children around the world increasingly display goal-directed problem-solving behavior, this is especially evident for children from technologically advanced societies in which formal schooling is necessary to become a successful adult. Much of what children learn in school can be acquired only (or best) by deliberate study. This contrasts with how children in cultures without formal schooling often learn complicated tasks. In all cultures, much of what children learn about their world they acquire incidentally, without specific intention and, sometimes, even without specific awareness. This type of learning and development is important also, and recent research, particularly in the area of memory development, has recognized this (see Chapter 8).

Many factors are involved in the development of strategic cognition, one of them being how much knowledge children have of the information they are asked to process. For example, when children are asked to remember sets of categorically related words—such as different examples of fruits, clothing, and mammals—they are more likely to use a memory strategy (for instance, remembering all the items from the same category together in clusters) and to remember more of the words if they are *typical* of their category (Schneider, 1986; Schwenck, Bjorklund, & Schneider, 2009). Typical items for the category clothing, for example, would include words such as *shirt*, *dress*, and *pants*, whereas atypical clothing items would include *hat*, *socks*, and *belt*. The latter are all common words and would be well known to children, but they are less typical of what we think of as clothes. How the role of knowledge base influences children's cognition has been a much-studied topic in cognitive development (Pressley & Hilden, 2006; Schneider, 2015).

Becoming a strategic learner involves learning to regulate one's thought and behavior. This involves a set of basic-level cognitive abilities, referred to as executive function. **Executive function** refers to the processes involved in regulating attention and in determining what to do with information just gathered or retrieved from long-term memory. It plays a central role in planning and behaving flexibly, particularly when dealing with novel information. Among the basic cognitive abilities that comprise executive function are (a) *working memory*, the structures and processes used for temporarily storing and manipulating information; (b) inhibiting responding and resisting interference; and (c) cognitive flexibility, the ability to switch between different sets of rules or different tasks. Thus, becoming a "self-directed thinker" (see Chapter 7) involves an understanding of the development of both lower-level cognitive processes (for example, executive function) and higher-level cognitive processes (for example, strategies).

Cognitive Development Involves Changes in Both Domain-General and Domain-Specific Abilities

Theories that postulate cognitive development results from increases in **domain-general abilities** assume that at any point in time, a child's thinking is influenced by a single set of factors, with these factors affecting all aspects of cognition. In contrast to domain-general accounts of cognitive development are theories that postulate that development unfolds as the result of changes in **domain-specific abilities**. This position hypothesizes a certain degree of **modularity** in brain functions, meaning that certain areas of the brain are dedicated to performing specific cognitive tasks (such as processing language). According to these theories, knowing a child's ability for one aspect of cognition might tell us nothing about his or her level of cognitive ability for other aspects of thinking because different cognitive domains are controlled by different mind/brain functions. At the extreme, domain-specific theories propose that different areas of the brain affect different aspects of cognition, with these areas being unaffected by what goes on in other areas of the brain.

Robbie Case (1992) put the controversy between domain-general and domain-specific theorists succinctly: "Is the mind better thought of as a general, all-purpose computing device, whose particular forte is general problem solving? Or is it better thought of as a modular device, each of whose modules has evolved to serve a unique biological function that it performs in its own unique and specialized way?" (p. 3). As we'll see in Chapters 5 and 7, the predominant theories of cognitive development throughout the 20th century were domain-general ones. Moreover, when talking of individual differences in intelligence, such as those measured by IQ tests, those differences have usually been thought of as being domain general in nature (see Chapters 12 and 13). Domain-specific theories arose primarily because of the failure of the domain-general theories to account for the unevenness of cognitive function that is frequently observed in development.

Modularity implies inflexibility, in that the individual is constrained by biology to process certain information in certain ways. This can be good, increasing the likelihood that complex information will be properly processed and understood. In discussing the benefits of constraints for infants, Annette Karmiloff-Smith (1992) states, "They enable the infant to accept as input only those data which it is initially able to compute in specific ways. The domain specificity of processing provides the infant with a limited yet organized (nonchaotic) system from the outset" (pp. 11–13). But the hallmark of human cognition is flexibility. Our species has come to dominate the globe, for better or worse, because we are able to solve problems that biology could not have imagined and have developed technological systems that expand our intellectual powers (such as writing, mathematics, and computers). Such cognition could not be achieved by a totally encapsulated mind/brain, and of course, no serious domain-specific theorist proposes this degree of modularity. What we must keep in mind is the certainty that both domain-general and domain-specific abilities exist, and we must be cautious of claims that postulate otherwise.

