

# 2

## Learning, Cognition, and Memory



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## Case Study: *The New World*

Rita attends fourth grade at a school in Michigan. Her class has recently had a unit on Michigan's state history. Rita still knows little about U.S. history; she will study that subject as a fifth grader next year. Despite her limited background in history, Rita willingly responds to an interviewer's questions about the New World.

**Interviewer:** Our country is in the part of the world called America. At one time, America was called the New World. Do you know why it was called the New World?

**Rita:** Yeah. We learned this in social studies.

**Interviewer:** What did you learn?

**Rita:** Because they used to live in England, the British, and they didn't know about . . . they wanted to get to China 'cause China had some things they wanted. They had some cups or whatever—no, they had furs. They had fur and stuff like that and they wanted to have a shorter way to get to China so they took it and they landed in Michigan, but it wasn't called Michigan. I think it was the British that landed in Michigan and they were there first and so they tried to claim that land, but it didn't work out for some reason so they took some furs and brought them back to Britain and they sold them, but they mostly wanted it for the furs. So then the English landed there and they claimed the land and they wanted to make it a state, and so they got it signed by the government or whoever, the big boss, then they were just starting to make it a state so the British just went up to the Upper Peninsula and they thought they could stay there for a little while. Then they had to fight a war, then the farmers, they were just volunteers, so the farmers went right back and tried to get their family put together back again.

**Interviewer:** Did you learn all this in state history this year?

**Rita:** Um hum.<sup>1</sup>

- Which parts of Rita's response accurately describe the history of the New World? Which parts are clearly inaccurate?
- Michigan's Upper Peninsula is separated from the rest of the state by the Straits of Mackinac, which connect Lake Michigan and Lake Huron. Why might Rita think that making Michigan a state caused the British to move to the Upper Peninsula?
- At the time that British colonists were first settling in Michigan, merchants back in England were seeking a new trade route to the Far East so they could more easily secure the tea, spices, and silk available there. Why might Rita initially suggest that the British wanted to get cups from China? Why might she then say that they wanted to get furs?

<sup>1</sup> VanSledright & Brophy, 1992, p. 849.

Rita has certainly learned some facts about her state and its history. For example, she is aware of a region called the Upper Peninsula, and she knows that many of the state's early European settlers were British. But she has taken what she knows to spin a tale that could give a historian heart failure.

To some extent, Rita's lack of information about certain things is limiting her ability to make sense of what she has learned about Michigan's history. More specifically, Rita doesn't know that the British and the English were the *same people*. Thinking of them as two different groups, she assumes that the arrival of the latter group drove the former group to the Upper Peninsula.

Yet occasionally what Rita *does* know is a source of difficulty as well. For instance, she associates *China* with dinnerware (including cups), and she has learned that some early European explorers were seeking furs to send back to their homeland. She uses such information to draw logical but incorrect inferences about why the British were so eager to find a new route to China.

To understand how children and adolescents acquire understandings about their physical and social worlds, about academic subject matter, and about themselves as human beings, we must first understand the nature of learning. As Rita's depiction of Michigan's history clearly illustrates, learning is often a matter of creating, rather than absorbing, knowledge about the world. In other words, learning is a *constructive process*, as we shall see now.

## LEARNING AS A CONSTRUCTIVE PROCESS

For purposes of our discussion, we will define **learning** as a long-term change in mental representations and associations due to experience. Let's divide this definition into its three parts. First, learning is a *long-term change* in that it isn't just a brief, transitory use of information—such as remembering a phone number long enough to dial it and then forgetting it—but it doesn't necessarily last forever. Second, learning involves *mental associations* and so presumably has its basis in the brain. Third, learning is a change *due to experience*, rather than the result of physiological maturation, fatigue, alcohol or drugs, or onset of mental illness.

Psychologists have been studying the nature of learning for more than a century. In the process they have taken a variety of theoretical perspectives. Table 2.1 summarizes five diverse perspectives that have contributed considerably to our understanding of what learning involves, and it introduces a number of concepts (e.g., *reinforcement*, *self-regulation*, *working memory*, *schemas*, *internalization*) that we will find quite helpful in our discussions of various learning phenomena. The table also lists examples of theorists associated with each perspective. You will find many of these theorists cited in footnotes in this and later chapters.

For the most part, diverse perspectives of learning complement rather than contradict one another, and together they can give us a rich, multifaceted picture of human learning. As we explore the nature of learning in this book, then, we will draw useful ideas from all five perspectives. In Chapter 2, however, we will be looking primarily at what goes on inside the learner, and so we will find the information processing and constructivist approaches most helpful.

A few basic principles underlie much of what theorists have learned about learning. These principles are as follows:

### **By the time they reach school age, young learners are usually actively involved in their own learning.**

Sometimes children learn from an experience without really giving the experience much thought. For example, as infants and toddlers acquire the basic vocabulary and syntax of their first language, they seem to do so without consciously trying to acquire them and without thinking about what they are learning. Much of the learning

**learning** Long-term change in mental representations and associations due to experience.

**TABLE 2.1**  
**General Theoretical Approaches to the Study of Learning**

**THEORETICAL PERSPECTIVES**

Theoretical Perspective	General Description	Examples of Prominent Theorists
<b>Behaviorism</b>	Behaviorists argue that because thought processes cannot be directly observed and measured, it is difficult to study thinking objectively and scientifically. Instead, they focus on two things that researchers <i>can</i> observe and measure: people's behaviors ( <i>responses</i> ) and the environmental events ( <i>stimuli, reinforcement</i> ) that precede and follow those responses. Learning is viewed as a process of acquiring and modifying associations among stimuli and responses, largely through a learner's direct interactions with the environment.	B. F. Skinner Ivan Pavlov
<b>Social Learning Theory</b>	Social learning theorists focus on the ways in which people learn from observing one another. Environmental stimuli affect behavior, but cognitive processes (e.g., <i>awareness</i> of stimulus-response relationships, <i>expectations</i> about future events) also play a significant role. Oftentimes people learn through <i>modeling</i> : They watch and imitate what others do. Whether people learn and perform effectively is also a function of their <i>self-efficacy</i> , the extent to which they believe they can successfully accomplish a particular task or activity. Although the environment certainly influences people's behaviors, with time most people begin to engage in <i>self-regulation</i> ; that is, they take charge of and direct their own actions. In recent years social learning theory has increasingly considered the role of thought processes in learning, and so it is sometimes called <b>social cognitive theory</b> .	Albert Bandura Dale Schunk Barry Zimmerman
<b>Information Processing Theory</b>	While not denying that the environment plays a critical role in learning, information processing theorists investigate what goes on <i>inside</i> learners, focusing on the cognitive processes involved in learning, memory, and performance. From observations of how people execute various tasks and behave in various situations, these theorists draw inferences about how people may perceive, interpret, and mentally manipulate information they encounter in the environment. They speculate about what internal mechanisms underlie human cognition (e.g., <i>working memory</i> and <i>long-term memory</i> ) and about how people mentally process information (e.g., through <i>elaboration</i> and <i>visual imagery</i> ). Initially, some information processing theorists believed that human thinking is similar to how a computer works (hence, they borrowed terms such as <i>encoding, storage, and retrieval</i> from computer lingo), but in recent years most theorists have largely abandoned the computer analogy.	Richard Atkinson Richard Shiffrin John Anderson Alan Baddeley Elizabeth Loftus
<b>Constructivism</b>	Constructivists, like information processing theorists, concern themselves with internal aspects of learning. They propose that people create (rather than absorb) knowledge from their observations and experiences. They suggest that people combine much of what they learn into integrated bodies of knowledge and beliefs (e.g., these might take the form of schemas and theories) that may or may not be accurate and useful understandings of the world. Some theorists focus on how individual learners create knowledge through their interactions with the environment; this approach is known as <b>individual-constructivism</b> . Others emphasize that by working together, two or more people can often gain better understandings than anyone could gain alone; this approach is called <b>social constructivism</b> .	Jean Piaget John Bransford Carl Bereiter Marlene Scardamalia Giyoo Hatano
<b>Sociocultural Theory</b>	Sociocultural theorists emphasize that the social, cultural, and historical contexts in which children develop have profound influences on thinking, learning, and instructional practices. In social interactions within their communities, young learners encounter culturally appropriate ways of thinking about and interpreting objects and events. With time and practice, these ways of thinking—which are first used in a social context—are gradually <i>internalized</i> into nonspeaking, mental processes that learners use on their own. Because of their varying environments, historical circumstances, and needs, different cultures have developed somewhat different ways of thinking, learning, and teaching.	Lev Vygotsky Barbara Rogoff Jean Lave

that occurs during infancy and toddlerhood is such *implicit learning*, and even older children and adults continue to learn some things about their environments in a non-intentional, “thoughtless” way.<sup>2</sup> But as children grow, they increasingly engage in intentional, *explicit learning*: They actively think about, interpret, and reconfigure what they see and hear in their environment. As a simple example, try the following exercise.

<sup>2</sup> See Kelly, Burton, Kato, & Akamatsu, 2001; Reber, 1993.

**SEE FOR YOURSELF****Remembering Words**

Study the twelve words below, Then cover up the page, and write down the words in the order they come to mind.

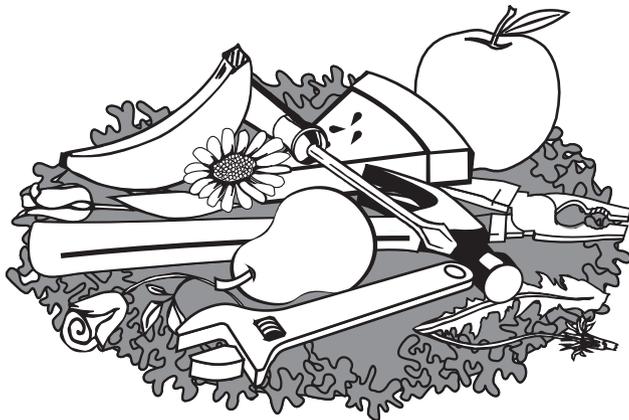
daisy	apple	dandelion
hammer	pear	wrench
tulip	pliers	watermelon
banana	rose	screwdriver

In what order did you remember the words? Did you recall them in their original order, or did you rearrange them somehow? If you are like most people, you grouped the words into three categories—flowers, fruit, and tools—and remembered one category at a time. In other words, you *organized* the words. As children get older, they are more likely to organize what they learn, and learners of all ages learn more effectively when they organize the subject matter at hand.

**Cognitive processes influence what is learned.**

The various ways in which people think about what they are seeing, hearing, studying, and learning is known as **cognition**, and the more specific things they do are often referred to as **cognitive processes**. As will become clear as we proceed through the chapter, the cognitive processes that learners use to understand and remember information can have a profound effect on what they specifically learn and on how well they can remember it over the long run.

An example of a cognitive process is **encoding**, in which a learner changes incoming information in some way in order to remember it more easily. Whenever people mentally change the information they are learning—whether they interpret it, organize it, weave a story or poem around it, form a mental image of it, draw inferences about it, or in some other way modify or add to it—they are encoding it. In the preceding “Remembering Words” exercise, chances are that you learned not only a list of words but also a categorical structure for the words. But let’s consider some alternative strategies you might have used to remember the list. For instance, you might have created a story or poem that included all twelve words (e.g., “As *Daisy* and *Tulip* were walking, they ran across *Dandy* and *Rose*. They stopped in dismay when they noticed that *Dandy* had *pliers* on her nose . . .”). Or you might have formed a mental image of the twelve items in an elaborate, if not entirely edible, fruit salad (see Figure 2.1). All of these approaches are forms of encoding the twelve-word list.



**Figure 2.1** A visual image for encoding a list of twelve words

**Learners must be selective about what they focus on and learn.**

People are constantly bombarded with information. Consider the many stimuli you are encountering at this very moment. How many separate stimuli appear on the two open pages of your book? How many objects do you see in addition to the book? How many sounds are reaching your ears? How many objects—perhaps on your fingertips, on your toes, at your back, or around your waist—do you feel? I suspect that you have been ignoring most of these stimuli until just now; you were not actively processing them until I asked you to do so. People can handle only so much information at a given time, and so they must be selective. Effective learners focus on what they think is important and ignore almost everything else.

As an analogy, consider the hundreds of items a typical adult receives in the mail each year, including all the packages, letters, bills, brochures, catalogs, fliers, advertisements, requests for donations, and sweepstakes announcements. Do you open, examine, and respond to every piece of mail? Probably not. If you’re like me, then you “process” only a few key items (e.g., packages, letters, bills, and some miscellaneous things that catch your eye). You may inspect other items long enough to know that you don’t need them. You may even discard some items without opening them at all.

**cognition** Various ways of thinking about information and events.

**cognitive process** Particular way of mentally responding to or thinking about information or an event.

**encoding** Changing the format of information being stored in memory in order to remember it more easily.

People don't always make good choices about what to attend to, of course. Just as they might overlook a small, inconspicuous rebate check while opening a colorful "You May Already Have Won . . ." sweepstakes announcement, so, too, might they fail to catch an important idea in a classroom lesson because they're focusing on trivial details in the lesson or on a classmate's attention-getting behavior across the room. An important job for teachers, then, is to help students understand what is most important to learn and what can reasonably be cast aside as "junk mail."

### Learners create (rather than receive) knowledge.

As was apparent in Rita's depiction of Michigan's history, learning is not simply a process of absorbing information from the environment. Rather, it is a process of *making*—actively and intentionally constructing—knowledge and understandings. As an example, try the following exercise.

#### SEE FOR YOURSELF

##### Rocky

Read the following passage *one time only*:

Rocky slowly got up from the mat, planning his escape. He hesitated a moment and thought. Things were not going well. What bothered him most was being held, especially since the charge against him had been weak. He considered his present situation. The lock that held him was strong but he thought he could break it. He knew, however, that his timing would have to be perfect. Rocky was aware that it was because of his early roughness that he had been penalized so severely—much too severely from his point of view. The situation was becoming frustrating; the pressure had been grinding on him for too long. He was being ridden unmercifully. Rocky was getting angry now. He felt he was ready to make his move. He knew that his success or failure would depend on what he did in the next few seconds.<sup>3</sup>

Now summarize what you've just read in two or three sentences.

