development is a testimony to how much one person can do. Before Piaget began his work, no recognizable field of cognitive development existed. Yet despite thousands of studies on children's thinking having been conducted in the interim, even Piaget's earliest research is still informative. What explains the longevity of Piaget's theory?

Perhaps the most basic reason is that Piaget's theory communicates an almost tangible sense of what children's thinking is like. His descriptions feel right. Many of his individual observations are quite surprising, but the general trends he describes appeal to our intuitions and to our memories of childhood.

A second important reason is that the theory addresses topics that have been of interest to parents, teachers, scientists, and philosophers for hundreds of years. At the most general level, the theory speaks to such questions as "What is intelligence?" and "Where does knowledge come from?" At a more specific level, the theory examines development of the concepts of time, space, number, and other ideas that are among the basic intellectual acquisitions of humankind. Placing the development of such fundamental concepts into a single coherent framework has made Piaget's theory one of the significant intellectual achievements of our century.

A third reason for the theory's longevity is its exceptional breadth. It covers an unusually broad age span—the entire range from infancy through adolescence. Children's understanding of concepts such as cause and effect can be seen evolving from rudimentary forms in infancy to more complex forms in early childhood to yet more complex forms in middle childhood to even more complex forms in adolescence. The theory also encompasses an unusually broad variety of achievements at any given age. For example, it brings together 5-year-olds' scientific and mathematical reasoning, their moral judgments, their drawings, their idea of cause and effect, their use of language, and their memory for past events. One of the purposes of scientific theories is to point out the commonalities underlying seemingly unrelated facts. Piaget's theory is especially strong on this dimension.

A fourth reason for the theory's having endured is that Piaget had the equivalent of a gifted gardener's "green thumb," a knack for making interesting observations. One of these observations was quoted at the outset of this chapter: the one concerning infants' failure to search for objects if they cannot see them. Many of his other intriguing observations are described throughout this chapter.

Because of the range and complexity of Piaget's theory, it seems worthwhile to approach it first in general terms and then in greater depth. The first section of this chapter provides an overview of Piaget's theory. The second section describes children's thinking during each of his four stages of development. The third focuses on his description of the development of several especially important concepts from birth through adolescence. The fourth is an evaluation of the theory. Table 2.1 depicts this organization.

At age 7 months, 28 days, I offer him a little bell behind a cushion. So long as he sees the little bell, however small it may be, he tries to grasp it. But if the little bell disappears completely he stops all searching.

I then resume the experiment using my hand as a screen. Laurent's arm is out-stretched and about to grasp the little bell at the moment I make it disappear behind my hand which is open and at a distance of about 15 cm. from him. He immediately withdraws his arm, as though the little bell no longer existed. I then shake my hand... Laurent watches attentively, greatly surprised to rediscover the sound of the little bell, but he does not try to grasp it. I turn my hand over and he sees the little bell; he then stretches out his hand toward it. I hide the little bell again by changing the position of my hand; Laurent withdraws his hand. (Piaget, 1954, p. 39)

What does this infant's odd behavior tell us? Piaget (1954) advanced one provocative interpretation: that Laurent did not search for the bell because he did not know that it still existed. In other words, his failure to search was due to his inability to mentally represent the bell's existence. It was as if the infant's thinking embodied the strongest possible version of the adage "Out of sight, out of mind."

This chapter is the only one in the book whose title includes a person's name. This is no accident. Jean Piaget's contribution to the study of cognitive
TABLE 2.1 Chapter Outline

I. An Overview of Piaget’s Theory
   A. The Theory as a Whole
   B. The Stages of Development
   C. Developmental Processes
   D. Orienting Assumptions

II. The Stage Model
   A. The Sensorimotor Period (Birth to Roughly 2 Years)
   B. The Preoperational Period (Roughly 2 Years to 6 or 7 Years)
   C. The Concrete Operations Period (Roughly 6 or 7 Years to 11 or 12 Years)
   D. The Formal Operations Period (Roughly 11 or 12 Years Onward)

III. The Development of Some Critical Concepts
   A. Conservation
   B. Classes and Relations

IV. An Evaluation of Piaget’s Theory
   A. How Accurately Does the Theory Describe Particular Aspects of Children’s Thinking?
   B. How Stage-like Is Children’s Thinking?
   C. How Well Do Piaget’s General Characterizations Fit Children’s Thinking?
   D. The Current Status of Piaget’s Theory

V. Summary

An Overview of Piaget’s Theory

Piaget’s theory is sufficiently broad and complex that it is easy to lose the forest for the trees. This section provides an overview of the forest.

THEORY AS A WHOLE

To appreciate Piaget’s theory, it is essential to understand his motivation for developing it. This motivation grew out of Piaget’s early interest in biology and philosophy. When he was 11 years old, he published his first article, which described an albino sparrow he had observed. Between the ages of 15 and 18, he published several more articles, most of them about mollusks. The articles must have been impressive. When Piaget was 18, the head of a natural history museum, who had never met him but who had read his articles, wrote a letter offering him the position of curator of the mollusk collection at the museum. Piaget turned down the offer so that he could finish high school.

In addition to this early interest in biology, Piaget was keenly interested in philosophy. He was especially drawn to epistemology, the branch of philosophy concerned with the origins of knowledge. The theory of the eighteenth-century philosopher Immanuel Kant, who, like Piaget, was most interested in the origins of knowledge, was a source of particular fascination for him.

The combination of philosophical and biological interests influenced Piaget’s later theorizing in several ways. It led to the fundamental question underlying the theory: “Where does knowledge come from?” It also influenced the particular problems Piaget chose to study. He followed Kant in viewing space, time, classes, causality, and relations as basic categories of knowledge. At the same time, he opposed Kant’s position that these basic categories of knowledge were innate to human beings. Instead, he believed that children come to understand the concepts increasingly deeply during infancy, childhood, and adolescence. Perhaps most important, the joint interest in philosophy and biology suggested to Piaget that long-standing philosophical controversies could be resolved by applying scientific methods. Just as Darwin attempted to answer the question “How did people evolve?” Piaget attempted to answer the question “How does knowledge evolve?”

Having this background, we can now consider the theory itself. At the most general level of analysis, Piaget was interested in intelligence. By this he meant a broader quality than what is measured on intelligence tests. He viewed intelligence as the ability to adapt to all aspects of reality. He also believed that within a person’s lifetime, intelligence evolves through a series of qualitatively distinct stages. These stages, and the developmental processes that produce the transitions from one stage to the next, are described in the next two sections.

THE STAGES OF DEVELOPMENT

As noted in Chapter 1, stage theorists such as Piaget make certain characteristic assumptions. They assume that children’s reasoning in earlier stages differs qualitatively from their reasoning in later ones. They also assume that at a given point in development, children reason similarly on many problems. Finally, they assume that after spending a prolonged period of time “in” a stage, children abruptly make the transition to the next stage.

Piaget postulated that all children progress through four stages and that they do so in the same order: first the sensorimotor period, then the preoperational period, then the concrete operational period, and finally the formal operational period. The sensorimotor period typically spans the period from birth to about the second birthday; the preoperational period lasts roughly from age 2 to age 6 or 7, the concrete operational period extends from about 6 or 7 to 11 or 12, and the formal operational period includes all of adolescence and adulthood.

First consider Piaget’s characterization of the sensorimotor period, which lasts from birth through age 2. Piaget believed that at birth, a child’s cognitive system is limited to motor reflexes. Within a few months, however, children build on these reflexes to develop more sophisticated procedures. They begin to systematically repeat initially inadvertent behaviors, to generalize their activities to a wider range of situations, and to coordinate them into increasingly lengthy chains of behavior. Children’s physical interactions with objects provide the impetus for this development.
The preoperational period encompasses the age range from 2 to 6 or 7 years. The greatest achievement of this period is the acquisition of means for representing the world symbolically: mental imagery, drawing, and especially language. Children's vocabulary increases 100-fold between 18 and 60 months (McCarthy, 1954), and their utterances progress from one- and two-word phrases to sentences of indefinite length. In Piaget's view, however, preoperational children can use these representational skills only to view the world from their own perspective. They focus their attention too narrowly, often ignoring important information. They also cannot accurately represent transformations and instead are able to represent only static situations.

The concrete operational period encompasses the age range from 6 or 7 to 11 or 12 years. Concrete operational children can take other points of view, can simultaneously take into account more than one perspective, and can accurately represent transformations as well as static situations. This allows them to solve many problems involving concrete objects and physically possible situations. However, they do not yet consider all of the logically possible outcomes and do not understand highly abstract concepts.

Formal operations, attained at roughly age 11 or 12, is the crowning achievement of the stage progression. Children who attain formal operations are said to reason in terms of theories and abstractions as well as concrete realities. This broader perspective brings with it the potential for solving many types of problems that are impossible for children in earlier stages. Although Piaget recognized that particular knowledge and beliefs continue to change, he believed that the basic mode of reasoning that characterizes the formal operational stage is sufficiently powerful to last a lifetime.

**DEVELOPMENTAL PROCESSES**

How do children progress from one stage to another? Piaget viewed three processes as crucial: assimilation, accommodation, and equilibration.

**Assimilation.** Assimilation refers to the way in which people transform incoming information so that it fits their existing way of thinking. As an example, consider the following anecdote. When Siegler's older son was 2, he encountered a man who was bald on the top of his head and had long, frizzy hair growing out from each side. To Siegler's embarrassment, on seeing the man, his son gleefully shouted, "Clown, clown." (Actually, it sounded more like "Kown, kown.") The man apparently possessed the features that the boy believed distinguished clowns from other people, and thus became a "kown."

