and insights from the neighboring disciplines of biology and neuroscience, and
the second builds on findings and insights from sociology and anthropology.
These approaches to understanding children's thinking are introduced in the next
two sections.

**How Do Changes in the Brain Contribute to Cognitive Development?**

In general, the bigger the brain of a species, the more intelligent individuals of
that species are likely to be. Without question, changes in the size, structure, and
connection patterns of the brain during the course of a child's development pro-
foundly contribute to changes in the child's thinking. These changes, which are
both quantitative and qualitative, occur at three levels: (1) changes in the brain
as a whole; (2) changes in particular structures within the brain; and (3) changes
in the billions of cells that make up the brain (neurons).

*Changes in the brain as a whole.* The changes that occur in the brain as
a whole are evident in large-scale increases in its weight from birth to adulthood.
The brain weighs roughly 400 grams at birth; 850 grams at 11 months; 1100 grams
by age 3 years; and 1450 grams by adulthood (Kolb & Whishaw, 2003). Thus, the
brain of an adult weighs almost four times as much as the brain of a newborn.
These changes in size make possible much more advanced thinking.

*Changes in structures within the brain.* The relative sizes and levels of
activity of the main parts of the brain also change over the course of development.
The brain can be divided into two main parts: subcortical structures and the cor-

tex. The subcortical structures are areas atop the spinal cord, such as the thalamus,
medulla, and pons (Figure 1.2). They are quite similar in the brains of humans and
of other mammals, especially other primates such as apes and monkeys.

Like these subcortical areas, the cortex includes some structures that are
similar in humans and other primates. Among them are the hypothalamus and
the amygdala. In addition, however, the cortex includes a large structure that
is far more highly developed in humans than in any other animal: the cerebral
cortex. Sitting atop the rest of the brain, this large structure is what makes
possible the high-level cognitive skills that are unique to human beings, such as
language and complex problem solving.

At birth and for several years thereafter, the cerebral cortex is immature rel-

tive to other parts of the brain. This is evident both in its being a lower per-
centage of its adult weight and in its being less like its mature form in
organization and patterns of electrical and chemical activity. The relative imma-

ture of the cerebral cortex has important consequences for cognitive functioning.
It leads to some types of cognition being impossible early on and to others
being accomplished at first by more mature parts of the brain, even though the cortex will later play a dominant role in them.

As shown in Figure 1.3, the cerebral cortex includes four main lobes: the frontal lobe, at the front of the brain; the parietal lobe, at the top; the occipital lobe, at the back; and the temporal lobe, toward the bottom. Each area is particularly active in producing certain types of cognitive activity. For example, the occipital lobe is especially heavily involved in processing visual information, whereas the frontal lobe is especially involved in consciousness, planning, and the regulation of cognitive activity. As you might expect from the types of activities in which the frontal lobe is particularly active, it is especially immature at birth, relative to other parts of the brain and even other parts of the cerebral cortex. Its profound development during infancy and early childhood seems to be crucial to the rapid advances in cognitive capabilities that occur during that period. (For a good discussion of the different rates of maturation of different parts of the brain, see Chugani and Phelps, 1986.)

The cerebral cortex is divided into two halves, or hemispheres, connected by a dense tract of nerve fibers called the corpus callosum. For the most part, each hemisphere processes sensory information and motor responses from the opposite side of the body; thus, sensory inputs and motor responses on the left side of the body are processed largely by the right hemisphere, and vice versa. The two
hemispheres also appear to be specialized for processing information in different ways. For example, in most right-handed adults, the left hemisphere is specialized for processing information in a sequential, analytic fashion, whereas the right hemisphere is specialized for processing information in a more holistic, integrative manner. As a consequence, linguistic and logical information tends to be processed primarily in the left hemisphere, and emotional and spatial information tends to be processed primarily in the right hemisphere. Because one hemisphere plays a dominant role in carrying out these functions, they are said to be lateralized.

Recent studies suggest that cerebral lateralization is present even in infancy. For example, infants show hand preferences in motor tasks as early as 6 months of age, suggesting that these functions are lateralized by that time (Michel, 1998). As another example, one study compared patterns of mouth opening in 5- to 12-month-old infants as they produced babbling sounds, which are an early step in language acquisition, and non-babbling sounds. When the infants produced
babbling sounds, they opened their mouths wider on the right side than on the left, suggesting left-hemisphere control, but when they produced non-babbling sounds, they opened the two sides of their mouths equally wide (Holowka & Petitto, 2002). These findings suggest that the left hemisphere is preferentially involved in language processing from early in the first year.