Were you able to make sense of the passage? What did you think it was about? A prison escape? A wrestling match? Or perhaps something else altogether? The passage about Rocky includes a number of facts but leaves a lot unsaid. For instance, it tells us nothing about where Rocky was, what kind of "lock" was holding him, or why timing was of the utmost importance. Yet you were probably able to use the information you were given to construct an overall understanding of Rocky's situation. Most people do find meaning of one sort or another in the passage.

This active sense-making process—what theorists sometimes refer to as *constructing meaning*—is hardly limited to verbal material. For another example, try the following exercise.

#### SEE FOR YOURSELF

##### Three Faces

Figure 2.2 contains three pictures. What do you see in each one? Most people perceive the picture on the left as being that of a woman, even though many of her features are missing. Enough features are visible—an eye, parts of the nose, mouth, chin, and hair—that you can construct a meaningful perception from them. Is enough information available in the other two figures for you to construct two more faces? Constructing a face from the figure on the right may take you a while, but it can be done.



**Figure 2.2** Can you construct a person from each of these pictures?

From "Age in the Development of Closure Ability in Children," by C. M. Mooney, 1957, *Canadian Journal of Psychology*, 11, p. 220. Copyright 1957. Canadian Psychological Association. Reprinted with permission.

<sup>3</sup> R. C. Anderson, Reynolds, Schallert, & Goetz, 1977, p. 372.

Objectively speaking, the three configurations of black splotches in Figure 2.2, and especially the two rightmost ones, leave a lot to the imagination. For example, the woman in the middle is missing half of her face, and the man on the right is missing the top of his head. Yet knowing how human faces typically appear is probably enough to enable you to add the missing features (mentally) and perceive complete pictures. Curiously, once you have constructed faces from the figures, they then seem obvious. If you were to close this book now and not pick it up again for a week or more, you would probably see the faces almost immediately, even if you had had considerable difficulty perceiving them originally.

### Learners make sense of new experiences using what they already know and believe.

In the “Rocky” and “Three Faces” exercises you just did, you were able to make sense of situations even though a lot of information was missing. Your prior knowledge—perhaps about how prison escapes or wrestling matches typically proceed, and certainly about how human facial features are arranged—allowed you to fill in many missing details. Prior knowledge and beliefs usually play a major role in the meanings people construct.

Different people often construct different meanings from the same situation, in part because they each bring unique prior experiences and knowledge to the situation. For example, when the “Rocky” passage was used in an experiment with college students, physical education majors frequently interpreted it as a wrestling match, but music education majors (most of whom had little or no knowledge of wrestling) were more likely to think it was about a prison break.<sup>4</sup> Not only do learners bring different areas of expertise to a learning task, they also bring different childhood experiences, cultural backgrounds, and assumptions about the world, and such differences are apt to have a significant impact on how they interpret new information.

The brain is, of course, the place where human beings think about, make sense of, and learn from their environment. We now look briefly at what the brain is like and how it functions.

## THINKING AND LEARNING IN THE BRAIN

The brain is an incredibly complicated mechanism that includes somewhere in the neighborhood of *one hundred billion* nerve cells.<sup>5</sup> These nerve cells, known as **neurons**, are microscopic in size and interconnected in innumerable ways. Some neurons receive information from the rest of the body, others synthesize and interpret the information, and still others send messages that tell the body how to respond to its present circumstances. Curiously, however, neurons don’t actually touch one another. Instead, using a variety of substances known as **neurotransmitters**, they send chemical messages to their neighbors across the tiny spaces—**synapses**—between them. Any single neuron may have synaptic connections with hundreds or even thousands of other neurons.<sup>6</sup>

As we’ll discover in Chapter 5, the brain changes in important ways over the course of childhood and adolescence. Yet three basic points about the brain are important to keep in mind as we explore cognition and learning in this chapter:

### The various parts of the brain work closely with one another.

Groups of neurons in different parts of the brain seem to specialize in different things. Structures in the lower and middle parts of the brain specialize in essential physiological processes (e.g., breathing, heart rate), bodily movements (e.g., walking, riding a bicycle), and basic perceptual skills (e.g., coordinating eye movements, diverting attention to potentially life-threatening stimuli). Complex thinking, learning, and knowledge are located primarily in the upper and outer parts of the brain

**neuron** Cell in the brain or another part of the nervous system that transmits information to other cells.

**neurotransmitter** Chemical substance with which one neuron sends a message to another.

**synapse** Tiny space across which one neuron regularly communicates with another; reflects a well-established connection between the two neurons.

<sup>4</sup> R. C. Anderson et al., 1977.

<sup>5</sup> Goodman & Tessier-Lavigne, 1997.

<sup>6</sup> Goodman & Tessier-Lavigne, 1997; Lichtman,

2001; R. F. Thompson, 1985.

collectively known as the **cortex**, which rests on the top and sides of the brain like a thick, bumpy toupee<sup>7</sup> (see Figure 2.3). The portion of the cortex located near the forehead, known as the *prefrontal cortex*, is largely responsible for a wide variety of very “human” activities, including sustained attention, reasoning, planning, decision making, coordinating complex activities, and inhibiting nonproductive thoughts and behaviors. Other parts of the cortex are important as well, being actively involved in interpreting visual and auditory information, identifying the spatial characteristics of objects and events, and keeping track of general knowledge about the world.

To some degree, the left and right halves, or *hemispheres*, of the cortex have different specialties.<sup>8</sup> For most people, the left hemisphere has primary responsibility for speech, language comprehension, reading, and mathematical calculations. The right hemisphere is more dominant in visual and spatial processing, such as locating objects in space, perceiving shapes, comparing quantities, drawing and painting, mentally manipulating visual images, recognizing faces and facial expressions, and interpreting gestures. In general, the left side is more apt to handle details, whereas the right side is better suited for looking at and synthesizing an overall whole.

Yet contrary to a popular belief, people rarely if ever think exclusively in one hemisphere. There is no such thing as “left-brain” or “right-brain” thinking: The two hemispheres typically collaborate in day-to-day tasks. In fact, the various parts of the brain *all* communicate constantly with one another. Recall a point made earlier: Neurons have synapses with many, many other neurons. As information travels through the brain, messages go across areas that handle very different sensory modalities and tasks. In essence, learning or thinking about virtually anything tends to be *distributed* across many parts of the brain. A task as seemingly simple as identifying a particular word in speech or print involves numerous areas of the cortex.<sup>9</sup>

### Most learning probably involves changes in neurons and synapses.

From a physiological standpoint, how and where does learning occur? Many theorists and researchers believe that the physiological basis for most learning lies in changes in the interconnections among neurons. In particular, learning may involve strengthening existing synapses or forming new ones.<sup>10</sup> In some instances, however, learning may actually involve *eliminating* synapses. Effective learning requires not only that people think and do certain things but also that they *not* think or do other things—in other words, that they inhibit tendencies to think or behave in particular ways.<sup>11</sup>

Another phenomenon may be involved in learning as well. Until recently, it was common “knowledge” that all the neurons a person would ever own are produced in the first few weeks after conception—that is, long before the person is even born. Researchers are finding, however, that some formation of new neurons continues throughout life in the *hippocampus* (a small, seahorse-shaped structure in the middle of the brain) and possibly also in certain areas of the cortex.<sup>12</sup> Neuron formation appears to be stimulated by new learning experiences, but the precise role it plays in the learning process is still unclear.

As for *where* learning occurs, the answer is: many places. The prefrontal cortex is active when people must pay attention to and think about new information and events, and all of the cortex may be active to a greater or lesser extent in interpreting

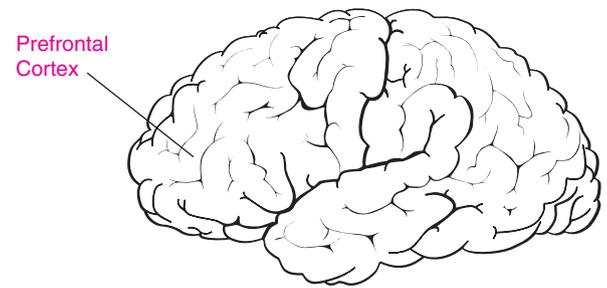


Figure 2.3 Cortex of the human brain

<sup>7</sup> Kimberg, D’Esposito, & Farah, 1997; Nadel & Jacobs, 1998; E. E. Smith, 2000.

<sup>8</sup> Byrnes, 2001; Ornstein, 1997; T. Roberts & Kraft, 1987.

<sup>9</sup> Bressler, 2002; Byrnes, 2001; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001; Thelen & Smith, 1998.

<sup>10</sup> Byrnes & Fox, 1998; Greenough, Black, & Wallace, 1987; Merzenich, 2001; Rosenzweig, 1986.

<sup>11</sup> Bruer & Greenough, 2001; Byrnes, 2001; Dempster, 1992; Haier, 2001.

<sup>12</sup> Gould, Beylin, Tanapat, Reeves, & Shors, 1999; Sapolsky, 1999; R. A. Thompson & Nelson, 2001.

**cortex** Upper and outer parts of the human brain, which are largely responsible for conscious and higher-level human thought processes.

new input in light of previously acquired knowledge.<sup>13</sup> The hippocampus also seems to be a central figure in learning, in that it pulls together the information it simultaneously receives from various parts of the brain.<sup>14</sup>

### Knowing how the brain functions and develops tells us only so much about learning and instruction.

Even as researchers pin down how and where learning occurs, current knowledge of brain physiology doesn't begin to tell us everything we need to know about learning or how to foster it. For instance, brain research cannot tell us much about what information and skills are most important for people to have in a particular community and culture.<sup>15</sup> Nor does it provide many clues about how teachers can best help their students acquire important information and skills.<sup>16</sup> In fact, educators who mistakenly talk about “using brain research” or “brain-based learning” are, in most instances, actually talking about what psychologists have learned from studies of human *behavior* rather than from studies of brain anatomy and physiology.

By and large, if we want to understand the nature of human cognition and identify effective ways of helping children and adolescents learn more effectively, we must look primarily at what psychologists, rather than neurologists, have discovered.<sup>17</sup> We begin our exploration of cognitive processes by looking at what psychologists have learned about human memory.

## HOW HUMAN MEMORY OPERATES

The term **memory** refers to learners' ability to “save” things (mentally) that they have learned. In some cases we will use the term to refer to the actual process of saving knowledge or skills for a period of time. In other instances we will use it to talk about a particular “location” where knowledge is held. For instance, we will shortly be talking about two components of the human memory system known as *working memory* and *long-term memory*.

The process of “putting” something into memory is called **storage**. Just as you might store groceries in a kitchen cabinet, so, too, do you store newly acquired knowledge in your memory. At some later time, you may find that you need to use what you've learned. The process of remembering previously stored information—that is, “finding” it in memory—is called **retrieval**. The following exercise illustrates the retrieval process.

### SEE FOR YOURSELF

#### Retrieval Practice

See how quickly you can answer each of the following questions:

1. What is your name?
2. What is the capital of France?
3. In what year did Christopher Columbus first sail across the Atlantic Ocean to reach the New World?
4. What did you have for dinner three years ago today?
5. When talking about serving appetizers at a party, we sometimes use a French term instead of the word *appetizer*. What is that French term, and how is it spelled?

As you probably noticed when you tried to answer these questions, retrieving information from memory is sometimes an easy, effortless process. For example, you undoubtedly had little difficulty remembering your name. But other things can be re-

**memory** Ability to save something (mentally) that has been previously learned; also, the mental “location” where such information is saved.

**storage** Process of “putting” new information into memory.

**retrieval** Process of “finding” information previously stored in memory.

<sup>13</sup> Byrnes, 2001.

<sup>14</sup> Bauer, 2002; Squire & Alvarez, 1998.

<sup>15</sup> L. Bloom & Tinker, 2001; Chalmers, 1996; Gardner, 2000b.

<sup>16</sup> Byrnes, 2001; Mayer, 1998.

<sup>17</sup> For a classic article on this topic, see Bruer, 1997.

trieved only after some thought and effort. For example, it may have taken you a few seconds to recall that the capital of France is Paris and that Columbus first sailed across the Atlantic in 1492. Still other pieces of information, even though you may have stored them in memory at one time, may be almost impossible to retrieve. Perhaps a dinner menu three years ago and the correct spelling of *bors d'oeuvre* fall into this category.

Psychologists do not agree about the exact nature of human memory. But many believe that it may have three components that hold information for different lengths of time.<sup>18</sup> A model of memory that includes these components is depicted in Figure 2.4. Working from the model and drawing from countless research studies of human memory, we can derive some general principles about how human memory operates.

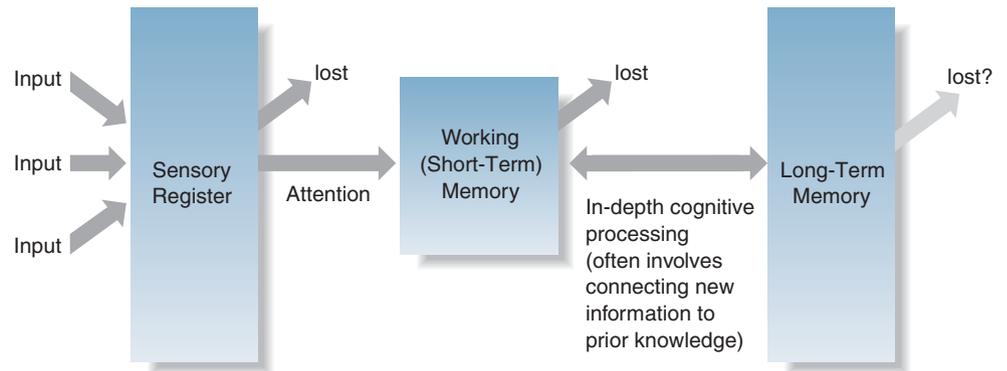


Figure 2.4 A model of human memory

### Sensory input stays in a raw form only briefly.

If you have ever played with a lighted sparkler at night, then you've seen the tail of light that follows a sparkler as you wave it about. If you have ever daydreamed in class, then you may have noticed that when you tune back in to a lecture, you can still “hear” the three or four words that were spoken just *before* you started paying attention to your instructor again. The sparkler's tail and the words that linger are not “out there” in the environment. Instead, they are recorded in your sensory register.

The **sensory register** is the component of memory that holds the information you receive—*input*—in more or less its original, *unencoded* form. Much of what your body sees, hears, and otherwise senses is stored in the sensory register. In other words, the sensory register has a *large capacity*: It can hold a great deal of information at one time.

