adult begins the interview by showing a 6-year-old boy a box containing about a dozen wooden beads, two of which are white and the rest brown. The following discussion ensues:

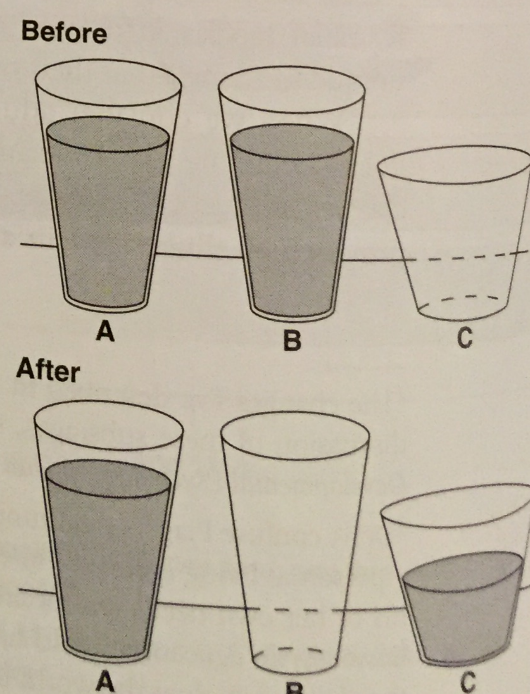
Adult: Are there more wooden beads or more brown beads?
Child: More brown ones, because there are two white ones.
Adult: Are the white ones made of wood?
Child: Yes.
Adult: And the brown ones?
Child: Yes.
Adult: Then are there more brown ones or more wooden ones?
Child: More brown ones.
Adult: What color would a necklace made of the wooden beads be?
Child: Brown and white. (Here [he] shows that he understands that all the beads are wooden.)
Adult: And what color would a necklace made with the brown beads be?
Child: Brown.
Adult: Then which would be longer, the one made with the wooden beads or the one made with the brown beads?
Child: The one with the brown beads.
Adult: Draw the necklaces for me.

The child draws a series of black rings for the necklace of brown beads. He then draws a series of black rings plus two white rings for the necklace of wooden beads.

Adult: Good. Now which will be longer, the one with the brown beads or the one with the wooden beads?
Child: The one with the brown beads. (dialogue from Piaget, 1952a, pp. 163–164)

Another example of the illogical quality of preoperational thinking is a young child's typical response to a **conservation of liquid** problem. Imagine three glasses: Glasses A and B are tall, thin, and filled to equal heights with water, whereas Glass C is short, fat, and empty, as is shown in the "Before" part of Figure 12.2. Clearly Glasses A and B contain the same amount of water.

Figure 12.2
The water in Glass B ("Before") is poured into Glass C ("After"). Does Glass C have the same amount of water that Glass B did?



But now the contents of Glass B are poured into Glass C, thereby creating the situation shown in the "After" part of Figure 12.2. Do Glass A and Glass C contain the same amount of water, or does one contain more?

Being a logical adult, you'd probably conclude that the two glasses hold identical amounts of water (excluding a few drops that might have been lost during pouring). In contrast, preoperational children are likely to say that the glasses hold different amounts of water: Most will say that Glass A has more because it's taller, although a few will say that Glass C has more because it's fatter. The children's thinking depends more on perception than logic during the preoperational stage and so is susceptible to outward appearances: The glasses *look* different and therefore must *be* different.

As children approach the later part of the preoperational stage, perhaps at around age 4 or 5, they show early signs of being logical. For example, they sometimes draw correct conclusions about class inclusion problems (e.g., the wooden beads problem) and conservation problems (e.g., the water glasses problem). But they base their reasoning on hunches and intuition rather than on any conscious awareness of underlying logical principles, and so they can't yet explain *why* their conclusions are correct.

Concrete Operations Stage (Age 6 or 7 Until Age 11 or 12)

When children move into the **concrete operations stage**, their thinking processes begin to take the form of logical *operations* that enable them to integrate various qualities and perspectives of an object or event. Such operational thought enables a number of more advanced abilities. For example, children now realize that their own viewpoints and feelings aren't necessarily shared by others and may reflect personal opinions rather than reality. Accordingly, they know they can sometimes be wrong and thus begin to seek out external validation for their ideas, asking such questions as "What do you think?" and "Did I get that problem right?"