Changes in neurons. A third, yet more specific, level of change that occurs in the brain involves specific neurons (nerve cells). Neurons are present in vast numbers in all parts of the brain—a total of between 100 and 200 billion. Over development, the neurons become increasingly interconnected.

Each neuron includes three main parts: a cell nucleus, which is the core of the nerve cell; a number of dendrites, which are fibers that bring information from other neurons to the cell nucleus; and one (or occasionally more) axons, which are larger fibers that transmit information from the cell nucleus to other neurons (Figure 1.4).

Neurons transmit information both electrically and chemically. Within a given neuron, the transmission is electrical. Electrical signals travel from the dendrites to the cell nucleus to the axon(s). Between neurons, the transmission is chemical. Neurons are not directly connected to each other; instead, there are tiny gaps, called synapses, separating the axon of one neuron from the dendrite of another. The electrical impulse traveling along the axon leads to release of chemical neurotransmitters, which flow across the synapse from the end of the axon to the beginnings of dendrites of adjacent neurons. When the neurotransmitters arrive at the dendrites of the receiving neurons, the information is converted back into electrical impulses, which are then transmitted within that neuron. In an adult, a single neuron often has more than 1,000 synapses with other neurons. These multiple connections allow information to be simultaneously transmitted to diverse areas of the brain (Thompson, 2000).

Synaptogenesis. The formation of synapses between neurons (synaptogenesis) is far from complete at birth. Within many parts of the brain, it follows a distinctive developmental course of overproduction and pruning. Early in development, there is an explosive proliferation of synapses, causing the number of synapses in a toddler’s brain to far exceed the number in an adult’s. Then, over the course of childhood, the number of synapses decreases to adult levels. In one part of the frontal lobe, for example, the density of synaptic connections increases tenfold between birth and 12 months. By age 2, the density of connections there is almost twice as great as in adults. After this point, it gradually decreases, reaching adult levels by about age 7 (Huttenlocher, 1994).

In other parts of the brain, the overproduction and pruning follows the same general pattern, but with different timetables (Huttenlocher & Dabholkar, 1997). For example, in the visual cortex, the peak density of synapses is generally reached earlier than in the frontal lobe—around 1 year—and the pruning continues longer—until age 11 (Huttenlocher, 1990). However, the basic cycle of
rapid initial generation of synapses, followed by prolonged pruning of them, seems to generally hold true.

What determines the ultimate pattern of synaptic connections in the brain? The early phases of the process of synaptogenesis appear to be largely genetically controlled (Bourgeois, 2001). However, experience also plays a crucial role, especially in later phases. In particular, experience appears to be an important determinant of which synapses are maintained and which ones pruned. If experiences lead to synapses firing so that neurotransmitters are released, they tend to be maintained. If not, they tend to wither (Greenough & Black, 1992;
Greenough, Black, & Wallace, 1987). Thus, in the brain as in behavior, development involves a complex interplay of genetics and experience.

Some researchers have proposed that the early surplus of synapses is related to infants and toddlers acquiring certain kinds of capabilities more effectively than adults (e.g., Bjorklund, 1997). For example, toddlers and young children are especially good at picking up the sounds and grammar of their native languages. They are far more effective learners than those who immigrate to a new country as adults and try to learn its language then (Johnson & Newport, 1989). It is not just that the children are learning their first language and the adults their second; young children also learn phonology and syntax more effectively when they are learning it in a second language (as when a 5-year-old comes to a new country). The extra synapses in the young children’s brains may be especially useful for learning the extremely complex systems of contingencies embodied in the phonology and grammar of languages such as English.

Because of the surplus of synapses available in early life, the immature brain displays an enormous capacity to adapt to variations in experience. This early plasticity is the reason why infants and children often show dramatic recovery from early brain damage, such as sometimes occurs as a result of injury or stroke (Stiles, Bates, Thal, Trauner, & Reilly, 2002). For example, infants or children who experience damage to portions of the brain that process language often recover fully, because other parts of the brain take over the processing of language. In effect, the brain becomes “rewired,” and portions of the brain not initially specialized for language take over that function. Adults who experience damage to these same brain regions typically fare less well, because the remaining neurons in other parts of their brain are already dedicated to other functions.