Section Review

Six Truths of Cognitive Development

1. Cognitive development proceeds as a result of the dynamic and reciprocal transaction of internal and external factors.
   - *Nativism* (a belief that all intellectual abilities are innate, and proposing a type of *genetic determinism*) and *empiricism* (a belief that all intellectual abilities are a result of experience) have been rejected as adequate explanations for cognitive development.
   - Biological and environmental factors are seen as interacting in bidirectional relationships, with children playing critical roles in their own development, as reflected by *developmental contextual models*.
2. Cognitive development is constructed within a social context.
   - Contemporary theorists view the social environment as being particularly important for cognitive development, as reflected by *sociocultural perspectives*.
   - Some theorists further argue that developmental contextual and sociocultural models of development should be integrated with evolutionary theory to produce a coherent understanding of psychological development.
3. Cognitive development involves both stability and plasticity over time.
   - *Stability* refers to the degree to which children maintain their same rank order relative to their peers over time.
   - *Plasticity* refers to the extent to which individuals can be shaped by the environment.
   - Although for most of the 20th century it was believed that intelligence is relatively stable over time and that experiences later in life cannot greatly affect patterns of intelligence established earlier, more recent research suggests that human intelligence can be substantially modified under certain circumstances.
4. Cognitive development involves changes in the way information is represented.
   - Most researchers today believe that children, beginning in infancy, have multiple ways of representing information, although their ability to mentally represent people, objects, and events increases in sophistication over infancy and childhood.
5. Children develop increasing intentional control over their behavior and cognition.
   - *Strategies* are deliberate, goal-directed mental operations aimed at solving a problem.
   - Strategies are especially important for children from technologically advanced societies in which formal schooling is necessary to become a successful adult.
   - Strategic cognition is influenced by a host of factors, including how much knowledge a child has, and also by a child's levels of *executive function*, referring to processes involved in regulating attention and in determining what to do with information just gathered or retrieved from long-term memory.
6. Cognitive development involves changes in both domain-general and domain-specific abilities.
   - Most traditional approaches to cognitive development have posited *domain-general abilities*.
   - Recent research has shown that many aspects of cognition and its development are *domain-specific* in nature, with some forms of cognition being *modular*.

Ask Yourself . . .

5. What does it mean to say something is innate?
6. What is meant by an integrative approach to development, and what are the three levels of analysis proposed in this textbook?

7. Why is an integrative approach to development important?
8. What does stability in cognitive development refer to? How is this related to plasticity in cognitive development?
9. What do cognitive psychologists mean when they talk about representations?
10. What is strategic cognition, and what factors are important in its development?
11. What is modularity? How does it relate to domain-specific and domain-general abilities?

GOALS OF COGNITIVE DEVELOPMENTALISTS

Although we believe the topics discussed in the previous section reflect the major issues in the study of cognitive development, what underlies all of these issues, as we mentioned in the opening pages of this chapter, is a search for the mechanisms responsible for change. We can observe changes in how children represent their world and see evidence of enhanced intentional, goal-directed behavior with age, but as scientists, we very much want to know the causes of these changes, and much of the research in the remainder of this book addresses this issue. Thus, description of change is not enough, although it is a necessary start.

Another goal for many cognitive developmentalists is to produce research that can be applied to real-world contexts. For example, issues about the stability and plasticity of intelligence have direct applications to the remediation of intellectual impairment and to some learning disabilities. Understanding how children learn to use strategies of arithmetic, memory, and reading, for example, are directly pertinent to children's acquisition of modern culture's most important technological skills (see Chapter 11). Research on factors that influence children's recollection of experienced or witnessed events has immediate relevance to the courtroom, where children have increasingly been called to testify (see Chapter 8). Understanding the typical development of both basic (and unconscious) cognitive processes as well as forms of higher-order (and conscious) cognition provides insight into the causes of some learning disabilities, whether in math and reading (see Chapter 11) or, perhaps, as a result of attention deficit hyperactivity disorder (ADHD) (see Chapter 7). And although extensions to the schoolhouse or clinic may be the most obvious applications of cognitive development research and theory, we believe perhaps the greatest application is to an appreciation of children in general, particularly when they are your own.

KEY TERMS AND CONCEPTS

bidirectionality of structure and function (structure ↔ function)
cognition
development (ontogeny)
developmental contextual model
developmental function
domain-general abilities
domain-specific abilities
empiricism
executive function
function
genetic determinism
individual differences
modularity
nativism
plasticity (of cognition and behavior)
representation
sociocultural perspectives
stability
strategies
structure

SUGGESTED READINGS

Scholarly Works

Bjorklund, D. F. (2013). Cognitive development: An overview. In P. D. Zelazo (Ed.), *Oxford handbook of developmental psychology* (pp. 447–476). Oxford, UK: Oxford University Press. This introductory article for an entire section devoted to cognitive development briefly reviews the major areas of research interest in the field.