Assimilation is important throughout life, not just in early childhood. Consider the experience of a music critic, Bernard Levin. Levin noted that when he heard the premiere performance of Bartok's *Concerto for Violin and Orchestra*, early in Bartok's career, neither he nor other critics could make sense of it or later remember it in any detail. It was simply confusing and annoying to the ear.

However, when he next heard the piece, almost 20 years later, it seemed eminently musical. Levin's explanation was that in the ensuing period, "I had come to hear the world with different ears" (London Daily Telegraph, June 8, 1977). In Piaget's terms, he initially was unable to assimilate the Bartok piece to his understanding of music. Twenty years later, he was able to do so.

One interesting type of assimilation that Piaget described is functional assimilation, the tendency to use a mental structure as soon as it becomes available. Illustratively, when Siegler's older son was first learning to talk, he spent endless hours talking in his crib, even though no one else was present. A few years later, he would turn somersaults over and over again, despite encouragement from his parents to stop. Piaget contrasted this source of motivation with behaviorists' emphases on external reinforcers as motivators of behavior. In reinforcement, the reason for engaging in an activity is the external reward that is obtained. In functional assimilation, the reason for engaging in the activity is the sheer delight of mastering new skills.

**Accommodation.** Accommodation refers to the ways in which people adapt their thinking to new experiences. Returning to the "kown" incident, after biting his lip to suppress a smile, Siegler told his son that the man they had seen was not a clown; that even though his hair was like a clown's, he wasn't wearing a funny costume and wasn't trying to make people laugh. The goal was to help the child accommodate his idea of "clown" to the concept's standard meaning. Assimilation and accommodation mutually influence each other; assimilation is never present without accommodation and vice versa. On seeing a new object, an infant might try to grasp it as he has grasped other objects (thus assimilating the new object to an existing approach). However, he also would have to adjust his grasp to conform to the shape of the new object (thus accommodating his approach as well). The extreme case of assimilation is fantasy play, in which children gloss over the physical characteristics of objects and treat them as if they were something else. The extreme case of accommodation is imitation, in which children minimize their interpretations and simply mimic what they see. Even at the extremes, elements of each process are present. Children at play do not totally ignore physical properties. (Beds almost never are assimilated as teacups, even in fantasy play.) Conversely, when we do not understand what we are doing, imitation often is imperfect. (Try to repeat verbatim a 10-word sentence from a language that you do not speak.)

**Equilibration.** Equilibration is the process by which children integrate their many particular pieces of knowledge of the world into a unified whole. It thus requires balancing assimilation and accommodation. It also is the keystone of developmental change within Piaget's system. Piaget saw development as the formation of ever more stable equilibria between the child's cognitive system and the external world. That is, the child's model of the world increasingly resembles reality.
Piaget also suggested that regardless of when in life it occurs, equilibration includes three phases. First, children are satisfied with their mode of thought and therefore are in a state of equilibrium. Then they become aware of shortcomings in their existing thinking and are dissatisfied. This constitutes a state of disequilibrium. Finally, they adopt a more sophisticated mode of thought that eliminates the shortcomings of the old one. That is, they reach a more stable equilibrium.

To illustrate the equilibration process, suppose a 6-year-old girl thought that animals were the only living things. (In fact, most 4- to 7-year-olds do think this; see Hatano, Siegler, Richards, Inagaki, Stavy, & Wax, 1993.) At some point, the girl might realize that plants, like animals, grow and die. This realization might create a state of disequilibrium, in which she was unsure if plants were alive and what it meant to be alive. Eventually she would learn that the critical attributes of life are growth and reproduction, that both plants and animals possess them, and that both therefore are alive. The new understanding would constitute a more stable equilibrium, since further observations would not call it into question (unless the girl later became interested in certain viruses and bacteria whose status as living things continues to be debated by biologists).

This overview of assimilation, accommodation, and equilibration might create an impression that these change processes apply solely to specific, short-term cognitive changes. In fact, Piaget was especially interested in their capacity to produce far-reaching, longer-term changes, such as the change from one developmental stage to the next. Illustratively, the particular realizations that frizzy hair that looks like a clown’s does not make its bearer a clown, that plants are alive even though they don’t move, and that the sun’s looking like gold does not mean it is gold are part of a more general trend from preoperational to concrete operational reasoning. Piaget believed that children generalize the assimilations, accommodations, and equilibrations involved in these particular changes into a broad shift from emphasizing external appearances to emphasizing deeper, enduring qualities.

**Orienting Assumptions**

The child as scientific problem solver. Piaget often likened children’s thinking to that of scientists solving problems about the fundamental nature of the world. He applied the metaphor even to the thinking of infants. When an infant varied the height from which she dropped food from her highchair and observed how the results varied, Piaget detected the beginnings of scientific experimentation.

At least three considerations led Piaget to concentrate on scientific reasoning and problem solving. One was his view of what development was. Piaget viewed development as a form of adaptation to reality. A problem can be viewed as a miniature reality. The way children solve problems thus could lead to insights about how they adapted to all kinds of challenges that life posed.

A second reason for Piaget’s emphasis on problem solving relates to his views about how and why development occurs. Equilibration only happens when some problem arises that disturbs a child’s existing equilibrium. Thus, problems, which by their very nature challenge existing understandings, have the potential for stimulating cognitive growth. If encountering problems stimulates cognitive growth, then an interest in cognitive growth would naturally lead to an interest in problem solving.

A third reason for Piaget’s focus on problem solving concerns the insights that can be gained by observing children’s reactions to unfamiliar situations. Piaget noted that everyday activities may be performed by rote; when this is the case, they reveal little about children’s reasoning. For example, if we ask a boy to name the capital of France, and he says “Paris,” we learn little about his reasoning. We just learn that he knows the particular fact. By contrast, when children are unfamiliar with problems, their solution strategies reveal their own logic.

The role of activity. Piaget emphasized cognitive activity as the means through which development occurs. Assimilation, accommodation, and equilibration are all active processes by which the mind transforms, and is transformed, by incoming information. As Gruber and Voneche (1977) noted, it was significant that Piaget titled one of his most famous books *The Construction of Reality in the Child*. Within Piaget’s approach, reality is not waiting to be found; children must construct it from their own mental and physical actions.

This distinction between a found reality and a constructed reality is analogous to the distinction between a picture of a bridge and an engineer’s model of the forces operating on the bridge. A picture simply reflects the bridge’s superficial appearance. In contrast, the engineer’s model emphasizes the relations among components and how the structure distributes stresses. Piaget believed that children’s mental representations, like the engineer’s model, emphasize structural relations and causes. He also believed that the only way that children can form such representations is to assimilate their experience to their existing understandings. Even when a relation is explained to them, they must actively integrate it with their own general understanding in order to remember it.

Methodological assumptions. Early in his career, Piaget perceived a trade-off between the precision and replicability that accompany standardized experimental procedures and the rich descriptions and insights that can emerge from methods that are tailored to the individual child. He also recognized the trade-off between the unexpected information that can emerge from talking with children and having them explain their reasoning and the possibility of underestimating the quality of their reasoning because of their inarticulateness. Recognizing these trade-offs, Piaget used different methods to study different topics. His studies of infants, conducted early in his career, were based on observations of his own children, Jacqueline, Laurent, and Lucienne, in everyday
situations and in simple informal experiments that he devised. His early studies of moral reasoning, causation, play, and dreams relied almost entirely on children's answers to hypothetical questions. His later studies of number, time, velocity, and proportionality relied on a combination of children's interactions with physical materials and their explanations of their reasoning.

Generally, when the choice was whether to follow standardized methods or to flexibly tailor tasks and questions to the individual child's actions and statements, Piaget opted for flexibility. This choice may have led him astray at times. Some of his conclusions may have been due to his methods' underestimating children's knowledge. However, the flexible methods also allowed him to follow up unexpected observations, resulting in remarkable discoveries and insights that might never have emerged using standardized procedures.

Possessing this overview of Piaget's theory, we now can examine the major trends that characterize his four hypothesized stages of development. To describe them as clearly as possible, this discussion will generally avoid phrases such as "Piaget said," "Piaget believed," and "Piaget argued." These qualifying phrases should be understood to be implicit, since many of the claims are controversial. Before getting into the controversies, though, we need to understand what Piaget was saying.

The Stage Model

THE SENSORIMOTOR PERIOD (BIRTH TO ROUGHLY 2 YEARS)

Several years ago, at the first class meeting of a developmental psychology course Siegler was teaching, he asked each student to name the five most important aspects of intelligence in infancy, early childhood, later childhood, and adolescence. A number of students commented that they found it odd to describe infants as having intelligence at all. By far the most frequently named characteristics of infants' intelligence were physical coordination, alertness, and ability to recognize people and objects. Part of Piaget's genius was that he perceived much more than this. He saw the beginnings of some of humankind's most sophisticated thought processes in infants' flailings and grasplings.

Piaget's account of the development of sensorimotor intelligence constitutes a theory within a theory. Infants are said to progress through six stages of intellectual development within a two-year period. (For clarity, we will refer to these as "substages" to distinguish them from the broader stages such as the sensorimotor and preoperational stages.) This might seem like too large a number of substages for such a brief time span, but when we consider that the brain of a 2-year-old weighs almost three times as much as that of a newborn, the number does not seem unreasonable. As a general rule, cognitive competence, like brain size, grows especially rapidly in the first few years.