Neural plasticity is not only important for recovery from injury—it also enables the brain to adapt to variations in experience due to patterns of use (Elbert, Heim, & Rockstroh, 2001). For example, compared to non-musicians, individuals who play stringed instruments display an enlarged cortical representation of the fingers of the left hand. Moreover, it appears that musical training has a greater effect on cortical organization when it begins at younger ages. Musicians who learned to play stringed instruments at an earlier age showed greater neural activation in response to stimulation of the little finger of the left hand than did musicians who learned to play at later ages (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995). This finding suggests that the plasticity of the human brain decreases over the life span.

**How Does the Social World Contribute to Cognitive Development?**

Understanding cognitive development requires understanding not only the brain, but also the contributions of the social world. From the day children emerge from the womb, they live in a profoundly social environment. It is social not just in
including other people who interact with children—parents, siblings, other adults and other children. It also is social in including many artifacts that exist only because of people’s efforts and ingenuity (such as books, television sets, computers, automobiles), many skills that reflect our cultural heritage (including reading, writing, mathematics, computer programming, video-game playing), and many values that guide strategies and problem-solving efforts in certain directions (such as speed, accuracy, neatness, truthfulness). Clearly, all of these manifestations of the social world influence what children think about and how they think about it. Developmental theories that emphasize the role of the social world in children’s development are called *sociocultural* theories. Such theories are the focus of Chapter 4; however, examples that illustrate the importance of other people in children’s cognitive development can be found throughout the book.

The sociocultural perspective on development was initially articulated by Lev Semenovich Vygotsky, a Russian developmental psychologist, in the early part of the 20th century. Vygotsky’s theory and its modern-day counterparts ascribe a central role to the social, cultural, and historical context in explaining the process of cognitive development. The context is viewed as an integral part of children’s experience, such that it is not meaningful to consider cognition or behavior as separable or distinct from the context in which it occurs (Rogoff, 1998). Moreover, developmental change is conceptualized as occurring, not only in individual children’s knowledge and cognitive processes, but also in children’s roles in social interactions and in their ways of participating in culturally determined forms of behavior. Thus, according to the sociocultural perspective, it is essential to investigate and analyze behavior in context if we are to understand performance at any age or developmental change in that performance.

What does it mean to investigate behavior in context? In practice, different lines of scientific inquiry have focused on different dimensions of the social and cultural context. One particularly influential approach to delineating aspects of context is Urie Bronfenbrenner’s (1979) conceptualization of context as a “set of nested structures, each inside the next, like a set of Russian dolls” (p. 3). Bronfenbrenner described several concentric layers of the social and cultural context, each of which influences psychological functioning both on its own and in interaction with other layers. This framework is depicted in Figure 1.5.

As shown in the figure, the innermost layer of context consists of the *microsystems* within which development occurs. Microsystems are social relationships in which the child plays a direct part, such as the mother-child relationship, sibling relationships, and relationships with teachers and classmates. Moving outward, the next layer consists of *mesosystems*, which are made up of multiple, interrelated microsystems. For example, the microsystems of family and school interact to form a mesosystem. Families hold expectations and provide opportunities for learning that influence how children perform in school. Likewise, schools sponsor activities that influence how families interact, such as social events and parent-teacher conferences. Next are *exosystems*, which are social systems in which the child does not play a direct part, but that nevertheless
influence children's development. A good example of an exosystem is the school board, which makes decisions about the organization of community schools, the length of the school year, and the nature of the required curriculum. Although children are not involved directly in this system, it clearly has an impact on their development. Finally, all of these systems are situated within the macroystem of the broader cultural context. The macroystem incorporates cultural expectations regarding how children should be cared for and what activities children should engage in at various points in development. More broadly, the macroystem incorporates cultural practices about how families and communities are organized, cultural values about children's roles within these communities, and cultural institutions such as school and day care.

All of these systems, from the microystems to the macroystem, change over time. For example, children's relationships with their parents change as they grow, and societal expectations about children's behavior vary with the child's age and over the course of history. Recent formulations of Bronfenbrenner's framework have also incorporated the dimension of time at various levels of context (e.g., Bronfenbrenner, 1998).

All of these aspects of context are addressed within sociocultural theories of development. However, the bulk of research within the sociocultural tradition has focused on social interactions in which the child plays a direct role (the micro- and mesoystems), and on the opportunities for development that are afforded in various cultures and subcultures (the macroystems).
Social interaction and cognitive development. Vygotsky's theory focused on what he termed the "higher" psychological processes—those processes that differentiate humans from animals, such as reasoning and concept formation. Vygotsky believed that all of the "higher" psychological processes had their origins in social interactions. Children initially perform cognitive tasks with support from social partners, and over time, these social interactions are gradually internalized, until children can perform tasks on their own. Thus, according to Vygotsky, the central mechanism of developmental change is the internalization of socially shared processes.