Children in the concrete operations stage are capable of many forms of logical thought. For example, they show **conservation**: They understand that if nothing is added or taken away, the amount stays the same despite any changes in shape or arrangement. They also exhibit class inclusion—for instance, recognizing that brown beads can simultaneously be wooden beads. They can readily explain their reasoning, as the following interview with an 8-year-old about the wooden beads problem illustrates:

> Adult: Are there more wooden beads or more brown beads?
> Child: More wooden ones.
> Adult: Why?
> Child: Because the two white ones are made of wood as well.
> Adult: Suppose we made two necklaces, one with all the wooden beads and one with all the brown ones. Which one would be longer?
> Child: Well, the wooden ones and the brown ones are the same, and it would be longer with the wooden ones because there are two white ones as well. (dialogue from Piaget, 1952a, p. 176)

Children continue to develop their newly acquired logical thinking capabilities throughout the concrete operations stage. For example, over time they become capable of dealing with increasingly complex conservation tasks. Some forms of conservation, such as the conservation of liquid task illustrated in Figure 12.2, appear at age 6 or 7. Other forms may not appear until several years later. Consider the task involving conservation of weight depicted in Figure 12.3. Using a balance scale, an adult shows a child that two balls of clay have the same weight. One

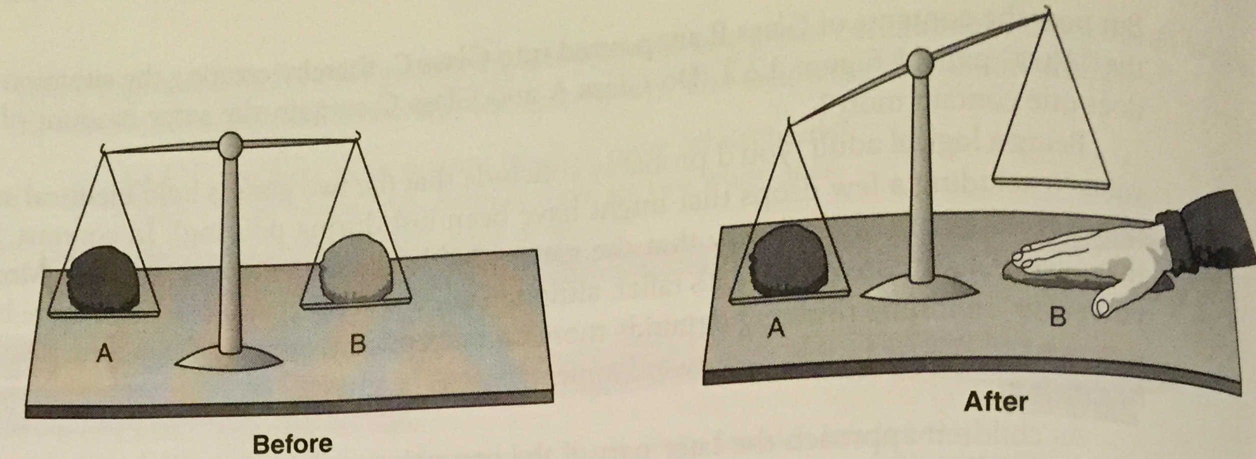


Figure 12.3
Balls A and B initially weigh the same ("Before"). When Ball B is flattened into a pancake shape ("After"), how does its weight now compare with that of Ball A?

ball is removed from the scale and smashed into a pancake shape. The child is then asked if the pancake weighs the same as the unsmashed ball or if the two pieces of clay weigh different amounts. Children typically don't achieve conservation of weight—that is, they don't realize that the flattened pancake weighs the same as the round ball—until relatively late in concrete operations.[4]

Despite their advancements in reasoning, children in the concrete operations stage are limited in one very important respect: They can apply their logical operations only to concrete, observable objects and events—hence the term *concrete* operations. They have trouble dealing with abstract concepts and with hypothetical ideas that contradict reality as they know it. For example, the concrete operational child should readily agree with this logic:

If all first graders are children,
And if all children are people,
Then all first graders are people.

Yet the concrete operational child would have trouble recognizing the logical validity of a similar problem that includes a contrary-to-fact premise:

If all first graders are children,
And if all children are hippopotamuses,
Then all first graders are hippopotamuses.

Concrete operational children cannot easily distinguish between logic and reality, and, after all, first graders *aren't* hippopotamuses.