That's the good news. The bad news is that information stored in the sensory register doesn't last very long.<sup>19</sup> Visual information (what you see) probably lasts for less than a second. As a child, I never could spell out my entire first name (Jeanne) with a sparkler; the *J* had always faded before I got to the first *N*, no matter how quickly I wrote. Auditory information (what you hear) probably lasts slightly longer, perhaps for two or three seconds. To keep information for any time at all, then, learners need to move it to *working memory*. Whatever information isn't moved is probably lost, or forgotten.

### Attention is essential for most learning and memory.

Information taken directly from the environment, such as the light cast by a sparkler, doesn't last very long no matter what we do. But we can preserve a memory of it by encoding it in some minimal way—for instance, by interpreting a sparkler's curlicue tail as the letters *Jea*. The first step in this process is **attention**: *Whatever people pay attention to (mentally) moves into working memory*. Information in the sensory register that doesn't get a person's attention typically disappears from the memory system.

Paying attention involves directing not only the appropriate sensory receptors (in the eyes, ears, fingertips, etc.) but also the *mind* toward whatever needs to be learned and remembered. Imagine yourself reading a textbook for one of your classes. Your eyes are moving down each page, but meanwhile you are thinking

**sensory register** Component of memory that holds incoming information in an unanalyzed form for a very brief time (perhaps 1–2 sec).

**attention** Focusing of mental processes on particular stimuli.

<sup>18</sup> For example, see R. C. Atkinson & Shiffrin, 1968; Reisberg, 1997; Willingham, 2004.

<sup>19</sup> Cowan, 1995; Darwin, Turvey, & Crowder, 1972; Sperling, 1960.



Observe how David's lack of attention affects learning in the "Memory and Metacognition: Middle Childhood" clip on Video CD 1.



Children learn effectively only when they pay attention, both physically and mentally, to the subject matter.

about something altogether different—a recent argument with a friend, a high-paying job advertised in the newspaper, or your growling stomach. What will you remember from the textbook? Absolutely nothing. Even though your eyes were focused on the words in your book, you weren't *mentally* paying attention to those words.

Children, too, often have trouble keeping their attention on a task at hand. We find an example in the "Memory and Metacognition: Middle Childhood" video clip on Video CD 1. Ten-year-old David remembers only three of the twelve words that an interviewer reads to him. When he says, "My brain was turned off right now," he really means that his *attention* was turned off, or at least directed to something other than what the interviewer was saying.

Unfortunately, people can attend to only a very small amount of information at any one time. In other words, attention has a *limited capacity*.<sup>20</sup> For example, if you are in a room where several conversations are going on at once, you can usually attend to—and therefore can learn from—only one of those conversations. If you are sitting in front of the television with your textbook open in your lap, you can attend to the *Friends* rerun playing on the TV screen *or* to your book, but not to both simultaneously. If you are preoccupied in class with your instructor's ghastly taste in clothing and desperate need for a fashion makeover, you will have a hard time paying attention to the content of the instructor's lecture.

Exactly *how* limited is the limited capacity of human attention? People can often perform two or three well-learned, automatic tasks at once. For example, you can walk and chew gum simultaneously, and you can probably drive a car and drink a cup of coffee at the same time. But when a stimulus or event is detailed and complex (as is true for both textbooks and *Friends* reruns) or when a task requires considerable thought (understanding a lecture and driving a car on an icy mountain road are examples of tasks requiring one's utmost concentration), then people can usually attend to only *one* thing at a time.

Let's return to a point made earlier in the chapter: Learners must be selective about what they learn. Now we see the reason why: Attention has a limited capacity, and so only a very small amount of information stored in one's sensory register ever moves on to working memory. The vast majority of information that the body initially receives is quickly lost from the memory system, much as we might quickly discard most of that junk mail we receive every day.

### Working memory—where the action is in thinking and learning—has a short duration and limited capacity.

**Working memory** is the component of memory where attended-to information stays for a short while so that we can make better sense of it. It is also where much of our thinking, or cognitive processing, occurs. It is where we think about the content of a lecture, understand a textbook passage, or solve a problem. Basically, this is the component that does most of the mental work of the memory system—hence its name *working* memory.<sup>21</sup>

Information stored in working memory doesn't last very long—perhaps five to twenty seconds at the most—unless people do something else with it.<sup>22</sup> Accordingly, it is sometimes called *short-term memory*. For example, imagine that you need to call a friend, so you look up the friend's number in the telephone book. Because you've paid attention to the number, it is presumably in your working memory. But you dis-

**working memory** Component of memory that holds and actively thinks about and processes a limited amount of information.

<sup>20</sup> J. R. Anderson, 1990; Norman, 1969; Reisberg, 1997.

<sup>21</sup> Rather than being a single entity, working memory probably has several components for holding and working with different kinds of information—for example, for handling visual

information, auditory information, and meanings—as well as a component that integrates multiple kinds of information (Baddeley, 2001; E. E. Smith, 2000; Willingham, 2004).

<sup>22</sup> For example, see Baddeley, 2001; L. R. Peterson & Peterson, 1959.

cover that someone else is using the phone. You have no paper and pencil handy. What do you do to remember the number until the phone is available?

To keep the number in your memory until you can dial it, you might simply repeat it to yourself over and over again. This process, known as **rehearsal**, keeps information in working memory for as long as you're willing to continue talking to yourself. But once you stop, the number may disappear fairly quickly.

Put your working memory to work for a moment in the following exercise.

### **SEE FOR YOURSELF**

#### **A Divisive Situation**

Try computing the answer to this division problem in your head:

$$59 \overline{)49,383}$$

Did you find yourself having trouble remembering some parts of the problem while you were dealing with other parts? Did you ever arrive at the correct answer of 837? Most people cannot solve a division problem with this many digits unless they write the problem on paper. The fact is, working memory just doesn't have enough space both to hold all that information and to perform mathematical calculations with it. Like attention, working memory has a *limited capacity*, perhaps just enough for a telephone number or very short grocery list.<sup>23</sup> In and of itself, it lets you hold and think about only a very small amount of material at once.

I sometimes hear students talking about putting class material in “short-term memory” so that they can do well on an upcoming exam. Such a statement reflects two common misconceptions: that (1) this component of memory lasts for several days, weeks, or months; and (2) it has a fair amount of “room.” Now you know otherwise: Information stored in working memory lasts only a few seconds unless it is processed further, and only a few things can be stored there at one time. Working (short-term) memory is obviously *not* the “place” to leave information that you need for an exam later in the week, or even for information that you'll need for a class later today. For such memory tasks, storage in long-term memory—the final component of the memory system—is in order.

### **Long-term memory has a long duration and virtually limitless capacity.**

**Long-term memory** is where we store such pieces of information as our names, frequently used telephone numbers, recollections of prior experiences, general knowledge about the world, and things we've learned in school (perhaps the capital of France or the correct spelling of *bors d'oeuvre*). Such knowledge about *what and how things are* is known as **declarative knowledge**. Long-term memory is also where we store knowledge about how to perform various behaviors, such as how to ride a bicycle, swing a baseball bat, or write a cursive letter *J*. Such knowledge about *how to do things* is known as **procedural knowledge**. When procedural knowledge includes knowing how to respond differently under different conditions, it is sometimes known as *conditional knowledge*.

As you might guess, information stored in long-term memory lasts much longer than information stored in working memory—perhaps a day, a week, a month, a year, or a lifetime (more on the “lifetime” point later in the chapter). Even when it's there, however, people cannot always find (retrieve) it when they need it. As we will see in upcoming sections, people's ability to retrieve previously learned information from long-term memory depends on both the way in which they initially stored it and the context in which they're trying to remember it.

Long-term memory seems to be able to hold as much information as a learner needs to store there. There is probably no such thing as someone “running out of room.” In fact, for reasons we'll discover shortly, the more information already stored in long-term memory, the easier it is to learn new things.

**rehearsal** Cognitive process in which information is repeated over and over as a possible way of learning and remembering it.

**long-term memory** Component of memory that holds knowledge and skills for a relatively long time.

**declarative knowledge** Knowledge related to “what is”—that is, to the nature of how things are, were, or will be.

**procedural knowledge** Knowledge concerning how to do something (e.g., a skill).

<sup>23</sup> Baddeley, 2001, G. A. Miller, 1956; Simon, 1974.

## Much of long-term memory is well integrated.

Information stored in long-term memory is organized and interconnected to some extent. To get a glimpse of how your own long-term memory is organized, try the following exercise.

### SEE FOR YOURSELF

#### Horse

What is the first word that comes to your mind when you see the word *horse*? And what word does that second word remind you of? And what does that third word remind you of? Beginning with the word *horse*, follow your train of thought, letting each word remind you of another one, for a sequence of at least eight words. Write down your sequence of words as each word comes to mind.

You probably found yourself easily following a train of thought from the word *horse*, perhaps something like the route I followed:

horse → cowboy → lasso → rope → knot → Girl Scouts → cookies → chocolate

The last word in your sequence might be one with little or no obvious relationship to horses. Yet you can probably see a logical connection between each pair of words in your sequence. Related pieces of information in long-term memory are often connected with one another, perhaps in a network similar to the one depicted in Figure 2.5.

In the process of constructing knowledge, learners create well-integrated entities that encompass particular ideas or groups of ideas. Beginning in infancy, they form **concepts** that enable them to categorize objects and events.<sup>24</sup> In Figure 2.6, 8-year-old Noah shows his knowledge about the concept *butterfly*. Some concepts, such as *butterfly*, *chair*, and *backstroke*, refer to a fairly narrow range of objects or events. Other concepts are fairly general ones that encompass numerous more specific concepts. For example, the concept *insect* includes ants, bees, and butterflies. The concept *furniture* includes chairs, tables, beds, and desks. The concept *swim* includes the backstroke, dog paddle, and butterfly. As you can see, the word *butterfly* can be associated with two very different, more general concepts (insects and swimming) and so might lead someone to follow a train of thought such as this one:

horse → cowboy → lasso → rope → knot → Girl Scouts → camping  
→ outdoors → nature → insect → butterfly → swimming

Learners often pull some of their concepts together into general understandings of what things are typically like. Such understandings are sometimes called **schemas**.<sup>25</sup> For example, let's return to our friend the horse. You know what horses look like, of course, and you can recognize one when you see one. Hence, you have a concept for *horse*. But now think about the many things you know *about* horses. What do they eat? How do they spend their time? Where are you most likely to see them? You probably have little difficulty retrieving many different things about horses, perhaps including their fondness for oats and carrots, their love of grazing and running, and their frequent appearance in pastures and at racetracks. The various things you know about horses are closely interrelated in your long-term memory in the form of a "horse" schema.

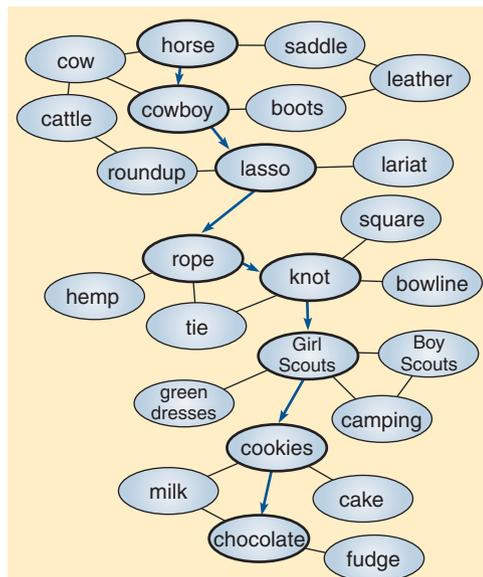
People have schemas not only about objects but also about events. For example, read the following passage about John.

### SEE FOR YOURSELF

#### John

Read the following passage *one time only*.

John was feeling bad today so he decided to go see the family doctor. He checked in with the doctor's receptionist, and then looked through several medical magazines



Long-term memory is organized, such that related pieces of information are often associated with one another. Here we can follow the author's train of thought from "horse" to "chocolate."

**Figure 2.5** Interconnectedness in long-term memory

**concept** Mental grouping of objects or events that have something in common.

**schema** General understanding of what an object or event is typically like.

<sup>24</sup> Behl-Chadha, 1996; Eimas & Quinn, 1994; Quinn, 2002.

<sup>25</sup> For example, see Rumelhart & Ortony, 1977.

that were on the table by his chair. Finally the nurse came and asked him to take off his clothes. The doctor was very nice to him. He eventually prescribed some pills for John. Then John left the doctor's office and headed home.<sup>26</sup>

You probably had no trouble understanding the passage because you have been to a doctor's office yourself and have a schema for how those visits usually go. You can therefore fill in a number of details that the passage doesn't ever tell you. For example, you probably inferred that John must have *gone* to the doctor's office, although the story omits this essential step. Likewise, you probably concluded that John took his clothes off in the examination room, *not* in the waiting room, even though the story never makes it clear where John did his striptease. When a schema involves a predictable sequence of events related to a particular activity, as is the case in a visit to the doctor's office, it is sometimes called a **script**.

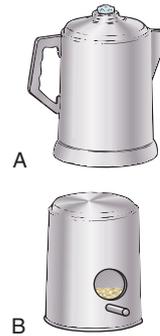
On a much larger scale, human beings—young children included—construct general understandings and belief systems, or **theories**, about how the world operates.<sup>27</sup> People's theories include many concepts and the relationships (e.g., association, cause and effect) among them. To see what some of your own theories are like, try the next exercise.

### SEE FOR YOURSELF

#### Coffeepots and Raccoons

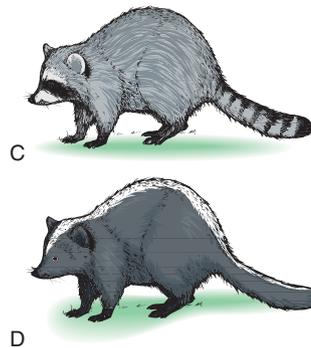
Consider each of the following situations:

1. People took a coffeepot that looked like Drawing A. They removed the handle, sealed the top, took off the top knob, sealed the opening to the spout, and removed the spout. They also sliced off the base and attached a flat piece of metal. They attached a little stick, cut out a window, and filled the metal container with birdseed. When they were done, it looked Drawing B.



After these changes, was this a coffeepot or a bird feeder?