Substage 1: Modification of reflexes (birth to roughly 1 month). Newborn infants enter the world possessing many reflexes. They suck when objects are placed in their mouths, close their fingers around objects that come into contact with their hands, focus on the edges of objects with their eyes, turn their heads toward noises, and so on. Piaget believed that these reflexes are the building blocks of intelligence.

Even within the first month after birth, infants begin to modify the reflexes to make them more adaptive. In the first days, they suck quite similarly regardless of the type of object in their mouth. Later in the first month, however, they suck differently on a milk-bearing nipple than on a harder, drier finger, and they suck differently on both of them than on the side of their hand. Thus, accommodation can be seen even in the first month out of the womb.

Substage 2: Primary circular reactions (roughly 1 to 4 months). By the second month, infants exhibit primary circular reactions. The term "circular" is used here in the sense of a repetitive cycle of events. The circles involve infants' actions, the effect of those actions on their environment, and the impact on the infants' subsequent actions of the effect of the earlier actions on the environment. Piaget (1954) provides the example of infants in their first few months trying to scratch and grasp all kinds of objects that they happen to touch: their mother's bare shoulder, the sheet folded over their blanket, their father's fist, and so on.

In primary circular reactions, if infants inadvertently produce some interesting effect, they attempt to duplicate it by repeating the action. If they are successful, the new instance of the interesting outcome triggers another similar cycle, which, in turn, can trigger another cycle, and so on.

These primary circular reactions are possible because Substage 2 infants begin to coordinate actions that originally were separate reflexes. In Substage 1, infants grasp objects that come into contact with their palms. They also suck on objects that come into their mouths. During Substage 2, infants put these actions together. They bring to their mouths objects that their hands grasp, and grasp objects with their hands that they are sucking on. Thus, the reflexes have already begun to serve as building blocks for more complex activities.

Primary circular reactions are more flexible than the earlier reflexes and allow infants to learn a great deal about the world. However, they also are limited in at least three ways. First, the 1- to 4-month-olds attempt to reproduce only the exact behavior that produced the original interesting event—they do not vary their behavior. Second, their actions are poorly integrated and have a large trial-and-error component. Third, they only try to repeat actions in which the outcome of the action involves their own bodies, as in sucking a finger.

Substage 3: Secondary circular reactions (roughly 4 to 8 months). In this stage, infants become increasingly interested in outcomes occurring beyond their bodies. For example, they become interested in batting balls with their hands and watching them roll away. Piaget labeled such activities secondary circular
reactions. Like all circular reactions, these activities are repeated over and over. Unlike the primary circular reactions, though, the interesting outcome (such as the ball rolling away) involves objects in the external world.

Between ages 4 and 8 months, infants also organize more efficiently the components of their circular reactions. Piaget described instances in which, after he started a mobile swinging, his children kicked their legs to continue the movement. As in the primary circular reactions, infants were only trying to reinstate the original interesting occurrence. However, they now could do so more efficiently. They reacted more quickly to the original event and wasted less motion.

At this point, it is tempting to conclude that infants understand the causal connection between their actions and the effects of their actions. Piaget was reluctant to credit them with this understanding, though. Rather, he thought that infants’ activities were not sufficiently voluntary to say that they had independent goals. In his view, in the first month they do not form any goals, and between 1 and 8 months, they only form goals directly suggested to them by the immediate situation. Not until after 8 months do they form true goals, independent of events in the immediate environment.

Substage 4: Coordination of secondary circular reactions (roughly 8 to 12 months). Infants approaching 1 year of age become able to coordinate two or more secondary circular reactions into an efficient routine. When Piaget (1952) put a pillow in front of a matchbox that his infant son Laurent liked, the boy pushed the pillow aside and grabbed the box. In earlier stages, the infant would not have been able to combine the two activities of pushing the barrier out of the way and getting the matchbox.

This example also illustrates another major development that occurs as children approach their first birthday. They realize that if they act in certain ways, particular effects will follow. Thus, Laurent now understood that removing the pillow would allow him to grab the matchbox.

Especially important, Substage 4 brings with it the ability to form relatively enduring internal representations of the world. Out of sight is no longer completely out of mind. Thus, when objects disappear from sight, as when they roll behind a chair, infants pursue them, rather than acting as if the objects had disappeared from the world. This ability to form mental representations is an especially important development, because it lays the foundation for all further cognitive growth.

Substage 5: Tertiary circular reactions (roughly 12 to 18 months). With the onset of tertiary circular reactions, shortly before 1 year of age, infants transcend the remaining limits on their circular reactions. They actively seek for new ways to interact with objects, and explore the potential uses to which objects can be put. As implied by the “circular reaction” label, they still repeat their actions again and again. Now, though, they deliberately vary both their own actions and the objects on which they act. Thus, the activities involve similar rather than identical behaviors. The following description of Piaget’s son Laurent conveys a sense of these new competencies.

He grasps in succession a celluloid swan, a box, etc., stretches out his arm, and lets them fall. He distinctly varies the positions of the fall. Sometimes he stretches out his arm vertically, sometimes he holds it obliquely, in front of or behind his eyes, etc. Then the object falls in a new position (for example on his pillow), he lets it fall two or three times more on the same place, as though to study the spatial relation; then he modifies the situation. (Piaget, 1951, p. 269)

These changes from primary to secondary to tertiary circular reactions show just how far infants come in the first year and a half. As shown in Figure 2.1, primary circular reactions, first seen between 1 and 4 months, involve repetitions of events whose outcomes center on the infants’ own bodies, such as putting their fingers into their mouths. Secondary circular reactions, first seen between 4 and 8 months, again involve repetition of an event that by chance produced an interesting outcome, but the interesting outcome is at least slightly removed from the infants’ bodies (such as the ball rolling away from them). Tertiary circular reactions, first seen between 12 and 18 months, involve the infant deliberately varying the behavior that produced the interesting outcome.

The changes embodied in these three types of circular reactions are useful for thinking about a broad range of developments in infancy. At first, infants’ activities center on their own bodies; later, they increasingly center on the external world. Goals begin at a concrete level (dropping an object) and become increasingly abstract (varying the heights from which objects are dropped). Correspondence between intentions and behaviors becomes increasingly precise, and exploration of the world becomes increasingly venturesome.

Substage 6: Beginnings of representational thought (roughly 18 to 24 months). Developments in this age range are transitional between the sensorimotor and preoperational periods. In the sensorimotor period, children can only act; they cannot form internal mental representations of objects and events. In the preoperational period, children can form such internal mental operations. Substage 6 is the transition point, in which internalized representations are first produced. Consider the following scenario involving Piaget playing with his daughter Lucienne. Piaget hides a watch chain inside an otherwise empty matchbox. Previously, he had left the matchbox open far enough that Lucienne could get the chain by turning over the matchbox, but now he closes it completely for the sake of a trick.

He looks at the slit (in the matchbox) with great attention; then, several times in succession, she opens and shuts her mouth, at first slightly, then wider and wider! Apparently, Lucienne understands the existence of a cavity subjacent to the slit (in the matchbox) and wishes to enlarge the cavity. The attempt at representation which she thus furnishes is expressed plastically, that is to say, due to inability to think out the situation in words or clear visual images, she uses a simple motor indication (her open mouth) as “signifier” or symbol. (Piaget 1951, p. 338)
The Preoperational Period (Roughly 2 Years to 6 or 7 Years)

Piaget's Theory of Development

Miller (1953) nicely captured children's position as they complete the sensorimotor period by likening them to mountain climbers who, after a hard trek, discover that what they have climbed is merely a foothill to Mt. Everest. By the end of the sensorimotor stage, infants have become toddlers. They interact smoothly with objects and people in their immediate environment. Their ability to form internal representations remains severely limited, however. The growth of representational ability is the key development of the preoperational period.

Early symbolic representations. Piaget suggested that the earliest sign of internal representations is deferred imitation, the imitation of an activity hours or days after it occurred. For children to show such delayed imitation, they must have formed a durable representation of the original activity. How else could they imitate it so much later?

Children do not exhibit deferred imitation until late in the sensorimotor period. Consider the following description of Piaget's daughter Jacqueline kicking and screaming in her playpen.

At 14(3) [Piaget's notation for 1 year, 4 months, and 3 days] Jacqueline had a visit from a little boy of 1,6 whom she used to see from time to time, and who, in the course of the afternoon, got into a terrible temper. He screamed as he tried to get out of a playpen and pushed it backward, stamping his feet. Jacqueline stood watching him in amazement, never having witnessed such a scene before. The next day, she herself screamed in her playpen and tried to move it, stamping her foot lightly several times in succession. [Piaget, 1951, p. 63]

Jacqueline had never before, to her father's knowledge, engaged in these behaviors. Thus, an internal representation of the playmate's tantrum must have helped her reproduce them.

Piaget distinguished between two types of internal representations: symbols and signs. The distinction is not identical to the standard English distinction between the two. Rather, it is the difference between idiosyncratic representations intended only for one's personal use (symbols) and conventional representations intended for communication (signs).