Formal Operations Stage (Age 11 or 12 through Adulthood)

Sometime around puberty, children enter the **formal operations stage**. At this point, they become capable of thinking and reasoning about things that have little or no basis in physical reality—abstract concepts, hypothetical ideas, contrary-to-fact statements, and so on. For example, they

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[4]The idea that *any* form of matter has weight—no matter how small in size—seems to be troublesome even for adolescents (and, I suspect, also for many adults). For example, although most eighth graders acknowledge that a large block of Styrofoam has weight, they may claim that a tiny piece torn from the block has no weight at all (C. L. Smith, Maclin, Grosslight, & Davis, 1997; Wiser & Smith, 2008).

become able to see the underlying meanings of proverbs such as *A rolling stone gathers no moss* and *Don't put the cart before the horse*. They become better able to understand abstract concepts in mathematics, science, and social studies: *negative number, infinity, momentum, quark, republic, human rights*, and so on.

Other abilities essential to mathematical and scientific reasoning emerge as well. For instance, children acquire **proportional thinking**, which enables them to comprehend the nature of proportions in various forms (e.g., fractions, decimals, ratios). And children become capable of **separation and control of variables**: In testing a hypothesis about which factor among many is responsible for a particular result, they'll test one factor at a time while holding all others constant. Consider, for example, the case of a pendulum—a suspended object that swings back and forth indefinitely (a yo-yo and a playground swing are two everyday examples). What one or more characteristics of a pendulum determine how fast it swings? You might generate several hypotheses regarding the underlying cause(s) of a pendulum's oscillation rate, including (1) the weight of the object at the bottom; (2) the length of the rope, string, or other material suspending the object; (3) the force with which the pendulum is pushed; and (4) the height from which the object is first released. To determine conclusively which one or more of these hypotheses are correct, you would need to test the effect of one characteristic at a time while keeping the other characteristics constant. For example, if you were testing the hypothesis that weight makes a difference, you might try objects of different weights while keeping constant the length of the string, the force with which you push each object, and the height from which you release or push it. Similarly, if you hypothesized that the length of the string is a critical factor, you might vary the length while continuing to use the same object and setting the pendulum in motion in the same manner. If you carefully separate and control variables, you would come to the correct conclusion: Only *length* affects a pendulum's oscillation rate.

With the onset of formal operations children are also able to examine their own thought processes and evaluate the quality and logic of those thoughts. For example, a child might say, "Oops, I just contradicted myself, didn't I?" In essence, children who have reached the formal operations stage can apply mental operations to *other* mental operations—they can think about their thinking.

Because learners capable of formal operational reasoning can deal with hypothetical and contrary-to-fact ideas, they can envision how the world might be different from—and possibly better than—the way it actually is. Thus they may initially be quite idealistic about social, political, and ethical issues. Many adolescents begin to show concern about world problems and devote some of their energy to worthy issues such as global warming, world hunger, or animal rights. However, they often offer recommendations for change that seem logical but aren't practical in today's world. For example, they might argue that racism would disappear overnight if people would just begin to "love one another," or perhaps they will propose that a nation should disband its armed forces and eliminate all of its weaponry as a way of moving toward world peace. Piaget suggested that adolescent idealism reflects an inability to separate one's own logical abstractions from the perspectives of others and from practical considerations.[5] Only through experience do adolescents eventually begin to temper their optimism with some realism about what's possible in a given time frame and with limited resources.

[5]In Piaget's view, the inability to separate logical abstractions from others' perspectives and practical considerations is another form of *egocentrism*—in this case, one that characterizes formal operational rather than preoperational thought.

Current Perspectives on Piaget's Theory

Perhaps Piaget's greatest contribution to our understanding of cognitive development was the nature of the research questions he asked and tried to answer about how children think and reason. In addition, some of his key ideas—for instance, that children actively seek information about their world, that they construct their own understandings of it, that they must relate new experiences to what they already know, and that encountering puzzling phenomena can sometimes spur them to revise their understandings—have stood the test of time.

However, Piaget's descriptions of processes that *propel* development—especially assimilation, accommodation, and equilibration—can be frustratingly vague (Chapman, 1988; diSessa, 2006; Klahr, 2001). And interaction with one's physical environment, while certainly valuable, may be less critical than Piaget believed. For instance, children with significant physical disabilities, who can't actively experiment with physical objects, learn a great deal about the world simply by observing what happens around them (Bebko, Burke, Craven, & Sarlo, 1992; Brainerd, 2003).