2. Doctors took the raccoon in Drawing C and shaved away some of its fur. They dyed what was left black. Then they bleached a single stripe all white down the center of the animal's back. Then, with surgery, they put in its body a sac of supersmelly odor, just as a skunk has. After they were all done, the animal looked like Drawing D.



After the operation, was this a skunk or a raccoon?<sup>28</sup>

Chances are, you concluded that the coffeepot had been transformed into a bird feeder but that the raccoon was still a raccoon despite its cosmetic makeover and major surgery. Even fourth graders come to these conclusions.<sup>29</sup> Now how is it possible that the coffeepot could be made into something entirely different, whereas the raccoon could not?

Even children as young as 8 or 9 seem to make a basic distinction between human-made objects (e.g., coffeepots, bird feeders) and biological entities (e.g.,

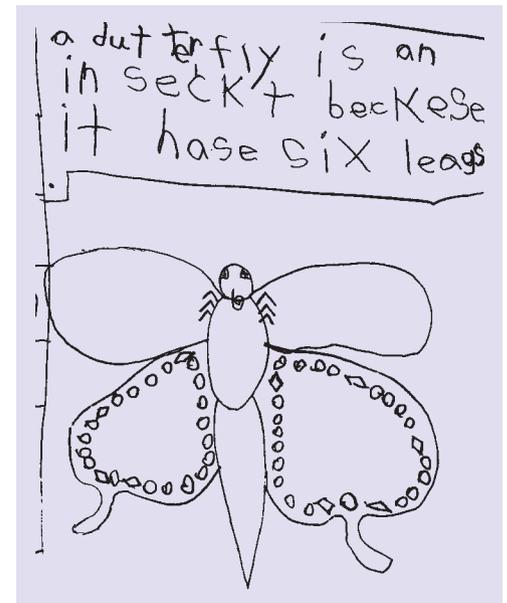


Figure 2.6 Eight-year-old Noah depicts his understanding of the concept *butterfly*.

<sup>26</sup> Bower, Black, & Turner, 1979, p. 190.

<sup>27</sup> Keil, 1989, 1994; Wellman & Gelman, 1998.

<sup>28</sup> Both scenarios based on Keil, 1989, p. 184.

<sup>29</sup> Keil, 1986, 1989.

**script** Schema that involves a predictable sequence of events related to a common activity.

**theory** Integrated set of concepts and principles developed to explain a particular phenomenon.

raccoons, skunks).<sup>30</sup> Furthermore, they seem to conceptualize the two categories in fundamentally different ways: Human-made objects are defined largely by the *functions* they serve (e.g., brewing coffee, feeding birds), whereas biological entities are defined primarily by their origins (e.g., the parents who brought them into being, their DNA). Thus, when a coffeepot begins to hold birdseed rather than coffee, it becomes a bird feeder because its function has changed. But when a raccoon is cosmetically and surgically altered to look and smell like a skunk, it still has raccoon parents and raccoon DNA and so cannot possibly *be* a skunk.

By the time children reach school age, they have constructed basic theories about their physical, biological, and social worlds.<sup>31</sup> They have also constructed preliminary theories about the nature of their own and other people's thinking. For instance, they realize that people's inner thoughts are distinct from external reality, and they understand that the people in their lives have thoughts, emotions, and motives that drive much of what they do (see Chapter 7). In general, children's self-constructed theories facilitate their acquisition of new information, and they help children organize and make sense of personal experiences, classroom subject matter, and other new information.<sup>32</sup> Yet because children's theories often evolve with little or no guidance from more knowledgeable individuals, they sometimes include erroneous beliefs about the world that can wreak havoc with new learning (more about this point shortly).

How well long-term memory is integrated and in what ways it is integrated are to some degree the result of how learners first store information in long-term memory, as we shall see now.

### Some long-term memory storage processes are more effective than others.

In the memory model depicted in Figure 2.4, you will notice that the arrow between working memory and long-term memory points in both directions. The process of storing new information in long-term memory often involves drawing on “old” information already stored there—that is, it involves using prior knowledge. To see what I mean, try the following exercise.

#### SEE FOR YOURSELF

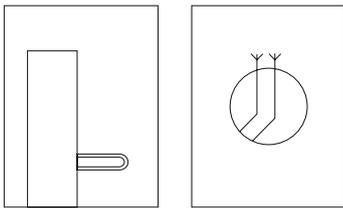
##### Two Letter Strings, Two Pictures

1. Study each of the following strings of letters until you can remember them perfectly:

AIIRODFMLAWRS

FAMILIARWORDS

2. Study each of the two pictures to the left until you can reproduce them accurately from memory.



Figures are from “Comprehension and Memory for pictures” by G. H. Bower, M. B. Karlin, and A. Dueck, 1975, *Memory and Cognition*, 3, p. 217. Reprinted by permission of Psychonomic Society, Inc.

No doubt the second letter string was easier for you to learn because you could relate it to something you already knew: the words *familiar words*. How easily were you able to learn the two pictures? Do you think you could draw them from memory a week from now? Do you think you would be able to remember them more easily if they had titles such as “a short man playing a trombone in a telephone booth” and “an early bird who caught a very strong worm”? The answer to the last question is almost certainly yes, because the titles help you relate the pictures to familiar shapes, such as those of trombones, telephone booths, and birds' feet.<sup>33</sup>

With the preceding exercise in mind, let's distinguish between two basic types of learning: rote learning and meaningful learning (e.g., see Table 2.2). People engage in **rote learning** when they try to learn remember something without attaching much meaning to it. This would be the case, for instance, if you tried to remember the letter string AIIRODFMLAWRS without trying to find some kind of “sense”—patterns in

**rote learning** Learning information in a relatively uninterpreted form, without making sense of it or attaching much meaning to it.

<sup>30</sup> Keil, 1987, 1989.

<sup>31</sup> Torney-Purta, 1994; Wellman & Gelman, 1998.

<sup>32</sup> Reiner, Slotta, Chi, & Resnick, 2000; Wellman &

Gelman, 1998.

<sup>33</sup> Bower, Karlin, & Dueck, 1975.

**TABLE 2.2** Long-Term Memory Storage Processes

Process	Definition	Example	Effectiveness
<b>Rote learning: Learning primarily through repetition and practice, with little or no attempt to make sense of what is being learned</b>			
Rehearsal	Repeating information verbatim, either mentally or aloud	Word-for-word repetition of a formula or definition	Relatively ineffective: Storage is slow, and later retrieval is difficult
<b>Meaningful learning: Making connections between new information and prior knowledge</b>			
Elaboration	Adding additional ideas to new information based on what one already knows	Thinking about possible reasons that historical figures made the decisions they did	Effective if associations and additions made are appropriate and productive
Organization	Making connections among various pieces of new information	Studying how one's lines in a play relate to the play's overall story line	Effective if organizational structure is legitimate and consists of more than just a "list" of separate facts
Visual imagery	Forming a mental picture of something; either by actually seeing it or by envisioning how it might look	Imagining how various characters and events in a novel might have looked	Individual differences in effectiveness; especially beneficial when used in combination with elaboration or organization

the letters, perhaps, or similarities to words you know—in the sequence. You would also be engaging in rote learning if you tried to remember the shapes in the “telephone booth” and “early bird” figures by simply trying to memorize where each line and curve is on the page.

One common form of rote learning is *rehearsal*, repeating something over and over, perhaps by saying it aloud or perhaps by continuously thinking about it in a more or less unaltered, verbatim fashion. We have already seen how rehearsal can help learners keep information in working memory indefinitely. Unfortunately, however, rehearsal is *not* a very effective way of storing information in *long-term* memory. If learners repeat something often enough, it might eventually “sink in,” but the process is slow, laborious, and not much fun. Furthermore, for reasons we will identify later, people who use rehearsal and other forms of rote learning often have trouble remembering what they’ve learned.<sup>34</sup>

In contrast to rote learning, **meaningful learning** involves recognizing a relationship between new information and something already stored in long-term memory. Seeing the words *familiar words* in the letter string FAMILIARWORDS and seeing meaningful shapes (a trombone, birds’ feet, etc.) in simple line drawings are two examples. Following are additional illustrations:

- Noticing how words in a foreign language are similar to, and have similar meanings as, words in English (e.g., the German word *buch* means “book,” and the French word *le crayon* means “pencil”).
- Seeing parallels among historical events (e.g., the rationale for the “ethnic cleansing” that occurred in Kosovo in the 1990s was in many ways similar to the Nazis’ belief in White superiority in the 1930s and 1940s)
- Relating subtraction facts to previously learned addition facts (e.g.,  $5 - 3 = 2$  is just a backward version of  $2 + 3 = 5$ )
- Identifying with characters in fiction (e.g., Holden Caulfield’s emotional concerns in J. D. Salinger’s *Catcher in the Rye* might be similar to those of an adolescent or young adult reading the novel)

In the vast majority of cases, meaningful learning is more effective than rote learning for storing information in long-term memory.<sup>35</sup> It is especially effective when learners relate ideas to *themselves* as human beings.<sup>36</sup>

<sup>34</sup> J. R. Anderson, 1995; Ausubel, 1968; Craik & Watkins, 1973.

<sup>35</sup> J. R. Anderson, 1995; Ausubel, Novak, & Hanesian, 1978; Bransford & Johnson, 1972; Mayer, 1996.

<sup>36</sup> For example, see T. B. Rogers, Kuiper, & Kirker, 1977.

**meaningful learning** Cognitive process in which learners relate new information to things they already know.

Meaningful learning can take a variety of forms, and in many cases it involves adding to or restructuring information in some way. For instance, in **elaboration**, learners use their prior knowledge to expand on a new idea, thereby storing *more* information than was actually presented. For example, a student who reads that allosaurs (a species of dinosaurs) had powerful jaws and sharp, pointed teeth might correctly deduce that allosaurs were meat eaters. Similarly, if a student learns that the crew on Columbus's first trip across the Atlantic threatened to revolt and turn the ships back toward Europe, the student might speculate, "I'll bet the men were really frightened when they continued to travel west day after day without ever seeing signs of land."

Another form of meaningful learning is **organization**, in which learners arrange new information in a logical structure. For example, they might group information in categories, just as you probably categorized the twelve words (daisy, apple, hammer, etc.) in the "Remembering Words" exercise near the beginning of the chapter. Another way of organizing information is to identify interrelationships among its various parts. For example, when learning about *velocity*, *acceleration*, *force*, and *mass* in a physics class, a student might better understand these concepts by seeing how they're interconnected—for instance, by learning that velocity is the product of acceleration and time ( $v = a \times t$ ) and that an object's force is determined by both the object's mass and its acceleration ( $f = m \times a$ ). The trick is not simply to memorize the formulas (this would be rote learning) but rather to make sense of and understand the relationships that the formulas represent. In most instances, learners who learn an organized body of information remember it better, and they can use it more effectively later on, than would be the case if they tried to learn the same information as a list of separate, isolated facts.<sup>37</sup>

Still another effective long-term memory storage process is **visual imagery**, forming a mental picture of objects or ideas. To discover firsthand how effective visual imagery can be, try learning a bit of Mandarin Chinese in the next exercise.

### SEE FOR YOURSELF

#### Five Chinese Words

Try learning these five Chinese words by forming the visual images I describe (don't worry about learning the marks over the words):

Chinese Word	English Meaning	Image
fǎng	house	Picture a <i>house</i> with <i>fangs</i> growing on its roof and walls.
mén	door	Picture a restroom <i>door</i> with the word <i>MEN</i> painted on it.
ké	guest	Picture someone giving someone else (the <i>guest</i> ) a <i>key</i> to the house.
fàn	food	Picture a plate of <i>food</i> being cooled by a <i>fan</i> .
shū	book	Picture a <i>shoe</i> with a <i>book</i> sticking out of it.

Now find something else to do for a couple of minutes. Stand up and stretch, get a glass of water, or use the restroom. But be sure to come back to your reading in just a minute or two. . . .

Now that you're back, cover the list of Chinese words, English meanings, and visual images. Try to remember what each word means:

ké	fàn	mén	fǎng	shū
----	-----	-----	------	-----

Did the Chinese words remind you of the visual images you stored? Did the images, in turn, help you remember the English meanings of the Chinese words?

**elaboration** Cognitive process in which learners embellish on new information based on what they already know.

**organization** Cognitive process in which learners find connections (e.g., by forming categories, identifying hierarchies, determining cause-effect relationships) among the various pieces of information they need to learn.

**visual imagery** Process of forming mental pictures of objects or ideas.

<sup>37</sup> Bjorklund, Schneider, Cassel, & Ashley, 1994; & Pearlstone, 1966; Tulving, 1962. Bower, Clark, Lesgold, & Winzenz, 1969; Mandler

You may have remembered all five words easily, or you may have remembered only one or two. People differ in their ability to use visual imagery: Some form images quickly and easily, whereas others form them only slowly and with difficulty.<sup>38</sup> Especially for people in the former category, visual imagery can be a powerful means of storing information in long-term memory.<sup>39</sup>

The three forms of meaningful learning we've just examined—elaboration, organization, and visual imagery—are clearly *constructive* in nature: They all involve combining several pieces of information into a meaningful whole. When you elaborate on new information, you combine it with things you already know to help you make better sense of it. When you organize information, you give it a logical structure (categories, cause-effect relationships, etc.). And when you use visual imagery, you create mental pictures (perhaps a house with fangs, or a restroom door labeled *MEN*) based on how certain objects typically look.

### Practice makes knowledge more automatic and durable.

Storing something in long-term memory on one occasion is hardly the end of the story. When people continue to practice the information and skills they acquire—and especially when they do so in a variety of situations and contexts—they gradually become able to use what they've learned quickly, effortlessly, and automatically. In other words, people eventually achieve **automaticity** for well-practiced knowledge and skills.<sup>40</sup>

As we noted earlier, rehearsal—repeating information over and over within the course of a few seconds or minutes—is a relatively *ineffective* way of getting information into long-term memory. But when we talk about acquiring automaticity, however, we're talking about repetition over the long run: reviewing and practicing information and procedures at periodic intervals over the course of a few weeks, months, or years. When practice is spread out in this manner, people of all ages (even young infants) learn something better and remember it longer.<sup>41</sup>

Practice is especially important for gaining procedural knowledge. As an example, think of driving a car, a complicated skill that you can probably perform easily. Your first attempts at driving years ago may have required a great deal of mental energy and effort. But now you can drive without having to pay much attention to what you are doing. Even if your car has a standard transmission, driving is, for you, an automatic activity.