Early in their acquisition of internal representations, children frequently use symbols (the personal representations). They may choose a particular piece of cloth to represent their pillow or a popsicle stick to represent a gun. Typically, these personal symbols physically resemble the object they represent. The cloth's texture is similar to that of the pillow, and both are comforting; the popsicle stick's shape and texture are something like those of a gun barrel. Signs, by contrast, often do not resemble the objects or events they signify. The word cow does not look like a cow, nor does the numeral 6 have any inherent similarity to six objects.

As Lucienne opens her mouth, symbolizing her desire for the opening in the matchbox to become wider, we can almost see her internally representing the situation. That is, the representation is moving from her external actions to her mind. Such internalized representations are the hallmark of the preoperational period.

FIGURE 2.1 The children expanding universe: primary (——), secondary (——), and tertiary (———) circular reactions. Diagram best read by starting at top of each circle and proceeding clockwise.
As children develop, they make less use of the idiosyncratic symbols and more of the conventional signs. This shift is an important achievement, as it greatly expands their ability to communicate. The transition from personal to publicly accepted representations is not easy, however.

The difficulty is illustrated in Piaget's description of egocentric communication. Piaget applied the term "egocentric" to preschool-age children, not to castigate them for being inconsiderate, but rather in a more literal sense. Their thinking about the external world is always in terms of their own perspective. Their use of language reflects this egocentrism, particularly their use of idiosyncratic words that are meaningless to other people.

Although even very young children use signs as well as symbols, they at first do not use them consistently in a manner that other people can understand. Figure 2.2 portrays an instance of this aspect of young children's conversations. Preschoolers often speak right past each other, without appearing to pay any attention to what others are saying. Many times, even sympathetic adults cannot figure out what the children mean.

Between ages 4 and 7 years, speech becomes less egocentric. One of the earliest signs of progress can be seen in children's verbal quarrels. The fact that a child's verbal statements elicit a playmate's disagreement indicates that the playmate is at least paying attention to a perspective other than his own. Some children also are aware of the symbolization process and find it interesting in its own right. When Siegler's daughter was 4, she took great delight in saying such things as, "When I say 'chair,' I'm going to mean 'milk'; could you give me a glass of chair?"

Piaget noted that mental imagery, like language, is a way of representing objects and events. He also suggested that the development of mental imagery resembles that of language. As children become able to describe situations verbally, they also become able to represent them as images. Further, he believed that the initial representations in both domains are limited to the child's own perspective. That is, they are egocentric.

Although language, mental imagery, and many other skills grow greatly during the preoperational period, Piaget emphasized what preoperational children cannot do. He viewed them as unable to solve many problems that are critical indicators of logical reasoning. Even the name, "preoperational," suggests deficiencies rather than strengths.

One of the limits on preschoolers' thinking has already been mentioned: their egocentrism. This trait is evident not only in their conversations, but also in their ability to take different spatial perspectives. Piaget had 4-year-olds sit or stand at a table in front of a model of three mountains of different sizes (Figure 2.3). The children's task was to choose which of several photographs corresponded to what children sitting at chairs at different points around the table would see. To solve the problem, children needed to recognize that their own perspective was not the only one possible and to mentally rotate the arrangement they saw to correspond to what the view would be elsewhere. This was impossible for most of the 4-year-olds; they could not imagine the view from other positions.

A second, related limit on preschoolers' thinking is that it centers on individual, perceptually striking features of objects, to the exclusion of other, less striking features. A good example of this centration is found in Piaget's research on children's understanding of the concept of time.

Piaget's interest in this concept has an interesting history. In 1928, Albert Einstein posed a seemingly simple question to Piaget: In what order do children acquire the concepts of time and velocity? Einstein's question was prompted by an issue within physics. In Newtonian theory, time is a basic quality and velocity is defined in terms of it (velocity = distance/time). Within relativity theory, in contrast, time and velocity are defined in terms of each other, with neither concept more basic. Einstein wanted to know whether understanding of either or both concepts was present from birth or if children understood one before the other.
Almost 20 years later, Piaget (1946a, 1946b) published a two-volume, five hundred-page reply to Einstein's question. The gist of Piaget's answer was that mastery of all three concepts emerged simultaneously during the concrete operations period.

To test this view, Piaget presented a task involving two toy trains running along parallel tracks in the same direction. After the cars stopped moving, Piaget asked, “Which train traveled for the longer time (or the faster speed, or the farther distance)?” Most 4- and 5-year-olds focused entirely on a single feature, usually the stopping point. They chose the train that stopped farther down the track as having traveled faster, for the longer time, and for the greater distance. Stated differently, they ignored when the trains started, when they stopped, and the total time for which they traveled. Not until roughly age 9 did they answer correctly.

The example illustrates another of the basic qualities of children’s thinking in the preoperational period. They tend to focus on static states rather than transformations. The point where each train ended constitutes a static position, readily perceivable and available for repeated inspection. The time, speed, and distance traveled are more transitory. The dimensions on which preoperational period children focus usually are static states; the dimensions they ignore usually involve transformations.

Thus, Piaget viewed 2- to 6-year-olds as having difficulty taking perspectives other than their own, as paying too much attention to perceptually salient dimensions and ignoring less salient ones, and as representing static states but not transformations. All of these descriptions suggest that such young children think about the world too simply and rigidly. They largely surmount these limitations in the next period of development.

THE CONCRETE OPERATIONS PERIOD (ROUGHLY 6 OR 7 YEARS TO 11 OR 12 YEARS)

The central development in the concrete operations period is the acquisition of operations. These operations are mental representations of dynamic as well as static aspects of the environment. All development up to this time has been a prelude to this achievement. In the sensorimotor period, children learned to operate physically on the environment. In the preoperational period, they learned to mentally represent static states. Finally, in the concrete operations period, they become able to represent transformations as well as static states.

The importance of operations can most easily be illustrated in the context of conservation problems. Consider children’s understanding of three types of conservation: liquid quantity, solid quantity, and number. Although these conservation problems differ among themselves in certain respects, all share a basic three-phase procedure (Figure 2.4). In the first phase, children see two or more identical objects or sets of objects; two identical rows of checkers, two identical glasses of water, two identical clay cylinders, and so on. Once the children agree

that the two are equal on some dimension, such as the number of objects, the second phase begins. Here, one object or set of objects is transformed in a way that changes its appearance but does not affect the dimension of interest. Children might see the row of checkers lengthened, the water poured into a differently-shaped glass, the clay cylinder remolded into a ball, and so on. Finally, in the third phase, children are asked whether the dimension of interest, which they earlier said was equal for the two choices, remains equal following the transformation of one of them. The correct answer invariably is “yes.”

These problems seem trivially easy to adults and older children. However, almost all 5-year-olds answer them incorrectly. On number conservation problems, they claim that the longer row has more checkers (regardless of the actual numbers in each row). On conservation of liquid quantity problems, they claim that the glass with the taller column of liquid has more (regardless of the cross-sectional areas of the glasses). On conservation of solid quantity problems, they believe that the longer sausage has more clay (again regardless of the cross-sectional areas).
Considering what children need to do to solve conservation problems makes the 5-year-olds' difficulty understandable. They must mentally represent the spreading, pouring, or remodeling transformation involved in the problem. They also must not focus all their attention on the perceptually salient dimension of height or length; they need to consider cross-sectional area and density as well. Finally, they need to realize that even though the transformed object may seem to have more of the dimension in question, it might not. That is, they need to understand that their own perspective can be misleading. Each of these is difficult for 5-year-olds to do.

In the concrete operations stage, children master all three conservation problems. They also master the train problem that was used to measure understanding of time, distance, and velocity. Piaget explained their mastery of these and many other concepts in terms of the children's now possessing mental operations. These operations allow them to represent transformations as well as static states.

Children's explanations of their reasoning on conservation problems are especially revealing. When 5-year-olds are asked to explain why the amount of water has changed, they regularly say that the water in the new glass is higher. When 8-year-olds are asked to explain why the amount of water remains the same, they point to the nature of the transformation ("You just poured it"), to changes in the less striking dimension offsetting changes in the more striking one ("The water in this one is taller, but the water in that one is wider"), to the water looking different but really being the same, and to the reversible nature of the operation ("You could pour it back and it would be the same"). Interestingly, 5-year-olds will grant many of these points, but do not see them as implying that the two glasses have the same amount of water.

Although children in the concrete operations period become capable of solving many problems, certain types of abstract reasoning remain beyond them. Some of these problems require reasoning about propositions that are contrary to fact ("If people could know the future, would they be happier than they are now?"). Others involve treating their own thinking as something to be thought about. To quote one adolescent, "I was thinking about my future, and then I began to wonder why I was thinking about my future, and then I began to think why I was thinking about why I was thinking about my future" (Mussen, Conger, Kagan, & Geiwitz, 1979). Still others involve thinking about abstract scientific concepts such as force, inertia, torque, and acceleration. These types of ideas become possible in the formal operations period.

THE FORMAL OPERATIONS PERIOD (ROUGHLY 11 OR 12 YEARS ONWARD)

Perhaps the most striking development during the formal operations period is that adolescents begin to see the particular reality in which they live as only one of an infinite number of imaginable realities. This leads at least some of them to think about alternative organizations of the world and about deep questions concerning meaning, truth, justice, and morality. As Inhelder and Piaget (1958) put it, "Each one has his own ideas (and usually he believes they are his own) which liberate him from childhood and allow him to place himself as the equal of adults" (pp. 340-341). From this perspective, it is no coincidence that many people first acquire a taste for science fiction during adolescence.