Goldhaber, D. (2012). *The nature-nurture debates: Bridging the gap*. New York: Cambridge University Press. This is a scholarly yet highly readable account of the perennial nature-nurture debate. Goldhaber concludes that it is only through an integration of modern evolutionary and developmental theories that we will attain a true understanding of human nature.

Lerner, R. M. (2006). Developmental science, developmental systems, and contemporary theories of human development. In R. M. Lerner (Series Eds.) & W. F. Overton & P. C. M. Molenaar (Vol. Eds.), *Handbook of child psychology and developmental science: Vol. 1. Theoretical models of human development* (6th ed., pp. 1–17). New York: Wiley. This is a relatively lengthy and thorough examination of contemporary theorizing on developmental psychology, focusing on developmental contextual models.

Reading for Personal Interest

Bjorklund, D. F. (2007b). *Why youth is* not *wasted on the young: Immaturity in human development.* Oxford, UK: Blackwell. This book, written for a general audience, takes an explicitly Darwinian view of childhood, including the potentially adaptive role of cognitive immaturity.

Rutter, M. (2006). *Genes and behavior: Nature-nurture interplay explained*. Malden, MA: Blackwell. This book provides a highly readable account of research in behavioral genetics, written by one of the leaders of the field who also knows a thing or two about development. We were tempted to include this in the category *Scholarly Works* because it is so thorough, but it is written so it can be understood by the educated layperson.

CHAPTER

2 BIOLOGICAL BASES OF COGNITIVE DEVELOPMENT

IN THIS CHAPTER

Half of the first term had expired, and Tyler's first-grade teacher requested a conference with his parents. The teacher said that Tyler was a bright, creative, and likeable boy, but he was having some problems concentrating and staying on task. He would often blurt out answers to questions or say things that were not on topic, sometimes about one of his favorite TV shows. He was easily distracted and sometimes acted impulsively with the other children. After discussing some things his parents could do at home to help Tyler stay on task, and proposing that he likely did not have attention deficit hyperactivity disorder, the teacher asked the parents in what month Tyler was born. Tyler's father's first thought was, *Uh oh, we've got a teacher who believes in astrology. What's next, Tarot cards?* But when they answered July, the teacher said, "I thought as much. He's a summer child, one of the youngest children in class, and a boy. His brain isn't as mature as most of the other children's. He'll catch up. He's a bright boy."

This experienced first-grade teacher may not have known that it was the slow-developing frontal cortex of Tyler's brain that was primarily responsible for his control problems or that psychologists refer to processing that involves staying on task, resisting interference, and planning as *executive function*. But this teacher had seen enough to know that "summer children," especially boys, were apt to get off to a slow start in first grade.

As we mentioned in Chapter 1, developmental psychology has become increasingly biological over the past few decades. For some time now, we've been including lectures on the biological basis of cognitive development in our undergraduate classes, discussing brain development and the evolution of mental abilities. This has not always been so. For much of the 20th century, social and behavioral scientists interested in cognition gave only lip service, at best, to biology. The mind might emanate from the brain, but understanding the brain was not seen as a prerequisite to understanding the mind. In fact, there existed in the social and behavioral sciences what can be called *biophobia* and an implicit belief that acknowledging biology was akin to rejecting the influence of environment or culture on behavior, something at odds with the central theme of the social sciences (see Tooby & Cosmides, 1992). The study of cognition was essentially isolated from the study of the brain.

Things have clearly changed. The field of cognitive science takes as a given the close connection between mind and brain. As philosopher John Searle (1992) stated, "Mental phenomena are caused by neurophysiological processes in the brain and are themselves features of the brain. . . . Mental events and processes are as much part of our biological natural history as digestion, mitosis, or enzyme secretion" (p. 1). Moreover, cognitive scientists are concerned not only with immediate biological causes (for example, how the brain affects behavior) but also with factors that influenced the evolution of human cognition.

Looking at the biological basis of cognition and its development does not mean that one ignores the psychological level. Biology and psychology provide different levels of analysis. Much as psychology and anthropology present different pictures of human behavior (one at the level of the individual and the other at the level of the culture), so too do biology and psychology. Moreover, just as concepts in biology must be consistent with the known facts of chemistry, concepts in psychology must be consistent with the known facts of biology. Thus, proposing theories of the mind that are inconsistent with what we know about physiology or evolution cannot lead to a productive theory of cognition (see Cosmides, Tooby, & Barkow, 1992).

Psychology, however, cannot be reduced to biology. Knowing how nerve cells function will not tell us all we need to know about how we think. Developing a theory of the brain is important, of course, but it is not enough. Having a theory of the brain does not obviate having a theory of the mind. Cognitive psychology is not just something to do until the biologists get better at their trade. Developmental psychologists should not blindly accept everything that biologists propose, but they should be mindful of the biological causes of cognitive development and formulate theories and design experiments accordingly (Bjorklund, 1997a).