Many complex procedures, such as driving a car, may begin largely as explicit, declarative knowledge—in other words, as *information* about how to execute a procedure rather than as the actual *ability* to execute it. When learners use declarative knowledge to guide them as they carry out a new procedure, their performance is slow and laborious, the activity consumes a great deal of mental effort, and they often talk themselves through their actions. As they continue to practice the activity, however, their declarative knowledge gradually evolves into procedural knowledge. This knowledge becomes fine-tuned over time and eventually allows learners to perform an activity quickly and easily—that is, with automaticity.<sup>42</sup>

### With age and experience, children acquire more effective learning strategies.

Sometimes learners engage in effective long-term memory storage processes (elaboration, organization, visual imagery, etc.) without intentionally trying to do so. For example, if I tell you that *I used to live in Colorado*, you might immediately think of a place with high mountains. In this case you are automatically engaging in elaboration

<sup>38</sup> Behrmann, 2000; J. M. Clark & Paivio, 1991; Kosslyn, 1985.

<sup>39</sup> Dewhurst & Conway, 1994; Johnson-Glenberg, 2000; Sadoski, Goetz, & Fritz, 1993; Sadoski & Paivio, 2001.

<sup>40</sup> J. R. Anderson, 1983; P. W. Cheng, 1985; Graham, Harris, & Fink, 2000; Proctor & Dutta,

1995; Schneider & Shiffrin, 1997; Semb & Ellis, 1994.

<sup>41</sup> J. R. Anderson & Schooler, 1991; Belfiore, Skinner, & Ferkis, 1995; Dempster, 1991; Linton, 1986; Proctor & Dutta, 1995; Rovee-Collier, 1993; West & Stanovich, 1991.

<sup>42</sup> J. R. Anderson, 1983, 1987.

**automaticity** Ability to respond quickly and efficiently while mentally processing or physically performing a task.

(my statement made no mention of mountains, so you supplied this information from your own long-term memory). If an image of pointy, snow-capped Rocky Mountains comes to mind, then you are using imagery as well.

At other times learners deliberately use certain cognitive processes in their efforts to learn and remember information. For example, in the “Remembering Words” exercise near the beginning of the chapter, you may have quickly noticed the categorical nature of the twelve words in the list and intentionally used the categories *flowers*, *fruit*, and *tools* to organize them. Similarly, in the “Five Chinese Words” exercise, you intentionally formed visual images in accordance with my instructions. When learners *intentionally* use a certain approach to learning and remembering something, they are using a **learning strategy**.

Even infants show some ability to organize their experiences, and by age 4, children may intentionally organize a set of objects in an effort to remember them.<sup>43</sup> In the preschool years, children elaborate on their experiences as well.<sup>44</sup> But for the most part, children don’t intentionally choose particular learning strategies until they reach school age. Rehearsal typically appears first, perhaps at around age 5 to 7, and children use it with increasing effectiveness—at least for things they need to remember for only a few minutes—as they progress through the elementary grades.<sup>45</sup> As children move through the elementary, middle school, and secondary grades, they increasingly organize information to help them learn it, and their organizational structures become more hierarchical and abstract.<sup>46</sup> (In the four “Memory and Metacognition” clips on Video CD 1, notice how 12-year-old Colin and 16-year-old Hilary more effectively organize a list of words than 6-year-old Brent and 10-year-old David.) The ability to use visual images effectively to encode and remember information also improves over the course of elementary school.<sup>47</sup> As an intentional learning strategy, elaboration appears fairly late in development (usually around puberty) and gradually increases during the teenage years.<sup>48</sup> Even so, many high school students rely largely on rehearsal, rather than on more effective strategies, to study and learn academic material.<sup>49</sup> Table 2.3 summarizes developmental trends in learning strategies across the grade levels.



Observe varying degrees of organization in long-term memory storage in the early childhood, early adolescence, and late adolescence “Memory and Metacognition” clips on Video CD 1.

### Prior knowledge and beliefs affect new learning, usually for the better but sometimes for the worse.

What learners already know provides a **knowledge base** on which new learning builds. To engage in meaningful learning, learners must, of course, have prior knowledge that’s relevant to what they’re learning. For instance, when you read the passage about John’s visit to the doctor’s office earlier in the chapter, you could make sense of the passage—in which a lot of important information was missing—only if you yourself have visited a doctor numerous times and so know how such visits typically go. Generally speaking, people who already know something about a topic learn new information about that topic more effectively than people who have little relevant background.<sup>50</sup> In other words, the rich (in knowledge) get richer, and the poor stay relatively poor.

Recall how in the case study at the beginning of the chapter, Rita misinterpreted what she learned about Michigan’s history because she did not know that two words in her history lessons, *British* and *English*, were essentially synonyms. When learners have little relevant knowledge on which to build, they are apt to struggle in their efforts to make sense of new information.

**learning strategy** One or more cognitive processes used intentionally for a particular learning task.

**knowledge base** One’s existing knowledge about specific topics and the world in general.

<sup>43</sup> Behl-Chadha, 1996; DeLoache & Todd, 1988; Quinn, 2002.

<sup>44</sup> Fivush, Haden, & Adam, 1995.

<sup>45</sup> Gathercole & Hitch, 1993; Kunzinger, 1985; Pressley & Hilden, 2006.

<sup>46</sup> Bjorklund & Jacobs, 1985; Bjorklund et al., 1994; DeLoache & Todd, 1988; Lucariello, Kyratzis, & Nelson, 1992; Plumert, 1994.

<sup>47</sup> Pressley & Hilden, 2006.

<sup>48</sup> Schneider & Pressley, 1989.

<sup>49</sup> Pressley, 1982; J. W. Thomas, 1993.

<sup>50</sup> P. A. Alexander, Kulikowich, & Schulze, 1994; Schneider, 1993.

**TABLE 2.3**  
**Typical Learning Strategies at Different Grade Levels**

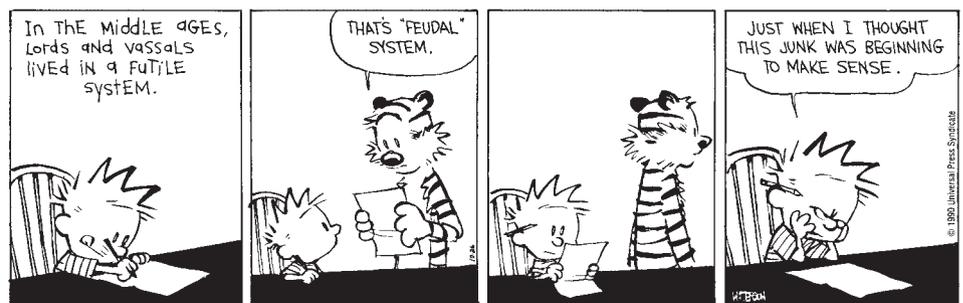
## Developmental Trends

Grade Level	Age-Typical Characteristics	Suggested Strategies
 K–2	<ul style="list-style-type: none"> <li>Organization of physical objects as a way to remember them</li> <li>Appearance of rehearsal to remember verbal material; used infrequently and relatively ineffectively</li> <li>Emerging ability to use visual imagery to enhance memory, especially if an adult suggests this strategy</li> <li>Few if any intentional efforts to learn and remember verbal material; learning and memory are a byproduct of other things children do (creating things, talking about events, listening to stories, etc.)</li> </ul>	<ul style="list-style-type: none"> <li>Get students actively involved in topics, perhaps through hands-on activities, engaging reading materials, or fantasy play.</li> <li>Relate new topics to students' prior experiences.</li> <li>Model rehearsal as a strategy for remembering things over the short run.</li> <li>Provide pictures that illustrate verbal material.</li> </ul>
 3–5	<ul style="list-style-type: none"> <li>Spontaneous, intentional, and increasingly effective use of rehearsal to remember things for a short time period</li> <li>Increasing use of organization as an intentional learning strategy for verbal information</li> <li>Increasing effectiveness in use of visual imagery as a learning strategy</li> </ul>	<ul style="list-style-type: none"> <li>Emphasize the importance of making sense of, rather than memorizing, information.</li> <li>Encourage students to organize what they are learning; suggest possible organizational structures for topics.</li> <li>Provide a variety of visual aids to facilitate visual imagery, and suggest that students create their own visual images of things they need to remember.</li> </ul>
 6–8	<ul style="list-style-type: none"> <li>Predominance of rehearsal as a learning strategy</li> <li>Greater abstractness and flexibility in categories used to organize information</li> <li>Emergence of elaboration as an intentional learning strategy</li> </ul>	<ul style="list-style-type: none"> <li>Suggest questions that students might ask themselves as they study; emphasize questions that promote elaboration (e.g., "Why would _____ do that?" "How is _____ different from _____?").</li> <li>Assess true understanding rather than rote memorization in assignments and quizzes.</li> </ul>
 9–12	<ul style="list-style-type: none"> <li>Continuing reliance on rehearsal as an intentional learning strategy, especially by low-achieving adolescents</li> <li>Increasing use of elaboration and organization to learn, especially by high-achieving adolescents</li> </ul>	<ul style="list-style-type: none"> <li>Ask thought-provoking questions that engage students' interest and help students see the relevance of topics for their own lives.</li> <li>Have students work in mixed-ability cooperative groups, in which high-achieving students can model effective learning strategies for low-achieving students.</li> </ul>

Sources: Bjorklund & Coyle, 1995; Bjorklund & Jacobs, 1985; Bjorklund et al., 1994; DeLoache & Todd, 1988; Gathercole & Hitch, 1993; Kunzinger, 1985; Lucariello et al., 1992; L. S. Newman, 1990; Plumert, 1994; Pressley, 1982; Pressley & Hilden, 2006; Schneider & Pressley, 1989.

Prior knowledge about a topic is not always helpful, however. Occasionally it actually *interferes* with new learning. In some instances it may do so because a learner makes an inappropriate connection. Figure 2.7 provides an example: Calvin thinks that a *feudal* system is a *futile* system. We see additional examples in the opening case study. Rita initially associates the word *China* with dinnerware and speculates that the Europeans wanted to import cups from the Far East. She also recalls that furs were an important commodity during the colonial period in the New World and so mistakenly reports that the furs came from China.

At other times things learned at an earlier time interfere with new learning because that previous "knowledge" is incorrect. Figure 2.8 presents some common misconceptions that children and adolescents often bring with them to the classroom. Imagine a group of children who think that the earth is flat. Such an idea is consistent with their early experiences, especially if they live in, say, Illinois or Kansas. You now tell them that the world is actually round. Rather than replacing the *flat* idea



**Figure 2.7** Learners benefit from their prior knowledge only when they make appropriate connections. Here Calvin is trying to learn new information meaningfully, but his efforts are in vain because he's unfamiliar with the word *feudal*.

CALVIN AND HOBBS © 1990 Watterson. Dist. by UNIVERSAL PRESS SYNDICATE. Reprinted with permission. All rights reserved.

**Figure 2.8** Common student misconceptions**ASTRONOMY****Fact:** The earth revolves around the sun.**Misconception:** The sun revolves around the earth. It “rises” in the morning and “sets” in the evening, at which point it “goes” to the other side of the earth.**Fact:** The earth is shaped more or less like a sphere.**Misconception:** The earth is shaped like a round, flat disk.**BIOLOGY****Fact:** A living thing is something that carries on such life processes as metabolism, growth, and reproduction.**Misconception:** A living thing is something that moves and/or grows. The sun, wind, clouds, and fire are living things.**Fact:** A plant is a food producer.**Misconception:** A plant grows in a garden and is relatively small. Carrots and cabbage are vegetables, not plants. Trees are plants only if they are small.**PHYSICS****Fact:** An object remains in uniform motion until a force acts upon it; a force is needed only to *change* speed or direction.**Misconception:** Any moving object has a force acting upon it. For example, a ball thrown in the air continues to be pushed upward by the force of the throw until it begins its descent.**Fact:** Gravity is the force whereby any two masses are attracted together.**Misconception:** Gravity is “glue” or “sticky stuff” that holds people to the earth.**GEOGRAPHY****Fact:** The Great Lakes contain fresh water.**Misconception:** The Great Lakes contain salt water.**Fact:** Rivers run from higher elevation to lower elevation.**Misconception:** Rivers run from north to south (going “down” on a map). For example, rivers can run from Canada into the United States, but not vice versa.

Sources: S. Carey, 1986; Kyle & Shymansky, 1989; Maria, 1998; Nussbaum, 1985; Sneider & Pulos, 1983; Vosniadou, 1994; Vosniadou & Brewer, 1987; geography misconceptions courtesy of R. K. Ormrod.

with a *round* one, they might pull both ideas together and conclude that the earth is shaped something like a pancake, which is flat *and* round.<sup>51</sup>

Especially when misconceptions are part of learners’ general theories about the world, instruction intended to correct them may do little to change learners’ minds.<sup>52</sup> Instead, thanks to the process of elaboration—a process that usually facilitates learning—learners may interpret or distort the new information to be consistent with what they already “know.” As a result, they can spend a great deal of time learning the wrong thing! Consider the case of Barry, an eleventh grader whose physics class was studying the idea that an object’s mass and weight do *not*, in and of themselves, affect the speed at which the object falls. Students were asked to design and build an egg container that would keep an egg from breaking when dropped from a third-floor window. They were told that on the day of the egg drop, they would record the time it took for the eggs to reach the ground. Convinced that heavier objects fall faster, Barry added several nails to his egg’s container. Yet when he dropped it, classmates timed its fall at 1.49 seconds, a time very similar to that for other students’ lighter containers. He and his teacher had the following discussion about the result:

**Teacher:** So what was your time?**Barry:** 1.49. I think it should be faster.**Teacher:** Why?**Barry:** Because it weighed more than anybody else’s and it dropped slower.**Teacher:** Oh really? And what do you attribute that to?**Barry:** That the people weren’t timing real good.<sup>53</sup>

This tendency to look for what one thinks is true and to ignore any evidence to the contrary is known as a **confirmation bias**. Confirmation bias is often observed in science classes. For instance, when students in a science lab observe results that contradict what they have expected will happen, many are apt to discredit the results, perhaps complaining that “our equipment isn’t working right” or “I can never do science anyway.”<sup>54</sup>

As you can see, then, although prior knowledge and beliefs about a topic are usually a blessing, they can sometimes be a curse. When we explore the topic of *conceptual change* later in the chapter, we’ll identify strategies that may help learners replace their naive notions with more accurate understandings.