Many of the differences between formal and concrete operational reasoners are evident in Inhelder and Piaget's (1958) descriptions of children's and adolescents' approaches to the chemical combinations problem. The task involved four beakers, each with a particular chemical solution, and a "special" beaker with an unknown mixture of one or more of the other chemicals in it. When another chemical was added to the special beaker, the solution turned yellow. The children were asked to determine which of the four chemicals were in the solution that turned yellow and what role each played.

Concrete operational children typically generated several pairs of the chemicals, then tried all four together, and then generated a few of the possible sets of three. They often repeated combinations they already had tried and left out other combinations altogether. In contrast, formal operational children first devised a plan for systematically generating all possible combinations of the chemicals. Then they used their plan to generate each combination without redundancies or omissions.

The formal operational reasoners' more systematic approach also helped them draw a more appropriate conclusion about when and why the yellow color appeared. Concrete operations children often stopped collecting evidence after they found a single combination that turned the solution yellow. They concluded that it must have been the original solution and that all chemicals in it were necessary for the reaction to occur. In contrast, formal operations children, who tried all possible combinations, eventually learned that two different combinations produced the yellow color. What these combinations had in common was the presence of two of the chemicals and the absence of a third. (The absence of the third chemical was what distinguished the two instances that did turn yellow from two others that had both necessary chemicals in them but that did not turn yellow.) Therefore, the formal operational reasoners reached the correct conclusion that two of the chemicals were necessary to produce the change in color, that a third would prevent it from happening even if the first two were present, and that the fourth had no effect. Their focusing on the system of possible combinations allowed them to obtain the relevant data and to interpret it appropriately.

Some of the largest changes in thinking during the formal operations period involve logical and scientific reasoning (Moshman, 1998). The abstract and systematic thinking that develop especially greatly during the formal operations period are particularly crucial in such contexts. Scientific and logical reasoning problems often require applying the most abstract ways of thinking to the most challenging problems. Not surprisingly, Piaget viewed such formal operations as
the culmination of the process of cognitive development, the fruition of all that had developed before.

The Development of Some Critical Concepts

The broad sweep of Piaget's descriptions of children's thinking emerges most clearly in his accounts of the development of particular concepts. Some concepts for which his descriptions are especially interesting are conservation, classes, and relations. He traced the development of each of these from their earliest origins in the sensorimotor period, through more refined versions in the preoperational and concrete operational periods, to the most sophisticated understandings in the formal operations period. People do not usually think of infants' thinking as having anything to do with that of teenagers. Part of Piaget's genius was that he saw the connection.

Conservation

Conservation in the sensorimotor period. During the sensorimotor period, children acquire a simple but crucial part of the conservation concept. This might be labeled "conservation of existence," though Piaget called it object permanence. Adults know that objects do not just disappear from the world (although they sometimes seem to). If we want a ball and it rolls behind another object, we search for it and remove barriers if necessary to get it. Piaget observed that infants younger than 8 months do not search like this; they simply turn their attention to something else. He did not attribute this to their losing interest or being too poorly coordinated to retrieve the object. Instead, he advanced the more radical view that they did not understand that the objects still existed. He further argued that full understanding of object permanence required the entire sensorimotor period.

In Substage 1, from birth to 1 month, infants look at objects directly in front of them. However, if an object moves away, they do not follow it with their eyes. Thus, an infant will look at her mother's face when it is directly above, but will stop looking if the mother moves aside. In Substage 2, between 1 and 4 months, infants prolong their looking at the place where an object disappeared, but do not follow its movement. If they are playing with a toy and drop it, they continue looking at their hand rather than at the floor. In Substage 3, between about 4 and 8 months, they anticipate where moving objects will go, and look for them there if they are partially visible. However, if the object is completely covered, they do not attempt to retrieve it (as illustrated in the quotation at the beginning of this chapter).

In Substage 4, between 8 and 12 months, infants begin to search for objects behind or under barriers. This indicates that they realize that objects have a permanent existence. Under certain circumstances, however, 8- to 12-month-olds make an interesting mistake. If they see an object hidden twice in succession under the same container, they retrieve the object from there each time. If they then see the same object hidden under a different container, however, they look under the container where they found it before, rather than under the one where it is now. It is as if this original container had assumed an independent status as a hiding place where the object can be found. This error has been termed the "A-not-B" error.

In Substage 5, roughly between 12 and 18 months, infants stop making the A-not-B error and search wherever they last saw the object hidden. However, they remain unable to deal efficiently with transformations in which the desired object cannot be directly perceived. When a toy is first hidden under a cover, and then the toy and cover together are hidden under a pillow, and then the cover is removed so that the toy remains under the pillow, 12- to 18-month-olds do not look under the pillow. By Substage 6, however, between 18 and 24 months, babies understand even this type of complex displacement and immediately search in the right place.

At first glance, Piaget's account of object permanence may seem extremely improbable. It may seem more likely that the infants younger than 8 months fail to search for objects either because they are not sufficiently well coordinated to do so or because they quickly lose interest in the objects. An experiment by Bower and Wishart (1972), however, rendered unlikely both of these possibilities. Five-month-olds saw a toy hidden under a transparent cup. The large majority of infants retrieved it. Then the infants saw the same toy hidden under an opaque cup. Only 2 of 16 retrieved it. This experiment ruled out both motoric immaturity and lack of motivation as explanations for the infants' failure to search under the opaque cup. If they lacked sufficient interest in the toy to retrieve it, or failed because they lacked the necessary coordination, why were they interested and coordinated enough to retrieve the same object when it was hidden under the transparent cup?

Conservation in the preoperational and concrete operational periods. In the sensorimotor period, infants come to realize that the existence of objects is conserved over certain types of transformations, specifically, ones in which the object is hidden. In the preoperational and concrete operational periods, children come to realize that certain qualities of objects also are conserved even when transformations change their appearance. Spreading out objects increases the length of the row but leaves unchanged the number of objects. Pouring water from a typical glass to a taller, thinner one changes the height of the liquid column but leaves unchanged the amount of water. By the end of the concrete operational period, children realize that even when transformations alter appearances, a great many tangible dimensions are conserved: number, amount, length, weight, area, and so on.

Conservation in the formal operational period. During the formal operations period, adolescents come to understand complex forms of conservation
that involve transformations of transformations. One such concept is conservation of motion. Inhelder and Piaget (1958) studied children's and adolescents' understanding of this concept by presenting them with a spring-powered plunger that shot balls of various sizes. The task was to predict where the balls would stop, to explain why some balls stop farther than others, and to explain why balls stop at all.

Performance on this problem at various ages illustrates the types of reasoning that Piaget thought were fundamental at those ages. Preoperational children focus on only one dimension and take only one perspective. They might consistently predict that a big ball will go farther because it is stronger. Concrete-operational children realize that multiple dimensions are important and take multiple perspectives. They might realize the importance of qualities of the surface on which the ball rolls, as well as the ball itself. They also might recognize that the problem can be thought of in terms of what makes the ball stop, as well as what makes it go. Thus, they might believe that bigger balls go farther, but also that rougher surfaces lead to balls going less far.

By the formal operations period, children think of the problem in terms of sophisticated scientific concepts, such as conservation of motion. That is, they conceptualize the problem in idealized terms ("If there were no air resistance or friction . . ."). This way of thinking is a distinctive achievement of formal operations, because it involves conservation of a dimension—motion—that itself involves a transformation—movement through space. In addition, it illustrates how adolescents proceed from the actual to the possible, since no one has experienced an environment without air resistance or friction.

**Classes and Relations**

Another of Piaget's insights was seeing the connection between children's understanding of classes and relations. This connection can be illustrated with regard to numbers. What does it mean when we say that a girl understands the concept "three"? One part of the understanding is seeing what three balls, three cars, and three spoons have in common—that they are all members of the class of three-member sets. She also should understand the relation of this class to other classes—larger than sets with two members and smaller than sets with four. Piaget viewed children as originally thinking of classes and relations as separate ideas, but eventually integrating them into a unified understanding.

**Understanding of classes and relations in the sensorimotor period.** Piaget contended that infants classify objects according to the objects' functions. He illustrated this point by describing his daughter Lucienne's reaction to a plastic parrot that sat atop her bassinet. Lucienne liked to make the parrot move by kicking her feet while lying in the bassinet. At six months of age, she made similar kicking motions when she was out of the bassinet but still could see the parrot. Piaget interpreted this as Lucienne classifying the parrot as "something that swings when I kick my feet." Far more sophisticated categories are seen as evolving from such simple classifications.

Understanding of relations, like understanding of classes, is seen as developing out of sensorimotor actions. Piaget described his three children at 3 and 4 months as being greatly amused by the relation between the vigor of their actions and the strength of the reaction they produced. More vigorous kicking produced more vigorous swinging of objects on the bassinet; more vigorous shaking of a rattle produced louder noises; and so on. Thus, they understand the relation "the more vigorously I do something, the larger its effect."

**Understanding of classes and relations in the preoperational period.** Children progress considerably in classificatory ability during the preoperational period. This progress is evident when they are asked to put together a group of blocks varying in size, color, and shape. Early in the preoperational period, a boy might try to put together all of the small objects, and therefore choose a small red square, then a small blue square, then a small red triangle. However, the fact that the last object was a triangle might grab his attention, leading him to add a large red triangle and a large green triangle, thus creating a group without any unifying characteristic. Not until later in the preoperational period, around age 4 or 5 years, do children come to classify on a consistent basis. At this point, they put all small objects into one group and all big ones into another.