The notion of internalization highlights the integral role of other people in guiding and supporting children's development. One type of assistance that other people provide to children is social scaffolding, which includes helping children think about a task appropriately, modeling ways of solving problems, and giving hints that guide the child in useful directions. The idea of social scaffolding is based on an analogy to the physical scaffolds used to construct buildings. Physical scaffolds are metal frameworks that allow construction workers to work high above the ground while putting up the basic structures of buildings. Once the basic structure is built, it can support the workers, and the scaffolding can be removed. Similarly, in social scaffolding, the activities of more competent people provide a temporary framework that allows children to think in more advanced ways than they otherwise could. After working for a while at this higher level, children can work at the level without the external support. Parents tend to teach their children in a way that fits the scaffolding model, playing active roles when children are just beginning to learn a skill, and progressively withdrawing to the background as the children show increasing mastery (Pratt, Kerig, Cowan, & Cowan, 1988; Wood, 1986).

The cultural context of cognitive development. Vygotsky's theory also highlighted the importance of the culture in which children develop. In particular, he focused on the importance of cultural tools in shaping and constituting thought. Cultural tools include the entire range of culturally constructed objects and ideas that allow people to achieve their goals: machines such as calculators and computers; representational devices such as books and maps; ways of knowing about the world such as mathematics and science; notational systems such as numbers and letters; and ideas such as gravity and efficiency.

Interacting with even the most mundane cultural tools helps children better understand the social and physical world. Think about calendars and clocks, for example. Learning about them involves much more than just telling time. It also involves learning the belief of our culture that it is useful to break up time into discrete units of years, months, days, hours, minutes, and seconds. The ways in which people use these tools also is revealing. We tell children to be home by 6:00 or 6:15, and to be at school at 8:05, but never to be at home or at school by 8:07 and 30 seconds, much less at 8:07 and 30 and 7/10 seconds. We view it as useful to break up time to a certain level of precision, but not ordinarily beyond
that. Countless such experiences shape the way in which children think about concepts even as basic as time.

Culture also plays a role in children's development by influencing the types of activities in which children engage. There is great variation across cultures in how children are cared for, and in the types of things that are typical for children to do. In some cultures, including the United States, children are typically segregated from adults' social and economic worlds for much of the day. In such cultures, many of children's opportunities for learning occur in the context of day care or formal schooling. In other cultures, children are routinely integrated into adult activities, including household activities such as cleaning and preparing meals, and economic activities such as farming and weaving textiles. In such cultures, most of children’s opportunities for learning take place in the context of everyday situations. Such variations in children’s opportunities for learning lead to variations in the nature and path of children’s cognitive development. Thus, culture influences children’s development by shaping how children participate in culturally valued activities.

The Book's Organization

The organization of this book can be viewed either on a chapter-by-chapter basis or in terms of the central themes that recur in many chapters. In the sections that follow, the book is described from each perspective.

The Chapter-by-Chapter Organization

The book is divided into three sections. The first section, which includes Chapters 1–4, explores broad perspectives on children’s thinking, including Piaget's theory, the information-processing approach to development, and the socio-cultural approach to development. The second section, which includes Chapters 5–11, focuses on more specific aspects of children’s thinking, such as how they perceive the world, how they use language to communicate, and how they learn reading, writing, and mathematics. The third section includes only a single chapter, Chapter 12. It is a summary of what has gone before and a look forward toward the issues that promise to be most important in the future.

The first chapter, which you are just finishing, is an attempt to define the field that is considered in this book and to introduce ideas that are important within it. Chapter 2 is devoted to the work of Piaget, whose investigations into children’s thinking can fairly be said to have created the modern field of cognitive development. On topics ranging from how children infer the origins of the sun to how they order the weights of different objects, Piaget saw much that other people had missed. In addition, Piaget observed children of an extremely
wide age range, stretching from the first days of infancy into late adolescence. Thus, his observations provide a feel for many aspects of development in infancy, childhood, and adolescence.

Chapter 3 examines another prominent approach to the study of children’s thinking, the information-processing approach. In some ways, this approach represents a modern extension of Piaget’s theory; in other ways, it represents an alternative. The basic assumptions of the information-processing approach are that children’s mental activities can be characterized in terms of processes that manipulate information; that processing capacities are limited; and that the interaction between the individual’s processing system and the environment leads to cognitive growth (Klahr & MacWhinney, 1998). The information-processing approach has proved especially useful for studying development, because it provides precise ideas about the mechanisms that produce cognitive change.