In this chapter, we first describe evolutionary theory and how such Darwinian ideas can contribute to an understanding of the developing modern child. In the next section, we examine several developmental theories that take biology seriously, particularly the relation between genetic/biologic factors and environmental/experiential factors. We then provide a brief overview of brain development. In this chapter, as in later chapters, we comment on the relation between the brain and cognitive development. Although no one ever doubted that the brain was the seat of cognition, only recently, with the emergence of the field of **developmental cognitive neuroscience**, have brain-cognition relations in development been taken seriously (see M. H. Johnson & de Haan, 2011; Markant & Thomas, 2013). Developmental cognitive neuroscience takes data from a variety of sources—molecular biology, cell biology, artificial intelligence, evolutionary theory, as well as conventional cognitive development—to create a picture of how the mind/brain develops. As will be made clear soon, contemporary biologically based theories of development do not hold that "biology is destiny" but, rather, deal with the classic nature/nurture controversy by explaining how genes and environments interact to produce a particular pattern of development.

Because most research in cognitive development over the last century essentially ignored biological causation, most of what is covered in the rest of the book is at the psychological rather than the biological level. However, we firmly believe that we will develop an understanding of cognitive development only by taking biology seriously, and reference to biological factors is made throughout the remainder of the book.

EVOLUTION AND COGNITIVE DEVELOPMENT

What is the adaptive value of particular cognitive abilities? How might cognitive abilities have a different adaptive value at different times in development? In what contexts should certain cognitive abilities develop? How do some evolved human characteristics, such as bipedality or prolonged immaturity, affect the development of cognition? Developmentalists ask these questions relating to evolution.

Evolutionary Theory

When biologists speak of **evolution**, they (usually) mean the process of change in gene frequencies within populations over many generations that, in time, produces new species. Modern evolutionary theory had its beginnings in the ideas of Charles Darwin, whose 1859 book *On the Origin of Species* represents one of the grandest ideas of science. The book made an immediate impact on the scientific community and is considered by many today to be one of the most important books ever written. The crux of the theory is that many more members of a species are born in each generation than will survive, and these members of the species all have different combinations of inherited traits (that is, there is substantial *variation* among members of a species). Conditions in the environment for that particular generation cause some members of that species to survive and reproduce whereas others do not, a process that Darwin referred to as **natural selection**. The inherited traits of the survivors will be passed on to the next generation of that species, whereas the traits of the nonsurvivors will not. Over the course of many generations, the predominant traits of a species will change by this mechanism. The major principle of Darwin's theory is *reproductive fitness*, which basically refers to the likelihood that an individual will become a parent and a grandparent.

Darwin's theory has gone through some substantial modifications during the last century or so, the most significant being the inclusion of modern genetic theory into formulations of evolution. Among scientists today, the *fact* of evolution is not questioned, although some lively debates center on the *mechanisms* of evolution (see S. J. Gould, 2002). Despite controversies, evolutionary theory is the backbone of modern biology, and because human cognition and behavior are rooted in biology, evolutionary theory should be the backbone of modern psychology.

One thing that evolutionary theory provides is a framework for interpreting all aspects of behavior and development. It does this, in part, by providing not only an explanation for *how* a particular mechanism came about (through natural selection) but also a possible explanation of *why* this mechanism evolved. In my early training, I (DB) was taught not to ask "why" questions. Scientists, I was told, ask "how" questions—for example, "How do children come to appreciate that other people have perceptions and ideas other than their own?" rather than *why* do they develop this ability. Evolutionary theory provides answers to both the "how" and the "why" questions. The "how" is through natural selection over evolutionary time, in that children who could not learn to see the perspectives of another person did not grow up to have children of their own. Of course, this is not a sufficient answer to how this ability develops in individual children, but it does provide a mechanism for how it developed in the species. The "why" suggests that this ability was likely important for survival, or that it was *adaptive*. Children who could understand the perspective of another were able to anticipate other people's actions and act accordingly. Such *adaptationist* reasoning must be used cautiously, of course. Not all aspects of present-day life were necessarily adaptive for our ancient ancestors. Some aspects might have been neutral, some associated with other adaptive characteristics, and others just not sufficiently maladaptive to result in extinction. But having a theory that provides a framework for asking why a particular behavior or pattern of development is present can help us develop a better understanding of human nature and to ask better "how" questions.