**confirmation bias** Tendency to seek information that confirms rather than discredits current beliefs.

<sup>51</sup> Vosniadou, 1994.<sup>52</sup> Derry, 1996; Sinatra & Pintrich, 2003a; C. L. Smith, Maclin, Grosslight, & Davis, 1997.<sup>53</sup> Hynd, 1998a, p. 34.<sup>54</sup> Minstrell & Stimpson, 1996.

Now that we've explored basic principles related to *putting* information in long-term memory, let's turn our attention to retrieval, the process of *finding* that information later on.

## WHY LEARNERS MAY OR MAY NOT REMEMBER WHAT THEY'VE LEARNED

Retrieving information from long-term memory appears to involve following a “pathway” of associations. Almost literally, it's a process of going down “Memory Lane.” One idea reminds you of another idea—that is, one idea *activates* another—the second idea reminds you of a third idea, and so on, in a manner similar to what happened when you followed a train of thought from the word *horse* earlier in the chapter. If the pathway of associations eventually leads you to what you're trying to remember, you do indeed remember it. If the path takes you in other directions, you're out of luck.

How easily and accurately people remember what they've previously learned can be described using the following general principles.

### How easily something is recalled depends on how it was initially learned.

People are more likely to remember something they've previously learned if, in the process of storing it, they connected it with something else in long-term memory. Ideally, the “new” and the “old” have a logical relationship. To illustrate this idea, let's return once again to all that mail that arrives in your mailbox. Imagine that, on average, you receive five important items—things you really want to save—every day. At six postal deliveries a week and 52 weeks a year (minus a dozen or so holidays), you save about 1,500 pieces of mail each year. If you save this much mail over the course of fifteen years, then you eventually have more than 22,000 important things stashed somewhere in your home.

One day you hear that stock in a clothing company (Mod Bod Jeans, Inc.) has tripled in value. You remember that your wealthy Uncle Fred sent you some Mod Bod stock certificates for your birthday several years ago, and you presumably decided they were important enough to save. But where in the world did you put them? How long will it take you to find them among all those important letters, bills, brochures, catalogs, fliers, and sweepstakes announcements?

How easily you find the certificates and, in fact, whether you find them at all depend on how you have been storing your mail as you've accumulated it. If you've been storing it in a logical, organized fashion—for instance, by putting all paid bills on a closet shelf, all mail-order catalogs on the floor under your bedside table, and all items from relatives in a file cabinet (in alphabetical order by last name)—then you should quickly retrieve Uncle Fred's gift. But if you simply tossed each day's mail randomly around the house, you will be searching your home for a long, long time, possibly without ever finding a trace of that Mod Bod stock.

Like a home with fifteen years' worth of mail, long-term memory contains a great deal of information. And like finding the Mod Bod certificates, the ease with which information is retrieved from long-term memory depends somewhat on whether the information is stored in a logical “place”—that is, whether it is connected with related ideas. Through making those important connections with existing knowledge—that is, through meaningful learning—people know where to “look” for information when they need it. In contrast, learning something by rote is like throwing Uncle Fred's gift randomly among thousands of pieces of unorganized mail: A person may never retrieve it again.

Learners are especially likely to retrieve information when they have *many* possible pathways to it—in other words, when they have associated the information with numerous other ideas in their existing knowledge. Making multiple connections is like using cross-references in your mail storage system. You may have filed the Mod Bod stock in the “items from relatives” file drawer, but you've also written the stock's location on notes left in many other places—perhaps with your

birth certificate (after all, you received the stock on your birthday), with your income tax receipts, and in your safe-deposit box. By looking in any one of these logical places, you will discover where to find your valuable stock.

### Remembering depends on the context.

When I hear certain “oldies” songs (songs by the Beatles, Supremes, Mamas and Papas, Turtles, etc.), I immediately recall my college years, when those songs were played regularly at parties, in my dormitory, and on the beach. The songs send me down that Memory Lane of associations that leads me to my stored versions of the people, places, events, and ideas that were so important to me in college. You too may find that certain songs, smells, pictures, or words stir up memories of days gone by. Things in the environment that remind people of something they’ve learned in the past—those things that facilitate retrieval—are **retrieval cues**.

Retrieval cues clearly help learners recall what they’ve previously learned.<sup>55</sup> As an example, try the following exercise.

#### **SEE FOR YOURSELF**

##### **The Great Lakes**

1. If you were educated in North America, then you probably learned the names of the five Great Lakes at one time or another. While timing yourself with the second hand of a clock or watch, see if you can recall all five of them within a 15-second period.
2. If you had trouble remembering all five lakes within that short time, here’s a hint: The first letters of the Great Lakes spell the word *HOMES*. Now see if you can recall all five lakes within 15 seconds.

If you did poorly at step 1, the word *HOMES* probably helped you do better at step 2 because it gave you some idea about where to “look” in your long-term memory. Perhaps you couldn’t initially remember Lake Michigan. If so, *HOMES* told you that one of the lakes begins with the letter *M*, and so you searched among the *M* words in your long-term memory until, possibly, you stumbled on “Michigan.” The letters in *HOMES* acted as retrieval cues that started your search of long-term memory in the right directions.

Whether people remember something they’ve learned when they need it later depends on whether something in their environment sends them down the appropriate pathway in long-term memory. In some cases the retrieval cue might be something inherent in the task to be done. For example, if I ask you to solve the problem  $13 + 24 = ?$ , the plus sign (+) tells you that you need to add, and so you retrieve what you know about addition. In other cases another person might give you a hint, just as I did when I suggested that you use *HOMES* to help you remember the Great Lakes. The presence or absence of such retrieval cues plays a critical role in people’s ability to apply, or *transfer*, what they’ve learned to new situations, as you’ll discover in Chapter 4.

### How easily something is recalled and used depends on how often it has been recalled and used in the past.

Practice doesn’t necessarily make perfect, but as we’ve seen, it does make knowledge more durable and automatic. Practice also makes knowledge easier to “find” when it’s needed. When we use information and skills frequently, we essentially “pave” the pathways we must travel to find them, in some cases creating superhighways.

Knowledge that has been learned to automaticity has another advantage as well. Remember, working memory has a limited capacity: The active, “thinking” part of the human memory system can do only so much at a time. When much of its capacity must be used for recalling single facts or carrying out simple procedures, little room is left for addressing more complex situations or tasks. One key reason for

**retrieval cue** Stimulus, that provides guidance about where to “look” for a piece of information in long-term memory.

<sup>55</sup> Tulving, 1983; Tulving & Thomson, 1973.

learning some facts and procedures to automaticity, then, is to free up working memory capacity for tackling complex tasks and problems that require those facts and procedures.<sup>56</sup> For example, fourth graders faced with the multiplication problem

$$\begin{array}{r} 87 \\ \times 59 \\ \hline \end{array}$$

can solve it more easily if they can quickly retrieve such basic facts as  $9 \times 8 = 72$  and  $5 \times 7 = 35$ . High school chemistry students can more easily interpret  $\text{Na}_2\text{CO}_3$  (sodium carbonate) if they don't have to stop to think about what the symbols *Na*, *C*, and *O* represent.

### Recall often involves reconstruction.

Have you ever remembered an event very differently than a friend did, even though the two of you had participated actively and equally in the event? Were you and your friend both certain of the accuracy of your own memories and therefore convinced that the other person remembered the situation incorrectly? Like storage, retrieval has a constructive side, which can explain your differing recollections.

Retrieving something from long-term memory isn't necessarily an all-or-none phenomenon. Sometimes people retrieve only certain parts of something they've previously learned. In such situations they may construct their "memory" of an event by combining the tidbits they can recall with their general knowledge and assumptions about the world.<sup>57</sup> The following exercise illustrates this point.

#### SEE FOR YOURSELF

##### Missing Letters

Fill in the missing letters of the following five words:

1. sep--rate
2. exist--nce
3. adole----nce
4. retr--val
5. hors d'o-----

Were you able to retrieve the missing letters from your long-term memory? If not, then you may have found yourself making reasonable guesses, using either your knowledge of how the words are pronounced or your knowledge of how words in the English language are typically spelled. For example, perhaps you used the "i before e except after c" rule for word 4. If so, you reconstructed the correct spelling of *retrieval*. Perhaps you used your knowledge that *-ance* is a common word ending. Unfortunately, if you used this knowledge for word 2, then you spelled *existence* incorrectly. Neither pronunciation nor typical English spelling patterns would have helped you with *hors d'oeuvre*, a term borrowed from the French. (The correct spellings for words 1 and 3 are *separate* and *adolescence*.)

When people fill in gaps in what they've retrieved based on what seems "logical," they often make mistakes—a phenomenon known as **reconstruction error**. In the opening case study, Rita's version of what she learned in history is a prime example. Rita retrieved certain facts from her history lessons (e.g., the British wanted furs; some of them eventually settled in the Upper Peninsula) and constructed what was, to her, a reasonable scenario.

### Long-term memory isn't necessarily forever.

People certainly don't need to remember everything. For example, you probably have no reason to remember the phone number of a florist you called yesterday, the plot of last week's rerun of *Friends*, or the due date of an assignment you turned in

**reconstruction error** Construction of a logical but incorrect "memory" by using information retrieved from long-term memory in combination with general knowledge and beliefs about the world.

<sup>56</sup> D. Jones & Christensen, 1999; Proctor & Dutta, 1995; L. B. Resnick, 1989; Stanovich, 2000.

<sup>57</sup> Kolodner, 1985; Leichtman & Ceci, 1995; Loftus, 1991; Roediger & McDermott, 2000; Rumelhart & Ortony, 1977; D. L. Schacter, 1999.

last semester. Much of the information you encounter is, like junk mail, not worth keeping. Forgetting enables you to get rid of needless clutter.<sup>58</sup>

Unfortunately, people sometimes forget important things as well as inconsequential ones. Some instances of forgetting may reflect **retrieval failure**: A person simply isn't looking in the right "place" in long-term memory.<sup>59</sup> Perhaps the forgetful person hasn't learned the information in a meaningful way, or perhaps the person doesn't have a good retrieval cue. But other instances of forgetting may be the result of **decay**: Knowledge stored in long-term memory may gradually weaken over time and perhaps disappear altogether, especially if it isn't used very often.<sup>60</sup> To some degree, then, the expression "Use it or lose it" may apply to human memory.

Regardless of whether forgetting is due to retrieval failure or to decay, human beings don't always remember the things they've learned. However, teachers can increase the odds that their students *do* remember academic subject matter. Let's switch gears and put theory into practice, identifying strategies for promoting effective learning and memory processes in the classroom.

## PROMOTING EFFECTIVE COGNITIVE PROCESSES

As we've seen, learning is an active, constructive process, and what students learn is rarely a carbon copy of what a teacher or textbook has presented. A teacher's goal, then, should not, and in fact *cannot*, be that students absorb all the information they are given. Instead, a more achievable goal is that students construct appropriate and useful understanding of academic subject matter—that they make reasonable *sense* of it.

How effectively students make sense and meaning from what they are studying depends in large part on the cognitive processes in which they engage. Although students are ultimately the ones "in charge" of their own thinking and learning, a teacher can do many things to help them think and learn more effectively.

### Grab and hold students' attention.

Let's revisit a point made earlier in the chapter: Information moves into working memory—something that must happen before it can be stored in long-term memory—only when the learner pays attention to it. The things teachers do in the classroom make a big difference in the extent to which students pay attention to the subject matter at hand. For example, teachers can pique students' interest in a topic, perhaps by building on students' existing interests and concerns, presenting unusual or puzzling phenomena, or modeling their own enthusiasm for a topic (12-year-old Claudia mentions this last point in the "Motivation: Early Adolescence" clip on Video CD 1). Incorporating a wide variety of instructional methods (discovery learning sessions, class debates, cooperative problem-solving activities, etc.) into the weekly schedule also helps keep students actively attentive to and engaged in mastering new information and skills. The Classroom Strategies box "Getting and Keeping Students' Attention" offers and illustrates several additional suggestions for teachers.

### Keep the limited capacity of working memory in mind.

Like all human beings, students have only limited "space" in their working memories, and so there is an upper limit to how much they can think about and learn within a given time period. Teachers must keep this point in mind when planning classroom lessons and activities. Many new teachers make the mistake of presenting too much information too quickly, and their students' working memories simply can't keep up. Instead, teachers should introduce new information in such a way that students have time to process it all. In addition to maintaining a reasonable pace, teachers might repeat the same idea several times (perhaps rewording it each time), stop to write important points on the chalkboard, provide numerous examples and illustrations, and have students use the content in a variety of activities and assignments.



In the "Motivation: Early Adolescence" clip on Video CD 1, hear Claudia describe things her teachers do that capture or lose her attention.

**retrieval failure** Inability to locate information that currently exists in long-term memory.

**decay** Weakening over time of information stored in long-term memory, especially if the information is used infrequently.

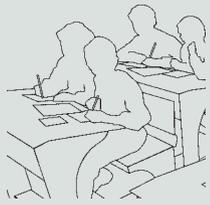
<sup>58</sup> D. L. Schacter, 1999.

<sup>59</sup> Loftus & Loftus, 1980.

<sup>60</sup> Altmann & Gray, 2002; J. R. Anderson, 1990; Reisberg, 1997; D. L. Schacter, 1999.

## Getting and Keeping Students' Attention

## Classroom Strategies



- Create stimulating lessons in which students *want* to pay attention.

In a unit on nutrition, a high school biology teacher has students determine the nutritional value of various menu items at a popular local fast-food restaurant.

- Get students physically involved with the subject matter.

A middle school history teacher plans a day late in the school year when all of his classes “go back in time” to the American Civil War. In preparation for the event, the students spend several weeks learning about the Battle of Gettysburg, researching typical dress and meals of the era, gathering appropriate clothing and equipment, and preparing snacks and lunches. On the day of the “battle,” students assume various roles: Union and Confederate soldiers, government officials, journalists, merchants, housewives, doctors and nurses, and so on.

- Incorporate a variety of instructional methods into lessons.