Chapter 4 addresses a third prominent approach to the study of children’s thinking, the sociocultural approach. As discussed above, the social and cultural world has a profound effect on what children do, on what they think about, and on how they think. Research guided by sociocultural theories investigates how social and cultural factors influence cognition and development.

Chapter 5 begins the second main section of the book, which examines seven specific aspects of children’s thinking: perception, language, memory, conceptual understanding, social cognition, problem solving, and academic skills. Chapter 5 focuses on perceptual development. The emphases are on the surprising number of visual and auditory skills that children possess from early in infancy, and on the relations between perception and action.

Chapter 6 examines language development. Here the discussion centers on what types of words children use first, when and how they learn grammar, how they acquire word meanings, and how they use language to communicate with others.

Chapter 7 is about the development of memory. It focuses on how the development of basic capacities, strategies, and content knowledge contribute to children’s growing abilities to remember. The chapter also addresses the practical issue of whether in court cases, children’s recall of what happened can be trusted, and how the accuracy of their testimony changes with age.

Chapter 8 concerns conceptual development. The early part of the chapter examines whether children internally represent concepts primarily in terms of dictionary-like definitions, in terms of loosely related characteristic features, or in terms of causally connected theories. The latter part of the chapter examines the development of several particularly important concepts: time, space, number, and living things.

Chapter 9 is about social cognition. The focus is on children’s developing understanding of social information, including knowledge about the self and others, knowledge about the mind and the mental states that give rise to behavior, and knowledge about the social world.
Chapter 10 focuses on problem solving. All of us solve problems daily, but such activities play an especially large role in the lives of young children. The reason is that many tasks that older individuals find routine pose novel challenges for younger ones. Among the problem-solving processes examined in the chapter are planning, causal inference, analogy, tool use, and scientific and logical reasoning.

Chapter 11 concerns the development of reading, writing, and mathematics. Many of the skills for which development is described in the preceding chapters—perception, language, memory, conceptual understanding, and problem solving—are put to use in the classroom. Children’s acquisition of academic skills illustrates how different types of thought processes work together to allow learning of complex concepts and skills.

The third main section of the book is Chapter 12. It summarizes the main conclusions that apply across the diverse areas of children’s thinking and identifies key issues for future investigation.

**The Central Themes**

This chapter-by-chapter organization provides one way of thinking about the material the book covers. Another way is to consider the themes that arise in many chapters. The following are eight recurring themes.

1. The most basic issues about children’s thinking are “What develops?” and “How does development occur?”
2. Four change processes that seem to be particularly large contributors to cognitive development are automatization, encoding, generalization, and strategy construction.
3. Infants and very young children are more cognitively competent than they appear. They possess a rich set of abilities that enable them to learn rapidly.
4. Differences between age groups tend to be ones of degree rather than kind. Not only are young children more cognitively competent than they appear, but older children and adults are less competent than we might think.
5. Changes in children’s thinking do not occur in a vacuum. What children already know about material that they encounter influences not only how much they learn but also what they learn.
6. The development of intelligence reflects changes in brain structure and functioning as well as increasingly effective deployment of cognitive resources.
7. Children’s thinking develops within a social context. Parents, peers, teachers, and the culture at large influence what children think about, as well as how and why they come to think in particular ways.
8. Increasing understanding of children’s thinking is yielding practical benefits as well as theoretical insights.

A simple strategy for improving your understanding of the material in this book is to spend a few minutes now re-reading and thinking about these eight themes. Then, as you read subsequent chapters, try to notice how they unite different aspects of children’s thinking.
Summary

For hundreds of years, people who have had contact with children have wondered about such questions as where the children’s ideas came from and whether infants perceive the world in the same way as adults. Recent conceptual and methodological advances have greatly improved our ability to explore these and many other questions about children’s thinking.

A number of the most important questions about children’s thinking have long histories. Are some capabilities innate? Do children proceed through qualitatively different stages of thinking, or is development continuous? How do changes in children’s thinking occur? How do individuals differ in qualities such as intelligence, and how much continuity is there between early and later abilities? How do the internal world of the maturing brain and the external world of other people shape development? These continue to be among the most basic questions about children’s thinking.

A number of themes are identified that recur throughout the book. Among these are the surprising cognitive competence of infants and young children, the continuous growth of children’s thinking beyond this initial competence, the challenge that children face of coping with complex tasks while having only limited processing resources, the ways in which existing knowledge influences learning, and the influence of brain development and of the social world on children’s thinking.

Recommended Readings