It is important to understand that what might have been adaptive for our ancestors 10,000, 100,000, or 1 million years ago might not be adaptive for us today. Our preference for sweets and fat is a good case in point. Although these foods would have been rare and much valued sources of energy for our ancient ancestors, they are easily available to people from postindustrial cultures today and are largely responsible for our high incidence of heart disease (Nesse & Williams, 1994). Many cognitive mechanisms can be seen in a similar light. Alternatively, many of the technological problems we must solve as modern humans are only centuries old at most, and no specific mechanisms have evolved to solve them.

Evolutionary Developmental Psychology

Evolutionary theory is currently influencing cognitive development through the field of **evolutionary developmental psychology** (Bjorklund & Ellis, 2014; Bjorklund, Hernández Blasi, & Ellis, 2016; Bjorklund & Pellegrini, 2002). Evolutionary psychologists have suggested that cognitive psychology is the missing link in the evolution of human behavior. Leda Cosmides and John Tooby (1987) proposed that information-processing mechanisms evolved and that "these mechanisms in interaction with environmental input generate manifest behavior. The causal link between evolution and behavior is made through psychological mechanisms" (p. 277). According to Cosmides and Tooby, adaptive behavior is predicated on adaptive thought. Natural selection operates on the cognitive level—information-processing programs evolved to solve real-world problems. How do I tell friend from foe? When do I fight, and when do I flee?

From this viewpoint, it becomes fruitful to ask what kind of cognitive operations an organism must have "if it is to extract and process information about its environment in a way that will lead to adaptive behavior" (Cosmides & Tooby, 1987, p. 285). From an evolutionary perspective, we must ask what is the purpose of a behavior and the cognitive operations that underlie that behavior, and what problem was it designed to solve.

It is also important to remember that cognitive processes *develop* and that the problems infants and children face are different from the problems adults face. Researchers can fruitfully ask how children's cognitions are adapted to the cultural contexts in which they find themselves rather than to the contexts experienced by adults (Bjorklund, 2007b; Turkewitz & Kenny, 1982). For example, what type of information should helpless infants be attentive to? Might some information that is of vital importance to them be less important to older children and adults, and vice versa?

Most mainstream evolutionary psychologists assume that what evolved are domain-specific mechanisms designed by natural selection to deal with specific aspects of the physical or social environment, such as face recognition or the processing of certain types of social relationships. However, natural selection has also influenced the evolution of domain-general mechanisms (for example, executive function, ability to inhibit thoughts and actions), and a number of developmental psychologists believe that these should also be examined from an evolutionary perspective (Bjorklund & Kipp, 2002; Geary, 2005).

Implicit in the idea that there are domain-specific mechanisms is that there are *constraints* on learning (R. Gelman & Williams, 1998; Spelke & Kinzler, 2007). Constraints imply restrictions, and restrictions are usually thought of as being bad. Human cognition is exceptional for its flexibility, not for its restrictiveness. But constraints, from this perspective, *enable* learning rather than hamper it. Jeffrey Elman and his colleagues (1996) have specified three general types of constraints—*architectural*, *chronotopic*, and *representational*—and we think this taxonomy helps articulate the ways that cognitive developmentalists consider biology to constrain psychological development.

Architectural constraints refer to ways in which the architecture of the brain is organized at birth. For example, some neurons are excitatory and others inhibitory, or neurons can differ in the amount of activation required for them to fire. At a somewhat higher level, neurons in a particular area of the brain might be more or less densely packed or have many or few connections with other local neurons. And at a higher level yet, different areas of the brain are connected with other areas of the brain, affecting the global organization of the organ. Because certain neurons/areas of the brain can only process certain types of information and pass it along to certain other areas of the brain, architectural constraints limit the type of and manner in which information can be processed. Thus, architectural constraints imply limits on what is processed as development progresses.

Chronotopic constraints refer to limitations on the developmental timing of events. For example, certain areas of the brain might develop before others. This would mean that early-developing areas would likely come to have different processing responsibilities than would later-developing areas. Similarly, some areas of the brain might be most receptive to certain types of experiences (to "learning") at specified times, making it imperative that certain experiences (exposure to patterned light or language, for example) occur during this *sensitive period* of development (S. C. Thomas & Johnson, 2008). For example, children around the world acquire language in about the same way and at about the same time. If, however, for some reason children are not exposed to language until later in life, their level of language proficiency is greatly reduced. The human brain appears to be prepared to make sense of language, thus making it easy for children to acquire the language that they hear around them. But such neural readiness is constrained by time. Wait too long, and the ability to acquire a fully articulated language is lost. The issue of developmental timing (and sensitive periods) is discussed with relation to language in Chapter 9.