Piaget's theory has inspired a great deal of research about cognitive development. In general, this research supports Piaget's proposed *sequence* in which different abilities emerge (Chapman, 1988; Flavell, Miller, & Miller, 2002; Ginsburg, Cannon, Eisenband, & Pappas, 2006). For example, the ability to reason about abstract ideas emerges only after children are already capable of reasoning about concrete objects and events, and the order in which various conservation tasks are mastered is much as Piaget reported. Contemporary researchers question the *ages* at which various abilities actually appear, however. They're also finding that children's logical reasoning capabilities may vary considerably depending on their previous experiences, knowledge, and cultural backgrounds. And most contemporary researchers seriously doubt that cognitive development is as stagelike as Piaget proposed.

Capabilities of Different Age-Groups

Infants are apparently more competent than Piaget's description of the sensorimotor stage suggests. For instance, they show preliminary signs of object permanence as early as 2½ months old and continue to firm up this understanding over a period of many months (Baillargeon, 2004; L. B. Cohen & Cashon, 2006). Also, by 12 months of age, infants who haven't yet acquired language can nonverbally communicate about—and so apparently can also *think* about—objects and events they aren't currently perceiving or experiencing (Liskowski, Schäfer, Carpenter, & Tomasello, 2009; Mandler, 2007).

Toddlers and preschoolers, too, are more capable that Piaget's preoperational stage would have us believe. For instance, preschool children don't always show egocentrism: If we ask them to show us their artwork, they hold it so that we (rather than they) can see it (Newcombe & Huttenlocher, 1992). Under some circumstances they're capable of class inclusion and conservation (Donaldson, 1978; Goswami & Pauen, 2005; Morra, Gobbo, Marini, & Sheese, 2008). Occasionally they even show rudimentary forms of abstract and contrary-to-fact thinking—thinking that, in Piaget's view, doesn't appear until adolescence (S. R. Beck, Robinson, Carroll, & Apperly, 2006; Ginsburg, Lee, & Boyd, 2008; McNeil & Uttal, 2009).

Piaget may have underestimated the capabilities of elementary school children as well. For example, even first and second graders show some ability to understand and use simple proportions (e.g., ½, ⅓, ¼) if they can relate these proportions to everyday objects (Empson, 1999; Van Dooren, De Bock, Hessels, Janssens, & Verschaffel, 2005). And some elementary school children can separate and control variables, especially when asked to choose among several possible experiments or given hints about the importance of controlling all variables except the one being tested (Barchfeld, Sodian, Thoermer, & Bullock, 2005; Lorch et al., 2010; Metz, 1995; Ruffman, Perner, Olson, & Doherty, 1993).

Yet Piaget seems to have *overestimated* what adolescents can do. Formal operational thinking processes (e.g., proportional reasoning, separation and control of variables) emerge much more gradually than Piaget suggested, and even high school students don't necessarily use them regularly (Flieller, 1999; Schliemann & Carraher, 1993; Tourniaire & Pulos, 1985; Zohar & Aharon-Kraversky, 2005). In fact, even *adults* don't always reason in the logical ways that supposedly characterize formal operational thought (X. Lin & Lehman, 1999; Morra et al., 2008; Pascarella & Terenzini, 1991). For instance, when adults draw conclusions and inferences about real-world events, they may overrely on their existing knowledge about the world—thus having the same difficulty in separating logic from reality that children in concrete operations do (D. Kuhn & Franklin, 2006). Perhaps the rules of formal logic—the kind you might learn in a philosophy class—don't reflect the typical ways in which children or adults reason (Halford & Andrews, 2006; D. Kuhn & Franklin, 2006). To some degree, Piaget's formal operations stage may capture people's capabilities under the best of circumstances rather than their normal, day-to-day reasoning processes (R. J. Sternberg, 2003).

Effects of Experience and Prior Knowledge

Piaget proposed that neurological maturation places significant constraints on children's reasoning abilities at any particular age. Although maturation certainly places limits on cognitive development (see Chapter 2), Piaget may have overrated its importance in logical thought, especially for older children and adolescents. Explicit training and other experiences often help youngsters acquire reasoning abilities sooner than Piaget predicted (Brainerd, 2003; D. Kuhn, 2006). For instance, children as young as age 4 or 5 begin to show conservation after having experience with conservation tasks, especially if they can actively manipulate the task materials and discuss their reasoning with someone who already exhibits conservation (D. Field, 1987; Halford & Andrews, 2006; Siegler & Chen, 2008; Siegler & Lin, 2010). Similarly, instruction with concrete manipulatives can help children grasp the nature of proportions (Fujimura, 2001; Sarama & Clements, 2009). Children ages 10 and 11 can more easily solve logical problems involving hypothetical ideas if they're taught relevant problem-solving strategies, and they become increasingly able to separate and control variables when they have numerous experiences that require them to do so (D. Kuhn & Pease, 2008; S. Lee, 1985; Lorch et al., 2010; Schauble, 1990).