After explaining how to calculate the area of squares and rectangles, a fourth-grade teacher has her students practice calculating area in a series of increasingly challenging word problems. She then breaks the class into cooperative groups of three or four members each. Each group is given a tape measure and calculator and asked to determine the area of the classroom floor, excluding those parts of the floor covered by several built-in cabinets that extend into the room. To complete the task, the students must divide the room into several smaller rectangles, compute the area of each rectangle separately, and add the “subareas” together.

- Provide frequent breaks from sedentary activities, especially when working with students in the elementary grades.

To provide practice with the alphabet, a kindergarten teacher occasionally has students make letters with their bodies: one child standing with arms extended up and out to make a Y, two children bending over and joining hands to form an M, and so on.

- In the middle school and high school grades, encourage students to take notes.

In a middle school science class, different cooperative groups have been specializing in and researching various endangered species. As each group gives an oral report about its species to the rest of the class, the teacher asks students in the “audience” to jot down questions about things they would like to know about the animal. Upon the completion of their prepared report, members of the presenting group answer their classmates’ questions.

- Minimize distractions when students must work quietly and independently.

The windows of several classrooms look out onto an area where a new parking lot is being created. Teachers in those classrooms have noticed that many of their students are being distracted by the construction activity outside. The teachers ask the principal to request that the construction company work elsewhere on the day that an important statewide assessment is scheduled to be administered.

Even so, the amount of new information presented in a typical classroom is much more than students can reasonably learn and remember, and students aren’t always the best judges of what is most important.<sup>61</sup> Teachers can help students make the right choices by identifying main ideas, offering guidelines on how and what to study, and omitting unnecessary details from lessons.

### Relate new ideas to students’ prior knowledge and experiences.

Students can more effectively learn and remember classroom subject matter if they connect it to things they already know. Yet students don’t always make such connections on their own, and as a result they often resort to rote learning. Teachers can encourage more meaningful learning by showing how new material relates to

- Concepts and ideas in the same subject area (e.g., showing how multiplication is related to addition)
- Concepts and ideas in other subject areas (e.g., talking about how scientific discoveries have affected historical events)
- Students’ general knowledge of the world (e.g., drawing parallels between the Black Death of the fourteenth century and the modern-day AIDS epidemic)
- Students’ personal experiences (e.g., finding similarities between the family feud in *Romeo and Juliet* and students’ own group conflicts)
- Students’ current activities and needs outside of the classroom (e.g., showing how persuasive writing skills might be used to write a personal essay for a college application)

<sup>61</sup> Calfee, 1981; E. D. Gagné, 1985; Garner, 1991; Reynolds & Shirey, 1988. Alexander, Gillingham, Kulikowich, & Brown,



Observe a teacher promote meaningful learning in the “Civil War” clip on Video CD 2.

In the “Civil War” clip on Video CD 2, you can find many examples of how a fifth-grade teacher tries to relate historical events to what children already know. Following are two examples:

If you think of the way people lived [prior to the American Civil War] and what we didn’t have in terms of stores, what’s something that everybody did for his family in this time? What did they do to make a living? What do you think they would all have had to do? (A student responds, “Farm.”) Good for you. They would have to have farmed, wouldn’t they, because . . . they had to eat.

We’ve talked about slavery. Now I want you to pretend inside your head that you are a slave. . . . One of the problems that the slaves had, of course, was that they wanted to be free. So they did things . . . and they were angry at their masters very many times, because they were beaten and they were not cared for as they should have been. If you were a slave, what are some things that you might have done? . . . How could you get back at a master? (A student responds, “Put rocks in the machines.”) They broke the equipment; I think that’s a little bit of what Jesse was saying. Yes, they would break the tools. Makes sense, doesn’t it?

In addition, teachers should use students’ existing knowledge as a starting point whenever they introduce a new topic. For example, in a first-grade classroom, they might begin a unit on plants by asking students to describe what their parents do to keep flowers or vegetable gardens growing. Or, in a secondary English literature class, they might introduce Sir Walter Scott’s *Ivanhoe* (in which Robin Hood is a major character) by asking students to tell the tale of Robin Hood as they know it. Having students bring relevant ideas to mind as they study a new topic is a strategy known as **prior knowledge activation**.

Despite such teaching strategies, many older students (e.g., many of those in the middle school and high school grades) are apt to engage in meaningful learning

only if they believe that doing so will pay off in classroom assessments. Unfortunately, classroom assessment practices often encourage students to learn school subjects in a rote rather than meaningful manner. Think back to your own experiences in school. How many times were you allowed to define a word by repeating a dictionary definition, rather than being expected to explain it in your own words? In fact, how many times were you *required* to learn something word for word? And how many times did an exam assess your knowledge of facts or principles without ever assessing your ability to relate those facts and principles to everyday life or to things you had learned in previous courses? Perhaps you had assignments and quizzes similar to the fill-in-the-

- 1) One of the coolest things about dinosaurs is that of all the millions there were, we only know about a few thousand of them.
- 2) The word “fossil” comes from the Latin word meaning dug up.
- 3) What four things can fossils tell us about dinosaurs?  
1. what they ate 2. what they did w/ their
- 4) Two steps in the process of fossilization are:  
1. look like 2. size/weight  
- need to die - then are covered in layers of sediment
- 5) One of the processes which forms a fossil is pre-mineralized. This means that minerals replace the bones of the dinosaur.
- 6) The evidence that dinosaurs once lived is found in discovering fossils.
- 7) Scientists can learn about dinosaurs by observing where their fossils are buried, how deep the fossils are, and what is buried nearby the dinosaur fossils.
- 8) Dinosaurs lived on earth for about 140 million years.
- 9) Dinosaurs died out about 65 million years ago.
- 10) One reason dinosaurs may have become extinct is a meteorite.

**Figure 2.9** Seventh-grade science students complete these and other fill-in-the-blank questions when they watch a video about dinosaurs. Although the questions probably help students pay attention to the video, they encourage rote rather than meaningful learning.

blank questions shown in Figure 2.9. When students discover that assignments and assessments focus on recall of unrelated facts—rather than on understanding and application of an integrated body of knowledge—many rely on rote learning, believing that this approach will yield a higher score and that meaningful learning would be counterproductive.<sup>62</sup> Ultimately, teachers must communicate in every way possible—including in their assignments, quizzes, and other assessments—that it is more important to *make sense* of classroom material than to memorize it. In Chapter 10 we will identify numerous strategies for assessing meaningful learning.

**prior knowledge activation** Process of reminding learners of things they have already learned relative to a new topic.

<sup>62</sup> Crooks, 1988.

## Show how new ideas are interrelated.

Let's look again at the opening case study. Rita has acquired a few tidbits about American history, but she has apparently learned them as separate, isolated facts and does not pull them together until an adult asks her to explain what she has learned. Unfortunately, such learning of isolated facts, without any true understanding of how they fit together, is all too common at both the elementary and secondary grade levels.<sup>63</sup>

The more interrelationships students form within the subject matter they are learning—in other words, the better they *organize* it—the more easily they can remember and apply it later on.<sup>64</sup> When students form many logical connections within the specific concepts and ideas of a topic, they gain a **conceptual understanding** of the topic. For example, rather than simply memorize basic mathematical computation procedures, students should learn how those procedures reflect underlying principles of mathematics. Rather than learn historical facts as a list of unrelated people, places, and dates, students should place those facts within the context of major social and religious trends, migration patterns, economic considerations, human personality characteristics, and so on.

One strategy for helping students find interrelationships within a topic of study is to organize instructional units around a few core ideas and themes, always relating specific ideas back to this core.<sup>65</sup> (For example, two core ideas in the chapter you are currently reading are the *constructive nature of learning and memory* and the *importance of meaningful learning*.) Another strategy is to ask students to teach what they have learned to others—a task that encourages them to focus on main ideas and pull these ideas together in a way that makes sense.<sup>66</sup> But ultimately, students are most likely to gain a conceptual understanding of what they are studying if they explore the topic in depth—for instance, by considering many examples, examining cause-effect relationships, and discovering how specific details relate to general principles. Accordingly, many educators advocate the principle “Less is more”: *Less* material studied more thoroughly is learned *more* completely and with greater understanding.<sup>67</sup>

## Accommodate diversity in students' background knowledge.

All students come to school with some common understandings about the world. For example, they all know that dogs and cats typically have four legs and that objects fall down (not up) when released. But in many ways students' prior knowledge and understandings are truly their own, because each one has been exposed to a unique set of experiences, interpersonal relationships, and cultural practices and beliefs. Thus students from diverse backgrounds may come to school with somewhat different knowledge—different concepts, schemas, scripts, self-constructed theories, and so on—that they will use to make sense of any new situation.<sup>68</sup> To see what I mean, try the next exercise.

### SEE FOR YOURSELF

#### The War of the Ghosts

Read the following story *one time only*:

One night two young men from Egulac went down to the river to hunt seals, and while they were there it became foggy and calm. Then they heard war-cries, and they thought, “Maybe this is a war-party.” They escaped to the shore, and hid behind a log. Now canoes came up, and they heard the noise of paddles, and saw one canoe coming up to them. There were five men in the canoe, and they said:

<sup>63</sup> J. Hiebert & Lefevre, 1986; Hollon, Roth, & Anderson, 1991; McCaslin & Good, 1996; McRobbie & Tobin, 1995; Paxton, 1999.

<sup>64</sup> L. M. Anderson, 1993; Bédard & Chi, 1992; J. J. White & Rumsey, 1994.

<sup>65</sup> Brophy & Alleman, 1992; Prawat, 1993; J. J. White & Rumsey, 1994.

<sup>66</sup> Hatano & Inagaki, 2003; McCaslin & Good, 1996.

<sup>67</sup> Brophy & Alleman, 1992; Kyle & Shymansky, 1989; Marshall, 1992; Sizer, 1992.

<sup>68</sup> Lipson, 1983; Reynolds, Taylor, Steffensen, Shirey, & Anderson, 1982; Steffensen, Joag-Dev, & Anderson, 1979.

**conceptual understanding** Knowledge about a topic acquired in an integrated and meaningful fashion.

“What do you think? We wish to take you along. We are going up the river to make war on the people.”

One of the young men said: “I have no arrows.”

“Arrows are in the canoe,” they said.

“I will not go along. I might be killed. My relatives do not know where I have gone. But you,” he said, turning to the other, “may go with them.”

So one of the young men went, but the other returned home.

And the warriors went on up the river to a town on the other side of Kalama. The people came down to the water, and they began to fight, and many were killed. But presently the young man heard one of the warriors say, “Quick, let us go home: that Indian has been hit.” Now he thought: “Oh, they are ghosts.” He did not feel sick, but they said he had been shot.

So the canoes went back to Egulac, and the young man went ashore to his house, and made a fire. And he told everybody and said, “Behold I accompanied the ghosts, and we went to fight. Many of our fellows were killed, and many of those who attacked us were killed. They said I was hit, and I did not feel sick.”

He told it all, and then he became quiet. When the sun rose he fell down. Something black came out of his mouth. His face became contorted. The people jumped up and cried.

He was dead.<sup>69</sup>

Now cover the story, and write down as much of it as you can remember.

Compare your own rendition of the story with the original. What differences do you notice? Your version is almost certainly the shorter of the two, and you probably left out many details. But did you also find yourself distorting certain parts of the story so that it made more sense to you?

A Native American ghost story, “The War of the Ghosts” may be inconsistent with some of the schemas and scripts you’ve acquired, especially if you were raised in a non-Native American culture. In an early study of long-term memory, students at England’s Cambridge University were asked to read the story twice and then to recall it at various times later on. Students’ recollections of the story often included additions and distortions that made the story more consistent with English culture. For example, people in England rarely go “to the river to hunt seals” because seals are saltwater animals and most rivers have fresh water. Students might therefore say that the men went to the river to *fish*. Similarly, the ghostly aspect of the story did not fit comfortably with the religious beliefs of most Cambridge students and so was often modified. When one student was asked to recall the story six months after he had read it, he provided the following account:

Four men came down to the water. They were told to get into a boat and to take arms with them. They inquired, “What arms?” and were answered “Arms for battle.” When they came to the battle-field they heard a great noise and shouting, and a voice said: “The black man is dead.” And he was brought to the place where they were, and laid on the ground. And he foamed at the mouth.<sup>70</sup>

Notice how the student’s version of the story leaves out many of its more puzzling aspects—puzzling, at least, from his own cultural perspective.

Some concepts, schemas, scripts, and theories are specific to particular cultures, and lessons that require them will cause difficulty for students from other cultural backgrounds. You probably discovered this principle firsthand when you did “The War of the Ghosts” exercise. As another example, consider how, in the opening case study, Rita focuses on what European settlers were doing as she explains events in the New World. In contrast, a Native American student might look at this time pe-



Even though these two students are working together on a science activity, their prior knowledge and beliefs may lead each one to derive a different understanding from the experience.

<sup>69</sup> From *Remembering: A Study in Experimental and Social Psychology* (p. 65), by F. C. Bartlett, 1932, Cambridge, England: Cambridge University Press. Copyright 1932, 1955 by Cambridge

University Press. Reprinted with permission of Cambridge University Press.

<sup>70</sup> Bartlett, 1932, pp. 71–72, reprinted with permission; see footnote 69.

riod from the perspective of those whose land was being occupied and ultimately taken away by self-serving foreigners. This student's description of events in Michigan might reflect a theme of *invasion* rather than settlement.<sup>71</sup>

All this is not to say that some students have *less* knowledge than their peers, only that they have *different* knowledge. For example, some (but by no means all) students from low-income families lag behind their classmates in such basic academic skills as reading, writing, and computation.<sup>72</sup> Yet they are apt to bring other strengths to the classroom. They are often more clever at improvising with everyday objects.<sup>73</sup> If they work part-time to help their families make ends meet, they may have a good understanding of the working world. If they are children of single, working parents, they may know far more than their classmates about cooking, cleaning house, and taking care of younger siblings. If financial resources have been particularly scarce, they may know firsthand what it is like to be hungry for days at a time or to live in an unheated apartment in the winter, and so they may have a special appreciation for basic human needs and true empathy for victims of war or famine around the world. In some areas, then, students who have grown up in poverty have more knowledge and skills than their economically advantaged peers.