Representational constraints are a more controversial type of constraint and refer to representations that are hardwired into the brain so that some types of "knowledge" are innate. This type of innateness corresponds to what most people think of when they talk about innate concepts. For example, several theorists have proposed that infants come into the world with (or develop very early in life) some basic ideas about the nature of objects (their solidity, for example), mathematics (simple concepts of numerosity), or grammar (see Pinker, 1997; Spelke & Kinzler, 2007; and Chapters 4, 6, and 9 of this book). Children enter a world of sights, sounds, objects, language, and other people. If all types of learning were truly equiprobable, children would be overwhelmed by the stimulation that bombards them from every direction. Instead, the argument goes, infants and young children are constrained to process certain information in "core domains" (such as the nature of objects, language) in certain ways, and this leads to faster and more efficient processing of information within specific domains.

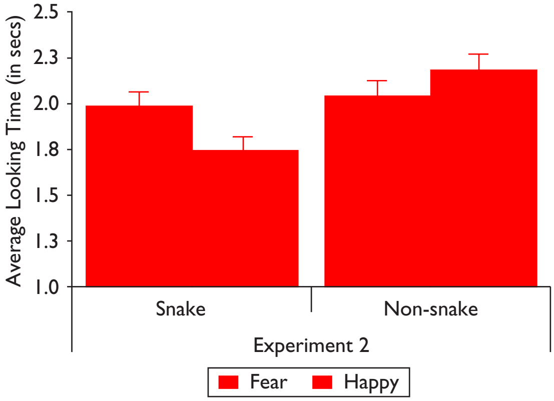
Evolved Probabilistic Cognitive Mechanisms

From this perspective, humans are "prepared" by natural selection to process some information more readily than others (language, for example). *But prepared is not preformed* (Bjorklund, 2003). Instead, these constraints are the products of structured gene × environment × development interactions that emerge in each generation and are influenced by prenatal as well as postnatal environments. Consistent with this idea, David Bjorklund, Bruce Ellis, and Justin Rosenberg (2007) proposed the concept of **evolved probabilistic cognitive mechanisms**:

> information-processing mechanisms that have evolved to solve recurrent problems faced by ancestral populations; however, they are expressed in a probabilistic fashion in each individual in a generation, based on the continuous and bidirectional interaction over time at all levels of organization, from the genetic through the cultural. These mechanisms are universal, in that they will develop in a species-typical manner when an individual experiences a species-typical environment over the course of ontogeny. (p. 22)

As an example of how evolved probabilistic cognitive mechanisms may work, consider the phenomenon of *prepared fear*. Monkeys raised in a laboratory show no fear of snakes. However, such monkeys are more likely to react fearfully after watching another monkey respond with fright to a snake than to a rabbit or a flower (Cook & Mineka, 1989), suggesting they are prepared to make fearful associations to snakes rather than having an innate fear of them. Something similar seems to happen with human infants and children. For instance, Vanessa LoBue and Judy DeLoache reported that 3- and 5-year-old children (LoBue & DeLoache, 2008, 2010) and 8- to 14-month-old infants (LoBue & DeLoache, 2010) more readily identified snakes or spiders among pictures of flowers or mushrooms than the reverse (something also found for adults; Öhman, Flykt, & Esteves, 2001). Yet children do not seem to have an innate fear of snakes but rather show a tendency to associate them with fearful responses. DeLoache and LoBue (2009) demonstrated this in studies in which 7- to 9-month-old infants and 14- to 16-month-old toddlers watched brief videos of snakes and other animals (for example, giraffes, rhinoceroses). The children initially showed no fear of the snakes. However, when the video clips were paired with either a happy or fearful voice, the toddlers looked longer at the snakes when they heard the fearful voice than when they heard the happy voice (see Figure 2.1). There was no difference in looking time to the two voices when they saw videos of other animals. This pattern of data suggests that, like monkeys, infants are not born with a fear of snakes. Rather they apparently possess perceptual biases to be attentive to certain classes of stimuli and to associate them with fearful voices, consistent with the idea of evolved probabilistic cognitive mechanisms (see Bjorklund, 2015).

FIGURE 2.1 **Infants looked significantly longer at the snakes when listening to a frightened-sounding voice than when listening to a happy voice.** Looking times to the other animals did not differ significantly for the happy and frightened voices.