Although children learn to solve this type of problem during the preoperational period, other classification problems remain difficult. The limitations of their reasoning are most evident when they simultaneously need to consider competing bases of classification, as in Piaget's class inclusion problem. On such problems, children might be presented eight toy animals, six of them cats and two dogs. They then would be asked, "Are there more cats or more animals?" Most children around age 7 or 8 answer that there are more cats, despite the number of cats inherently being less than or equal to the number of animals.

Piaget saw this behavior as stemming from preoperational children's tendency to focus on a single dimension to the exclusion of others. To solve the problem correctly, children need to keep in mind that an object (for example, Garfield) may simultaneously belong both to a subset (cats) and to a superset (animals). They find this difficult. Therefore, they reinterpret the question in a way that allows them to solve a problem that they do understand: whether there are more cats or more animals other than cat. This leads them to compare the number of cats to the number of dogs and thus to say that there are more cats than animals.

Children's understanding of relations also grows considerably during the preoperational stage. However, their ability to focus on the relation that is relevant in the particular situation, and to screen out irrelevant ones, remains limited. To illustrate both the growth and the remaining deficiencies, Piaget (1952) presented to preoperational children the type of seriation problem shown in Figure 2.5. He asked them to arrange the sticks from shortest to longest in a
single row. If they succeeded at this task, he presented them a second problem. Here they needed to insert a new stick of medium length at the appropriate point in the row they had made.

Early in the preoperational stage, between ages 2 and 4, children encounter great difficulty creating correct orderings. As in the first row of Figure 2.5, they might arrange two subsets of the sticks correctly, but not integrate the two into a single overall ordering. The shifting focus is similar to that shown when they first grouped together several small objects and then, after encountering a small triangle, started putting all triangles in the group.

Later in the preoperational stage, children can correctly order the lengths of the original set of sticks. However, they often fail to find the correct place to insert the additional stick without extensive trial and error. Piaget attributed this remaining difficulty to preoperational children’s difficulty in simultaneously viewing the new stick as smaller than one stick and larger than another quite similar in size.

Understanding of classes and relations in the concrete operational period. Piaget contended that in the concrete operational period, children come to treat classes and relations as a single, unified system. Their attempts to solve multiple classification problems illustrate this development. Consider the problem in Figure 2.6. Children see intersecting rows of stimuli that vary along two dimensions, in this case shape (square, circular, or oblong) and color (black, white, or gray). The task is to choose an object to put in the blank space so that all nine objects are ordered along the two dimensions. This requires identifying the two relevant classes (shape and color) and choosing an object that maintains the relations among objects already established within the rows and columns of the matrix.

Inhelder and Piaget (1964) reported that 4- to 6-year-olds selected objects that included at least one of the desired dimensions on 85 percent of problems. However, they chose the single object that included both desired dimensions on only 15 percent. By 9 or 10 years of age, the large majority of children choose the object that maintains both dimensions, revealing an ability to consider classes and relations together.

Understanding of classes and relations in the formal operational period. Formal operational reasoning enables adolescents to think about relations among relations and about classes of classes. For example, they might first divide the students in their high school into a number of classes (nerds, jocks, skaters, preppies, druggies, etc.), and then construct higher-order classes of the groups whose members tend to be friends with each other (such as preppies and jocks).

Formal operational reasoning also leads adolescents to interpret observed outcomes within the context of logically possible outcomes. This type of reasoning was illustrated in the description of the chemical combinations problem earlier in the chapter. Formal operational reasoners not only planned a way
to generate all possible combinations of the chemicals but also interpreted the results in terms of all of the outcomes, not just the ones where the event of interest (the yellow color) occurred. This led them to realize that although two chemicals were both present whenever the yellow color appeared, their presence was not sufficient to produce the color change, because in two other cases both were present and the solution remained clear. From this, they deduced that the color change reflected the absence of a third chemical as well as the presence of the two others.

A chronological summary. It is easy to become confused among the numerous developmental changes Piaget described. Table 2.2 places some of the most important changes in relation to each other and may create a better feel for which types of changes occur when in development.

<table>
<thead>
<tr>
<th>Stage of Development</th>
<th>Relevant Age Range</th>
<th>Typical Achievements and Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensorimotor Period</td>
<td>Birth to 1 month</td>
<td>Modification of reflexes to make them more adaptive.</td>
</tr>
<tr>
<td>(Birth to 2 years)</td>
<td>1 to 4 months</td>
<td>Primary circular reactions and coordination of actions.</td>
</tr>
<tr>
<td></td>
<td>4 to 8 months</td>
<td>Secondary circular reactions. No searching for hidden objects.</td>
</tr>
<tr>
<td></td>
<td>8 to 12 months</td>
<td>Coordination of secondary circular reactions. Baby retrieves hidden objects but continues searching where objects were previously found rather than where they were last hidden.</td>
</tr>
<tr>
<td></td>
<td>12 to 18 months</td>
<td>Tertiary circular reactions. Baby systematically varies heights from which he or she drops things.</td>
</tr>
<tr>
<td></td>
<td>18 to 24 months</td>
<td>Beginning of true mental representations. Deferred imitation.</td>
</tr>
<tr>
<td>Preoperational Period</td>
<td>2 to 4 years</td>
<td>Development of symbolic capacities. Growth of language and mental imagery. Egocentric communication.</td>
</tr>
<tr>
<td>(2 to 7 years)</td>
<td>4 to 7 years</td>
<td>Good language and mental imagery skills. Inability to represent transformations. Child focuses on single perceptual dimension in conservation, class inclusion, time, seriation, and other problems.</td>
</tr>
<tr>
<td>Concrete Operational Period</td>
<td>Whole period</td>
<td>Child can perform true mental operations, represent transformations as well as states, and solve conservation, class inclusion, time, and many other problems. Child still has difficulty thinking of all possible combinations, as in the chemical problem, and of transformations of transformations.</td>
</tr>
<tr>
<td>Formal Operational Period</td>
<td>Whole period</td>
<td>Adolescent can think about all possible outcomes, interpret particular events in terms of their relation to hypothetical events, and understand abstract concepts such as conservation of motion and chemical interactions.</td>
</tr>
</tbody>
</table>
An Evaluation of Piaget's Theory

How can we evaluate this rich and diverse theory of cognitive development? Some of the strengths of the theory were mentioned at the outset of the chapter. It provides us with a good feel for what children's thinking is like at different points in development. It addresses questions that have intrigued parents, teachers, philosophers, and scientists for hundreds of years. It surveys a remarkably broad spectrum of developments in children's thinking and covers the entire age span from infancy through adolescence. It includes countless surprising observations of how children think.

With these general virtues in mind, we can consider three more specific questions. How accurately does the theory describe the particulars of children's thinking at different ages? How useful are its stages as descriptions and explanations of children's thinking? How valid are its general characterizations of children's thinking, such as the claim that preoperational children are egocentric?

How accurately does the theory describe particular aspects of children's thinking?

Piaget's theory makes many specific claims about how children think and reason at different ages. How have these claims held up in the face of subsequent research?

The most basic issue for any scientific theory is whether other people can replicate the findings on which the theory is based. Piaget's observations were so surprising that many early experiments were conducted simply to replicate them. These replication experiments used larger, more representative samples of children and more standardized versions of Piaget's tasks, but otherwise closely resembled his approach.

In general, the attempts to replicate were successful. Larger samples of American, British, Canadian, Australian aboriginal, and Chinese children tested in the 1960s and 1970s showed the same type of reasoning that Piaget's small samples of Swiss children had shown almost half a century earlier (Corman & Escalona, 1969; Dens, 1973; Doidwell, 1965; Elkind, 1961a, 1961b; Goodnow, 1962; Lovell, 1961; Uzgiris, 1964). Children in non-Western societies reached the stages at older ages than children in Western societies, but when they did reach the stages they showed the expected type of reasoning. This was especially true for the sensorimotor, preoperational, and concrete operational periods. Formal operational reasoning seems to be exhibited by some adolescents, but only by a minority of them, even in advanced societies, at least on the scientific reasoning problem typically used to assess formal operations (Byrnes, 1988; Kuhn, García-Mila, Zohar, & Andersen 1995).

Can we accept these replications at face value? Perhaps the immature reasoning that children display in many situations is due not to their reasoning being immature, but rather to the verbal methods used both by Piaget and by the replication studies underestimating their knowledge. Critics of such methods argue that young children's inarticulateness often creates a falsely pessimistic impression of their cognitive capabilities (e.g., Brainerd, 1978). Just because children cannot explain their reasoning does not mean that the reasoning itself is deficient.

It now is apparent, however, that young children show similar reasoning when tested with nonverbal versions of Piaget's tasks. Siegler carried out one such series of experiments in which a nonverbal method was used to examine a number of Piaget's tasks, including balance scale problems; time, speed, and distance problems; and conservation of liquid quantity, solid quantity, and number problems (Siegler, 1976, 1978, 1981; Siegler & Richards, 1979). On each of these tasks, children reasoned much as would have been expected from Piaget's descriptions.

A third question is whether children possess conceptual understanding not revealed by Piaget's experiments. Here the situation is different. Throughout development, children seem to have basic understandings not evident in their performance on Piaget's problems. Many of the demonstrations of children's early understandings have been extremely clever.