Piaget acknowledged that as children gain new logical thinking skills, they may apply the skills in one subject area but not necessarily in another (Chapman, 1988; Piaget, 1940). It's becoming increasingly apparent that for people of all ages, the ability to think logically can vary considerably from one situation to the next, depending on knowledge, background experiences, and training relevant to the situation (Brainerd, 2003; D. Kuhn & Franklin, 2006). For instance, adolescents may demonstrate formal operational thought in one academic subject area while thinking more concretely in others (Klaczynski, 2001; Lovell, 1979; Tamburrini, 1982). Evidence of formal operations typically emerges in the physical sciences earlier than in such subjects as history and geography, perhaps because the latter subjects are further removed from students' everyday realities. And in general, adolescents and adults are apt to apply formal operational thought to topics about which they have a great deal of knowledge and yet think concretely about topics with which they're unfamiliar (Girotto & Light, 1993; M. C. Linn, Clement, Pulos, & Sullivan, 1989; Schliemann & Carraher, 1993).

One experience that promotes more advanced reasoning is formal education. Going to school and the specific nature of one's schooling are associated with mastery of concrete operational and formal operational tasks (Artman & Cahan, 1993; Dias, Roazzi, O'Brien, & Harris, 2005; Flieller, 1999; Rogoff, 2003). For instance, you'll be happy to learn that taking college courses in a particular area (in the psychology of learning, perhaps?) leads to improvements in formal reasoning skills related to that area (Lehman & Nisbett, 1990).

Effects of Culture

Although Piaget eventually acknowledged that different cultural groups might foster different ways of thinking, he gave virtually no attention to culture as a prominent factor affecting cognitive development (Chapman, 1988). Yet research indicates that the course of cognitive development varies somewhat from one cultural group to another, probably because different cultures give children somewhat different experiences (Maynard & Greenfield, 2003; Morra et al., 2008). For example, Mexican children whose families make pottery for a living acquire conservation skills earlier than their peers in other Mexican families (Price-Williams, Gordon, & Ramirez, 1969). Apparently, making pottery requires children to make frequent judgments about needed quantities of clay and water—judgments that must be fairly accurate regardless of the specific shape or form of the clay or water container. In other cultures, especially in some where children don't attend school, conservation appears several years later than it does in Western cultures, and formal operational reasoning may never appear at all (M. Cole, 1990; Fahrmeier, 1978). In such contexts, some logical reasoning skills may simply have little relevance to people's daily lives (J. G. Miller, 1997; Morra et al., 2008).

Views on Piaget's Stages

In light of all the evidence, does it still make sense to talk about discrete stages of cognitive development? Even Piaget acknowledged that the characteristics of any particular stage don't necessarily hang together as a tight, inseparable set of abilities (Chapman, 1988; Piaget, 1940). Most contemporary developmental theorists now believe that cognitive development can more accurately be described in terms of gradual *trends*—for instance, a trend toward increasingly abstract thought—rather than discrete stages (e.g., L. B. Cohen & Cashon, 2006; Flavell, 1994; D. Kuhn & Franklin, 2006; Siegler & Alibali, 2005). They further suggest that Piaget's stages may better describe how children *can* think—rather than how they typically *do* think—and that the nature of cognitive development may be somewhat specific to different contexts, content areas, and cultures (Halford & Andrews, 2006; Klaczynski, 2001; Rogoff, 2003).

Yet some psychologists believe that by entirely rejecting Piaget's notion of stages, we may be throwing the baby out with the bath water. We look at their neo-Piagetian perspectives now.

Neo-Piagetian Theories of Cognitive Development

Some theorists have combined some of Piaget's ideas with concepts from information processing theory to construct **neo-Piagetian theories** of how children's learning and reasoning capabilities change over time (e.g., Case, 1985, 1991; Case & Okamoto, 1996; Fischer & Bidell, 2006;