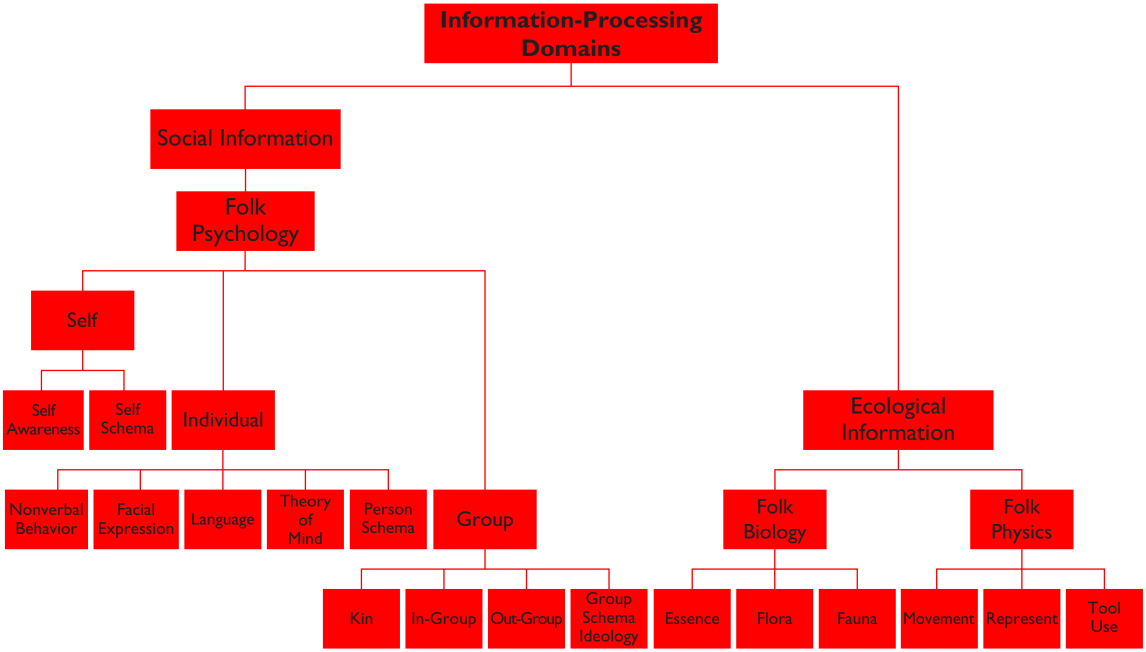


Source: DeLoache, J. S., & LoBue, V. (2009). The narrow fellow in the grass: Human infants associate snakes and fear. *Developmental Science*, *12*, 201–207 (Experiment 2, p. 205).

Structure of the Mind

One way of thinking about how the mind is structured has been presented by David Geary (2005), who proposes that what evolved is a set of hierarchically organized domain-specific modules that develop as children engage their physical and social worlds. Geary's model is shown in Figure 2.2. As can be seen, there are two overarching domains—social (folk psychology) and ecological—with each tapping into a limited pool of domain-general central executive resources and each consisting of more-specific domains (self, individual, and group for social and biological and physical for ecological). Geary acknowledges that this list of domains is not complete (for example, there is no numerical domain listed here, which Geary believes exists), and one could argue about the organization of some of these domains. For example, should language be organized within the social domain, or is it best conceptualized as a separate domain? Nonetheless, Geary's organization reflects one

FIGURE 2.2 **Geary proposed that the mind is hierarchically organized into domains, with lower-level modules, designed to process less-complex information, serving as building blocks for higher-level more complex and flexible modules.** Within the social domain of folk psychology, domains are further organized into those dealing with (a) self-knowledge, (b) individuals, and (c) groups. Within the ecological domain, Geary proposes two subdomains, one dealing with the biological world and the other the physical world.



Source: Geary, D. C. (2005). *The origin of mind: Evolution of brain, cognition, and general intelligence.* Washington, DC: American Psychological Association.

that is consistent with the dominant perspective of evolutionary psychologists (Buss, 2009; Tooby & Cosmides, 2005), and it captures much of the developmental data.

Despite the belief that many evolutionarily influenced cognitive abilities are domain-specific in nature, one should not lose track of the fact that human cognition is amazingly flexible. This implies that what evolved in *Homo sapiens* are not highly specific approaches to problems but genes and cognitive mechanisms that are sensitive to different environments and that yield different outcomes (phenotypes) in different contexts that are (or would have been, in ancient environments) adaptive to local conditions. Such mechanisms become more specific and finely tuned during development, primarily as a result of experience. And humans, more than any other mammal, have time to gather the experience that will be necessary to function optimally as an adult. In fact, evolutionary developmental psychologists have emphasized the importance of our species' extended childhood for cognitive development (Bjorklund & Pellegrini, 2002; Flinn & Ward, 2005). Humans spend a greater proportion of their life spans as juveniles than any other primate species. There are great dangers

TABLE 2.1 **Some distinctions between biologically primary and biologically secondary abilities.** Language is a good example of a biologically primary ability, whereas reading is a good example of a biologically secondary ability.