Consider Baillargeon's (1987) experiment on object permanence. Piaget claimed that infants younger than 8 months do not realize that objects continue to exist when they disappear from view. Baillargeon developed a more sensitive measure that showed that even with infants as young as 4 months, out of sight does not mean totally out of mind. Her experiment involved placing a box behind a wooden board (Figure 2.7). An axle went horizontally through the middle of the board so that pushing the board made it swing. At first, the board was in a position where the box was clearly visible. Then, the experimenter set the board swinging, which hid the box from the child's line of sight. In the physically possible condition, the swinging board reached the box, which was near the apex of its swing anyway, and then swung the other way. In the physically impossible condition, the board appeared to swing right through the place where the box had been. (This effect was accomplished with trick lighting and mirrors.) Despite the box's not being visible anymore, the 4-month-olds behaved as if they were surprised when they saw the seemingly impossible event. They looked much longer than they did when the physically possible event occurred. They apparently thought the board's swinging should be impeded by the box, even when they could not see it.

The results are not unique to this particular method. Baillargeon (1993) demonstrated that 3½-month-olds showed similar surprise when the upper half of a rabbit seemed to disappear as the rabbit moved across a window where, if not for trickery, it would have been visible. In other experiments, she has shown that infants can represent as many as three hidden objects simultaneously, and that they can represent not only the fact that an object continues to exist, but also its approximate height and location. Thus, children as young as 4 months possess some understanding of object permanence.
The demonstrations of earlier-than-predicted cognitive competence are not limited to sensorimotor acquisitions. Preschoolers also show rudimentary understanding of concepts that Piaget believed were too advanced for them. Consider conservation of taste and of weight. Piaget believed that both of these concepts were too difficult for preoperational stage children. However, when 3- to 5-year-olds see sugar dissolved in a cup of water, most believe that despite the sugar not being visible, the water will taste sweet, that it will continue to taste sweet in the future, and that it will weigh more than it did when no sugar was in the cup (Au, Sidle, & Rollins, 1993). To explain their views, the 3- to 5-year-olds advanced explanations indicating that the sugar still exists in tiny invisible particles that influence the taste and weight of the solution even though it looks identical to the solution with no sugar. Thus, children in the preoperational stage do have some understanding of conservation of taste and of weight.

The discovery of unsuspected cognitive strengths in infants and young children has been one of the leading stories in recent research in cognitive development. It is interesting to consider why these competencies are being discovered now. One reason is the development of clever new methods for finding out what children understand. Another reason is that a broader range of children's thinking is being considered. The research of Gelman and her colleagues illustrates this trend (Gelman, 1990; Gelman & Gallistel, 1978; Miller & Gelman, 1983). Piaget focused on preschoolers' frequent failures on number conservation tasks and concluded that they do not grasp the concept of number. Gelman's research indicated that whether or not preschoolers grasp the concept of number, they know a great deal about numbers. They count accurately, and in a way that suggests understanding of the principles underlying counting; they know the effects that addition and subtraction have on small collections of objects; they know which numbers are bigger and which smaller; and so on.

The number of insightful demonstrations of early competence is too large to review in any detail here. Examples include work on children's understanding of causality (Ahn, Kalish, Medin, & Gelman, 1995; Oakes & Cohen, 1995), categorization (Arterberry & Bornstein, 2002; Mareschal & Quinn, 2001; Rakison & Oakes, 2003) space (Blades & Spencer, 1994; Huttenlocher, Newcombe, & Sandberg, 1994; Newcombe, Huttenlocher, & Learmonth, 1999), time (Colombo & Richman, 2002; Friedman, 2002), and properties of objects (Goubet & Clifton, 1998; Kotovsky & Baillargeon, 1994; Needham, 2001; Speake, Berninger, Macomber, & Jacobson, 1992). In short, although Piaget's observations reveal a great deal about how young children think, and although they can be replicated using both verbal and nonverbal methods, they often underestimate the children's competence.

**HOW STAGELIKE IS CHILDREN'S THINKING?**

Stage models such as Piaget's imply that children's thinking changes qualitatively from one stage to another; that within any one stage, their reasoning is similar across diverse problems; and that they are unable to learn to think in ways associated with the next higher stage until they are near that stage or in it (Brainerd, 1978; Flavell, 1971). How well do these characterizations fit what is known today about children's thinking?

**Qualitative changes.** Whether children's thinking undergoes qualitative change depends in large part on how closely you look at it. When viewed from afar, many changes in children's thinking appear discontinuous; when viewed from close up, the same changes often appear as part of a continuous, gradual progression. Again, the development of object permanence can be used to illustrate the general point. As noted previously, infants younger than 7 or 8 months often do not reach for objects when they see them hidden. Under the same conditions, older infants almost always do reach for the objects. Piaget interpreted these results to mean that the older infants understand that objects have a permanent existence and that the younger ones do not.
Newer evidence suggests a different interpretation—that the change is not as sudden as Piaget believed. Infants as young as 6 months succeed on the classic Piagetian object permanence task if allowed to reach immediately after the object is hidden. The longer that infants must wait before trying to get the object, the older they must be before they reach for it (Diamond, 1985). Gradual improvements in memory for the locations of hidden objects, rather than a sudden insight that objects continue to exist, seems to underlie the change.

Even if we believe that infants experience some type of insight that elevates their understanding of the continued existence of hidden objects, it is still clear that after this insight, they continue to expand their ability to locate such objects. Reaching for objects that have been placed under opaque containers is part of a more general cognitive trend—improved skill in searching the physical environment for lost or hidden objects. These search skills develop over a long period; even 4-year-olds err on some hidden object problems. Further, when older children err, their mistakes parallel those of younger children. When presented with three, rather than two, potential hiding places, infants, 1-year-olds, and 4-year-olds most often make the same type of errors. They look at locations where they have found the object previously, rather than locations where they never have found it. The frequency of errors declines, but the type of errors remains the same. (For interesting articles on young children’s abilities to search physical environments and find hidden objects, see Baker-Ward & Ornstein, 1988; DeLoache, 1987, 1991, 2000; DeLoache, Miller, & Rosengren, 1997; Spencer, Smith, & Thelen, 2001.)

A branch of mathematics known as catastrophe theory provides justification for viewing development as both continuous and discontinuous. Catastrophe theory examines sudden changes such as the collapse of bridges. The forces that lead to bridges collapsing often build up slowly over a period of years. The visible collapse, however, can be breathtakingly sudden. Analogously, despite the seeming abruptness of cognitive progress when a boy solves a problem one day that he could not solve the day before, the progress may be based on years of gradually improving understanding. In the boy, as in the bridge, the change can be viewed as either a continuous process of small, invisible alterations or as a discontinuous shift from one state to another.

Similar reasoning on different problems. Saying that children are in a certain stage of reasoning implies that their reasoning across many tasks shares that stage’s characteristics. Within Piaget’s theory, an 8-year-old ideally would grasp all concrete-operations-level concepts—conservation of liquid quantity, class inclusion, seriation, and so on—and would fail to grasp all formal-operations-level concepts—thinking in terms of all possible combinations, conservation of motion, and so on.

It has become increasingly clear that this view does not accurately characterize children’s thinking. Consider three concrete-operations-level concepts: conservation of number, conservation of solid quantity, and conservation of weight. Theoretically, all of these should be mastered simultaneously; a child should understand either all or none of them. Actually, however, most children master Piaget’s number conservation task at around age 6, his solid quantity conservation task at around age 8, and his weight conservation task at around age 10 (Elkind, 1961a; Katz & Bellin, 1976; Miller, 1976). These data do not support the idea of concurrent development, even within the concept of conservation.

Despite the evidence against the view that children generally reason similarly across many problems, consistencies of reasoning across tasks continue to be of great interest. The motivation is rooted in everyday observations of children’s reasoning. There seems to be something characteristic of 2-year-olds’ reasoning that distinguishes it from 5-year-olds’; something in 5-year-olds’ reasoning that distinguishes it from 10-year-olds’; and so on. That is, children of a given age do seem to reason in a characteristic way in different contexts.

In one attempt to address the issue, Flavell (1988) hypothesized that the amount of consistency of reasoning across tasks may depend on when we observe the reasoning. Children seem to reason more similarly across different concepts when they are just beginning to understand them than when they understand them better. For example, 5-year-olds solve a large variety of problems that they are just beginning to understand by identifying a single relevant dimension of the problem and focusing on it. On conservation of liquid quantity, they predict that whichever glass has the taller liquid column also has more water, regardless of the cross-sectional areas. On conservation of solid quantity, they predict that whichever clay sausage is longer also has more clay, again regardless of the cross-sectional areas. In judging which side of a balance scale will tip, they rely entirely on relative amounts of weight, ignoring distance of the weights from the fulcrum. They exhibit similar reasoning with concepts as diverse as temperature, happiness, and morality (Case, 1985, 1992a; Ferretti, Butterfield, Cahn, & Kerkman, 1985; Levin, Wilkening, & Dembo, 1984; Siegler, 1981; Strauss, 1982).

In contrast, the ages at which children solve these problems correctly vary a great deal. Even 9-year-olds generally can solve conservation of liquid and solid quantity problems; even college students often cannot solve balance scale problems. Differing amounts of experience with the problems, differences in the ease of drawing analogies to better-understood problems, and differences in the complexity of the most advanced solution strategies contribute to these differences in age of mastery.

Another potential source of consistency in children’s reasoning is the level of their most advanced reasoning (Fischer, 1980; Fischer & Bidell, 1981; Halford, 1982, 1993). For example, the most advanced thinking of 9-year-olds might involve single operations. This would mean that none of their thinking involves operations on operations (as in the formal operations period). However, it would not mean that they solve correctly all problems that can be solved using single operations. Whether they solve a given problem depends on how much experience they have had with it, whether they were familiar with related problems, whether it occurred in a familiar context, and so on. In sum, unities in children’s
reasoning may be most apparent in their early reasoning, when they have little knowledge of the concepts involved, and in the level of the most advanced reasoning of which they are capable.

**Can development be accelerated?** Piaget’s views concerning the possibility of accelerating cognitive development through training are among his most controversial. Some of his comments indicate that no training could be successful. Others suggest that training might at times be effective, but only if the child already possesses some understanding of the concept and if the training procedure involves active interaction with materials.

In fact, young children can learn more than Piaget thought they could, and they can benefit from a greater variety of instructional techniques (Bellin, 1977; Field, 1987). The findings dovetail with the unsuspected early competence that children have been found to have even without training. Not only do children understand more than previously thought, they also can learn more.

However, it is important not to throw out the baby with the bathwater. Although young children can learn to solve these problems, they often find doing so exceptionally difficult. Older children who cannot yet solve the same problems typically learn them much more easily. It is indisputable that young children can learn concepts once thought to be “too advanced” for their age group. What we still don’t understand is why, when two children both don’t understand a concept, the older child so often can learn it more easily.

**HOW WELL DO PIAGET’S GENERAL CHARACTERIZATIONS FIT CHILDREN’S THINKING?**

In addition to describing children’s thinking in terms of particular examples of their reasoning at particular stages (e.g., “Preoperational stage children think that the glass with the taller liquid column must have more water”), Piaget also characterized children’s thinking in terms of intellectual traits. For example, he described preoperational stage children as being egocentric, precritical, semilogical, and perceptually oriented. These terms fit in some ways, but not in all. The characterization of preoperational children as egocentric illustrates many of the issues.

Recall from the discussion of egocentric communication and the cartoon of the two children talking past each other that 2- to 4-year-olds are not very skilled communicators. They often ignore what other people say to them, and they have trouble taking other people’s viewpoints. These types of observations led Piaget to label their thinking “egocentric.”

But in other situations, young children communicate non-egocentrically. If you ask 3-year-olds to show you their drawings, they hold the side with the artwork toward you. If they were completely egocentric, they would hold the drawing toward themselves, because they would assume that what they see is what you see. Similarly, even 2- and 3-year-olds practice deception. For example, Sullivan and Winner (1993) described a 2-year-old who feigned tears when his aunt would not play with him; when the aunt came over, the child said to his mother, “I tricked her. I made her think I was sad” (p. 160). If the 2-year-old believed that the aunt knew exactly what he knew, how could he “trick” her?

Similar demonstrations have shown that preschoolers’ representations of space also are not entirely egocentric. To measure spatial egocentrism, Piaget used tasks such as the three mountains problem shown in Figure 2.3. Such problems require not only taking another perspective but also choosing between competing frames of reference: the one that children actually see and the one they are asked to imagine seeing from the other vantage point. Even adults find such choices between competing frames of reference to be difficult (Rieser, Garing, & Young, 1994). In contrast, when the competing frame of reference is eliminated (by covering the original arrangement), and children are given ways of expressing the concepts “left” and “right” (by putting a sticker on one of their hands and referring to the sticker side and the non-sticker side), even 3-year-olds can take spatial perspectives other than their own (Newcombe & Huttenlocher, 1992). This does not mean that they can take other people’s perspectives as well as older children. After all, older children succeed on the three mountains task even when a competing frame of reference is present. The finding does mean, however, that under less demanding conditions, 3-year-olds can take perspectives other than their own.

Conversely, people well beyond the preoperational period continue to be “at risk” for egocentrism. A classic demonstration of this involved a situation analogous to a phone conversation. Two children were seated opposite each other at a table with a board between them; thus, they could not see each other. Each child was presented identical sets of pictures, with each picture containing an irregular design. The speaker had to describe one of the pictures so that the listener could figure out which one was being described (Krauss & Glucksberg, 1969).

Not surprisingly, older children communicate which picture they have in mind more effectively than younger ones. More surprising, even 8- and 9-year-olds often have difficulty overcoming their knowledge of what they are referring to sufficiently to generate a description that will allow the other child to understand. Further, children well beyond the preoperational period experience difficulty knowing who is to blame for the missed communication—whether the message is inadequate or whether the listener simply failed to respond properly to it. (See Beal & Belgrad, 1990; Lloyd, Mann, & Peers, 1998; Nadig & Sedivy, 2002; Robinson & Robinson, 1981; Sonnenschein, 1988; Waters & Tinsley, 1985, for discussions of egocentric communication.)

There seems little doubt that young children often behave more egocentrically than older ones. Labeling an age group “egocentric” is too strong, though. It leads us to ignore both the ways that younger children’s thinking is not egocentric and the ways that older children’s thinking is.
THE CURRENT STATUS OF PIAGET'S THEORY

If Piaget's theory underestimates young children's reasoning abilities, overestimates older children's reasoning abilities, and describes children's thinking in terms that are misleading as well as revealing, why pay so much attention to it? The simple reason is that with all of its shortcomings, the theory still gives us a good feel for how children think. It also points us in the right direction for learning more about children's thinking. Piaget recognized the intelligence in infants' early activities. In making these discoveries, he raised the issue of what additional capabilities infants might have, an issue that has led to many additional discoveries about infants' thinking. His estimate of the degree of unity in children's thinking was too high, but he discovered some important unities and pointed to the importance of searching for more of them. Finally, Piaget's basic questions are the right ones. What capabilities do infants possess at birth? What capabilities do they possess at later points in development? What processes lead to the remarkable increases in their understanding that occur with development? The remainder of this book is an attempt to answer these questions.

Summary

Piaget's theory remains a dominant force in developmental psychology, despite the fact that much of it was formulated half a century ago. Some of the reasons for its lasting appeal are the important acquisitions it describes, the large span of childhood it encompasses, and the reliability and charm of many of its observations.

At the most general level, Piaget's theory focused on the development of intelligence. The purpose of intellectual development was to allow children to adapt to the environment. This adaptation was achieved through generating progressively more accurate and encompassing representations of reality.

Piaget's general depiction included four stages of development: the sensorimotor, preoperational, concrete operational, and formal operational periods. The sensorimotor period occupies the age range between 0 and 2 years, the preoperational period between 2 and 6 or 7, the concrete operational period between 6 or 7 and 11 or 12, and the formal operational period from early adolescence to the end of life. Each period includes large changes in understanding of such important concepts as conservation, classification, and relations.

Piaget also identified three basic developmental processes: assimilation, accommodation, and equilibration. Assimilation refers to the means by which children interpret incoming information to make it understandable within their existing mental structures. Accommodation refers to the ways in which children's current understandings change in response to new experience. Equilibration is a three-step process that includes assimilation and accommodation. First, children are in a state of equilibrium. Then, failure to assimilate new information leads to their becoming aware of shortcomings in their current understanding. Finally, their mental structure accommodates to the new information in a way that creates a more advanced equilibrium.

During the sensorimotor period, infants acquire primary, secondary, and tertiary circular reactions, in which their actions become more deliberate and more systematic, and extend beyond their bodies. They also acquire a precursor of conservation—the object permanence concept—in which they realize that objects continue to exist even if they move out of sight. They also form simple understandings of classes and relations.

In the preoperational period, children become able to represent their ideas through language and mental imagery. Despite this development, Piaget primarily emphasized what preoperational children cannot do. He noted that 5-year-olds usually fail conservation, class inclusion, and seriation problems. He attributed such failures to the children's focusing on perceptual appearances rather than transformations, to their being egocentric, and to their centering on a single dimension rather than considering multiple dimensions simultaneously.

In the concrete operations period, children master these concepts and many others. They become able to represent transformations and to integrate multiple sources of information. These advances allow children to master such concepts as conservation of liquid and solid quantity, time, seriation, and class inclusion.

The formal operations period, according to Piaget, brings ability to think in terms of all possible outcomes and to view actual outcomes within this framework of logical possibilities. Children in this stage can perform systematic experiments, a skill made possible by sophisticated understanding of classes and relations. In sum, their reasoning comes to resemble that of scientists.

Piaget made a number of controversial statements about what children know at different points in development, about stages of development that they pass through, and about general characteristics of their thinking. When given either the original or nonverbal versions of Piaget's problems, children typically reason much as he described. However, they appear to have important cognitive capabilities that he did not detect.

Piaget's stage descriptions predict that children think in qualitatively different ways in different periods of development, that they reason similarly about diverse concepts, and that they cannot learn modes of thought much more advanced than those that characterize their current stage. Each of these views contains a certain amount of truth, but also has certain problems. When viewed from a distance, many developments appear to represent qualitative changes. However, when examined closely, the same changes often appear to be part of a gradual progression, with important precursors developing earlier and refinements and extensions continuing for years after. In general, the consistency of reasoning across tasks that Piaget predicted has not been found. However, considerable consistency has been apparent in children's early conceptual understanding. Young children do not learn as rapidly as older children, but it is nonetheless possible for them to acquire a great many concepts that are well beyond the understanding typical of children their age.