Biologically Primary Abilities

- Have undergone selection pressure and evolved to deal with problems faced by our ancestors
- Are acquired universally
- Are acquired by children in all but the most deprived of environments
- Children are intrinsically motivated to exercise biologically primary abilities and do so spontaneously
- Most children attain "expert" level of proficiency

Biologically Secondary Abilities

- Do not have an evolutionary history but are built on biologically primary abilities
- Are culturally dependent, reflecting the cognitive skills that are important in a particular culture (such as reading in literate cultures)
- Children are not intrinsically motivated to exercise them and must often be pressured by adults to acquire these skills
- Tedious practice is sometimes necessary to master biologically secondary abilities

Source: Adapted from Geary, D. C. (1995). Reflections of evolution and culture in children's cognition: Implications for mathematical development and instruction. *American Psychologist, 50*, 24–37.

associated with delaying reproduction, however, so there must be some substantial benefits to survival for this prolonged period of immaturity to have been selected. Although there is no single answer to the question of why humans have such an extended juvenile period, one reason proposed by many evolutionary developmental psychologists is that the long period of youth is necessary for children to master the complexities of human societies and technologies (Bjorklund, Periss, & Causey, 2009; Kaplan et al., 2000). This perspective argues that because of the variety of social and physical environments in which people live (both presently and in our evolutionary past), human cognition must be flexible, adapted not to a highly specific environment but to a broad range of potential environments, reflecting the diversity of social groups around the globe and throughout our species' history. To do this requires a long period of apprenticeship as well as a large brain capable of flexible learning and cognition.

Biologically Primary and Biologically Secondary Abilities

Another insight relevant to cognitive development and to education derived from evolutionary psychology is the idea that much of what we teach children in school is "unnatural," in that it involves tasks never encountered by our ancestors. For example, although our species has apparently been using language for tens of thousands of years, reading is a skill that goes back only a few thousand years, and only during the past century have a majority of people on the planet become literate. Geary (1995, 2007) refers to cognitive abilities that were selected over the course of evolution, such as language, as **biologically primary abilities**. Skills that build on these primary abilities but are principally cultural inventions, such as reading, are considered **biologically secondary abilities**. Biologically primary abilities are acquired universally, and children typically have high motivation to perform tasks involving them. Biologically secondary abilities, in contrast, are culturally determined, and tedious repetition and external pressure are often necessary for their mastery. It is little wonder that reading, a supposed "language art," and higher mathematics give many children substantial difficulty. (See Table 2.1 for a summary of the characteristics of biological primary and secondary abilities.)

It is important to emphasize here that an evolutionary account of development is *not* one of biological determinism. That is, although evolution works through changing frequencies of genes within the population, natural selection requires a dynamic interaction between organisms and their environments. Organisms choose environments, the very act of which modifies those environments. Environments in turn affect the organism by "selecting" some behaviors that "match" those environments over others. Because of this dynamic interaction between organisms and environments, we must evaluate these interactions if we want to understand adaptation and cognitive development. Thus, this position rejects any simple notion of biological determinism (for example, "genes cause behavior") on cognitive development, intelligence, or the educability of children.

Although not every cognitive developmental psychologist adopts the specific evolutionary position presented here, we think it's fair to say that virtually all cognitive developmentalists are Darwinians, and most also believe that infants enter the world prepared by natural selection to make sense of a structured world. Nora Newcombe (2011) has proposed that humans, beginning in infancy, have substantial learning capabilities and a strong capacity for probabilistic reasoning that interact with "expected" environments (that is, environments that most members of a species can expect to experience) to produce species-typical patterns of cognitive development. She refers to this approach as **neuroconstructivism**, and it is consistent with both the evolutionary developmental psychological approach presented here and the developmental systems approach discussed in the next section.

Section Review

Developmental psychology has become increasingly concerned about biological causes of cognition.

Evolution and Cognitive Development

- Darwin's idea of variation and *natural selection* remains the cornerstone for theories of *evolution*.
- *Evolutionary developmental psychologists* believe that both domain-specific and domain-general mechanisms have been modified over time as a result of natural selection.
- *Evolved probabilistic cognitive mechanisms* emerged to solve recurrent problems faced by ancestral populations; they are expressed in a probabilistic fashion in each individual in a generation, based on the continuous and bidirectional interaction over time at all levels of organization, from the genetic through the cultural.
- Three types of constraints have been proposed: *architectural*, referring to innate characteristics of neurons and their connections with other groups of neurons; *chronotopic*, referring to maturational (timing) constraints; and *representational*, referring to innate representations.
- Geary proposed that the mind is hierarchically organized, with two overarching domains evolved to deal with social information (folk knowledge) and ecological information (folk biology and folk physics).
- *Biologically primary abilities* such as language have been selected for in evolution and are acquired universally by children in all but the most deprived environment; children are intrinsically motivated to execute them,