### Provide experiences on which students can build.

In some instances, of course, students simply do not have the background knowledge they need to understand a new topic. When students don't have such knowledge, teachers can provide concrete experiences that provide a foundation for classroom lessons. For example, students can better understand how large the dinosaurs were if they see a life-size dinosaur skeleton at a museum of natural history. Students can more easily understand the events of an important battle if they visit the battlefield. Often teachers can create foundational experiences in the classroom itself, perhaps by offering opportunities to work with physical objects and living creatures (e.g., timing the fall of light versus heavy objects, caring for a class pet), providing computer software that simulates complex activities (e.g., running a lemonade stand, dissecting a frog), or conducting in-class activities similar to those in the adult world (e.g., trying a court case, conducting a political campaign).

### Present questions and tasks that encourage elaboration.

The more students elaborate on new material—for instance, the more they draw inferences and implications from what they are learning—the more effectively they are apt to understand and remember it. The Classroom Strategies box “Encouraging Elaboration of Classroom Topics” describes and illustrates several ways that teachers might help students embellish on what they have learned.

### Facilitate visual imagery.

As we have discovered, visual imagery can be a highly effective way to learn and remember information. Teachers can promote students' use of visual imagery in several ways.<sup>74</sup> They can provide visual materials (pictures, charts, graphs, etc.) that illustrate or graphically organize important ideas. They can ask students to imagine how certain events in literature or history might have looked. And they can ask students to draw their *own* illustrations or diagrams of things they are learning. You can find examples of such strategies in the “Scarlet Letter” clip on Video CD 2.

In many situations teachers better help students remember new ideas when they encourage students to encode classroom subject matter *both* verbally and visually.<sup>75</sup> In



Observe how a high school English teacher encourages visual imagery in the “Scarlet Letter” clip on Video CD 2.

<sup>71</sup> Banks, 1991.

<sup>72</sup> Goldenberg, 2001.

<sup>73</sup> Torrance, 1995.

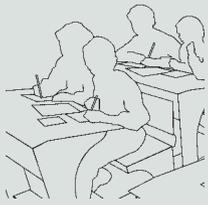
<sup>74</sup> R. K. Atkinson et al., 1999; Carlson, Chandler, & Sweller, 2003; Edens & Potter, 2001; Sadoski &

Paivio, 2001; Van Meter, 2001; Verdi, Kulhavy, Stock, Rittschof, & Johnson, 1996.

<sup>75</sup> Kulhavy, Lee, & Caterino, 1985; Sadoski & Paivio, 2001; Winn, 1991.

## Encouraging Elaboration of Classroom Topics

## Classroom Strategies



- Communicate the belief that students can and should make sense of the things they study.

A junior high school language arts teacher tells his class that he does not expect students to memorize the definitions he gives them for new vocabulary words. “Always put definitions in your own words,” he says, “and practice using

them in sentences. For example, one of the new words in this week’s list is *garish*. Look at the definition on the handout I gave you. In what situations might you see the word *garish*?”

- Ask questions that require students to draw inferences from what they are learning.

Students in a high school first-aid class have learned that when people suffer from traumatic shock, many normal bodily functions are depressed because less blood is circulating through the body. The teacher asks, “Given what you have learned about traumatic shock, why do experts recommend that if we find a person in shock, we *have them lie down and keep them warm but not hot*?”

- Have students apply what they’ve learned to new situations and problems.

To give her class practice in creating and interpreting bar graphs, a second-grade teacher asks children to write their favorite kind of pet on a sticky note she has given each of them. “Let’s make a graph that will tell us how many children like different kinds of

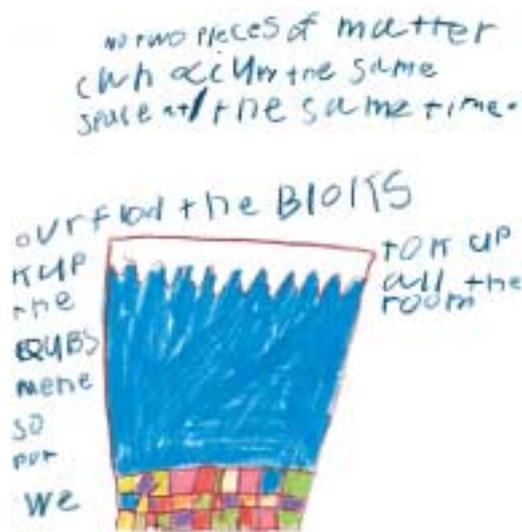
pets,” she says. On the chalkboard the teacher draws a horizontal line and a vertical line to make the graph’s x-axis and y-axis. “Let’s begin by making a column for dogs,” she continues. “How many of you wrote *dog* as your favorite pet? Seven of you? OK, come on up here and put your sticky notes on the graph where I’ve written *dog*. We’ll put them one above another to make a bar.” After the dog lovers have attached their notes to the graph, the teacher follows the same procedure for cats, birds, fish, and so on.

- Focus on an in-depth understanding of a few key ideas instead of covering many topics superficially.

In planning his geography curriculum for the coming school year, a fourth-grade teacher suspects that his students will gain little from studying facts and figures about numerous countries around the globe. Instead, he chooses six countries with very different cultures—Egypt, Italy, Japan, Peru, New Zealand, and Norway—that the class will focus on that year. Through an in-depth study of these countries, the teacher plans to help his students discover how different climates, topographies, cultures, and religions lead to different lifestyles and economies.

- Create opportunities for small-group or whole-class discussions in which students can freely exchange their views.

In a unit on World War II, a high school history teacher has students meet in small groups to speculate about the problems that Japanese people must have faced after atomic bombs were dropped on Hiroshima and Nagasaki.



**Figure 2.10** With both words and a picture, 9-year-old Nicholas describes his findings from a science experiment. The bottom sentence begins at the bottom and goes upward (Translation: “We poured so many cubes [that] the cup overflowed. The blocks took up all the room.”)

Figure 2.10, 9-year-old Nicholas uses both words and a picture to describe his findings from a third-grade science experiment, in which he observed what happened when he dropped small, heavy objects into a glass full of water. Nick has difficulties with written language that qualify him for special educational services. Notice how he misspells many words and writes *up* from the bottom of the page. Perhaps by writing upward rather than in the normal top-down fashion, Nick is thinking about how the water traveled up and out of the glass as blocks were dropped into it.

## Give students time to think.

We’ve talked about the importance of having students find personal meaning in, elaborate on, organize, and visualize classroom subject matter. Such processes require thought, and thought requires time. Yet teachers don’t always give students that time. For instance, when teachers ask students a question, they typically wait one second or less for a response. If students don’t respond in that short time, teachers tend to speak again—sometimes by asking another student the same question, sometimes by rephrasing the question, sometimes by answering the question themselves. Teachers are equally reluctant to let much time lapse after students answer questions or make comments in class—once again, they typically allow one second or less of silence before responding to a statement or asking another question.<sup>76</sup> The problem here is one of insufficient **wait time**.

When teachers instead allow at least *three seconds* to elapse after their own questions and after students’ comments, dramatic changes can occur in students’ behaviors. More students, especially more females and minority students, participate in class, and students begin to respond to one another’s comments and questions. Students are more likely to support their reasoning with evidence or logic and more likely to spec-

**wait time** Length of time a teacher pauses, after either asking a question or hearing a student’s comment, before saying something.

<sup>76</sup> M. B. Rowe, 1974, 1987.

ulate when they don't know an answer. Furthermore, they are more motivated to learn classroom subject matter, behavior problems decrease, and learning increases. Such changes are in part due to the fact that with increased wait time, *teachers'* behaviors change as well. Teachers ask fewer "simple" questions (e.g., those requiring recall of facts) and more thought-provoking ones (e.g., those requiring elaboration). They modify the direction of discussion to accommodate students' comments and questions, and they allow their classes to pursue a topic in greater depth than they had originally anticipated. And their expectations for many students, especially previously low-achieving ones, begin to improve.<sup>77</sup>

### Suggest mnemonics for hard-to-remember facts.

As we have seen, meaningful learning—making sense of something—is far more effective than rote learning. Yet some things are hard to make sense of. For instance, why do bones in the human body have such names as *humerus*, *fibula*, and *ulna*? Why is *fāng* the Chinese word for house? Why is Augusta the capital of Maine? For all practical purposes, there is no rhyme or reason to such facts.

When students are apt to have trouble making connections between new material and their prior knowledge, or when a body of information has an organizational structure with no apparent logic behind it (e.g., as is true for many lists), special memory tricks known as **mnemonics** can help them learn classroom material more effectively.<sup>78</sup> Three commonly used mnemonics are described in Figure 2.11.

Several examples of mnemonics are shown in the Video CDs that accompany the book. In the "Memory and Metacognition: Middle Childhood" clip on Video CD 1, 10-year-old David describes a mnemonic he uses to remember the Hebrew letter *pay* (פ):

*Pay*, it kind of goes like this, then this, then this, then this, then this, and then there's a little person right there. Well, not a little person, but a dot right there. . . . We pretend that in front of the dot is a counter and then the dot is a head, and then the head is "paying." So that's how we remember *pay*.

In the "Memory and Metacognition: Late Adolescence" clip on Video CD 1, 16-year-old Hilary remembers that Amendment 2 to the U.S. Constitution is the right to bear arms by thinking, "A bear has two arms." And in the second scenario in the "Group Work" clip on Video CD 2, a junior high school science teacher shows students how to develop a superimposed meaningful structure—in particular, a story—to help them remember the life cycle of a sheep liver fluke.

### Provide many opportunities to practice important knowledge and skills.

Some information and skills are so fundamental that students must become able to retrieve and use them quickly and effortlessly—that is, with automaticity. For instance, to read well, students must be able to recognize most of the words on the page without having to sound them out or look them up in the dictionary. To solve mathematical word problems, students should have such number facts as  $2 + 4 = 6$  and  $5 \times 9 = 45$  on the tips of their tongues. And to write well, students should be able to form letters and words without having to stop and think about how to make an uppercase *G* or spell *the*. Unless such knowledge and skills are learned to automaticity, a student may use so much working memory capacity retrieving and using them that there is little "room" to do anything more complex.<sup>79</sup>

Ultimately, students can learn basic information and skills to automaticity only by using and practicing them repeatedly. This is *not* to say that teachers should fill each day with endless drill-and-practice exercises involving isolated facts and procedures. Automaticity can occur just as readily when the basics are embedded in a



Observe mnemonics in the middle childhood and late adolescence "Memory and Metacognition" clips and in the "Group Work" clip on Video CD 1.

<sup>77</sup> Giaconia, 1988; Mohatt & Erickson, 1981; M. B. Rowe, 1974; 1987; Tharp, 1989; Tobin, 1987.

<sup>78</sup> Bower & Clark, 1969; Bulgren, Schumaker, & Deshler, 1994; M. S. Jones, Levin, Levin, & Beitzel,

2000; Pressley, Levin, & Delaney, 1982; Scruggs & Mastropieri, 1989.

<sup>79</sup> R. M. Gagné, 1983; Mayer & Wittrock, 1996; McCutchen, 1996; Perfetti, 1983.

**mnemonic** Memory aid or trick designed to help students learn and remember a specific piece of information.

**Figure 2.11** Common mnemonic techniques**VERBAL MEDIATION**

A **verbal mediator** is a word or phrase that creates a logical connection, or “bridge,” between two pieces of information. Verbal mediators can be used for such paired pieces of information as foreign language words and their English meanings, countries and their capitals, chemical elements and their symbols, and words and their spellings. Following are examples:

**Information to Be Learned**

*Handschuh* is German for “glove.”  
 Quito is the capital of Ecuador.  
 Au is the symbol for gold.  
 The word *principal* ends with the letters *pal* (not *ple*).  
 The *humerus* bone is the large arm bone above the elbow.

**Verbal Mediator**

A glove is a *shoe* for the hand.  
 Mosquitoes are at the *equator*.  
 ‘Ay, you stole my *gold* watch!  
 The *principal* is my *pal*.  
 The *humorous* bone is just above the *funny* bone.

**KEYWORD METHOD**

Like verbal mediation, the **keyword method** aids memory by making a connection between two things. This technique is especially helpful when there is no logical verbal mediator to fill the gap—for example, when there is no obvious sentence or phrase to relate a foreign language word to its English meaning. The keyword method involves two steps, which I will illustrate using the Spanish word *amor* and its English meaning *love*:

1. Identify a concrete object to represent each piece of information. The object may be either a commonly used symbol (e.g., a heart to symbolize *love*) or a soundlike word (e.g., a suit of armor to represent *amor*). Such objects are *keywords*.
2. Form a mental picture of the two objects together. To remember that *amor* means *love*, you might picture a knight in a suit of armor with a huge red heart painted on his chest.



You used the keyword method when you learned the meanings of *fáng*, *mén*, *ké*, *fàn*, and *shū* in the “Five Chinese Words” exercise earlier in the chapter. Following are additional examples:

**Information to Be Learned**

*Das Pferd* is German for “horse.”  
 Augusta is the capital of Maine.  
 Tchaikovsky composed *Swan Lake*.

**Visual Image**

Picture a *horse* driving a *Ford*.  
 Picture a *gust* of wind blowing through a horse’s *mane*.  
 Picture a *swan* swimming on a *lake*, wearing a *tie* and *coughing*.

**SUPERIMPOSED MEANINGFUL STRUCTURE**

A larger body of information, such as a list of items, can often be learned by superimposing a meaningful organization—a familiar shape, word, sentence, rhythm, poem, or story—on the information. Following are examples of such **superimposed meaningful structures**:

**Information to Be Learned**

The shape of Italy  
 The Great Lakes (Huron, Ontario, Michigan, Erie, Superior)  
 Lines on the treble clef (E G B D F)  
 The number of days in each month  
 How to turn a screw (clockwise to tighten it, counterclockwise to loosen it)  
 How to multiply in a mathematical expression of the form  $(ax + b)(cx + d)$

**Superimposed Meaningful Structure**

A “boot”  
 HOMES  
 Elvis’s guitar broke down Friday, or every good boy does fine.  
 Thirty days has September . . . .  
 Righty, tighy; lefty, loosey.  
 FOIL: multiply the *first* terms within each set of parentheses, then the two *outer* terms, then the two *inner* terms, and finally the *last* terms

**verbal mediator** Word or phrase that forms a logical connection or “bridge” between two pieces of information.

**keyword method** Mnemonic technique in which an association is made between two ideas by forming a visual image of one or more concrete objects (*keywords*) that either sound similar to, or symbolically represent, those ideas.

**superimposed meaningful structure** Familiar shape, word, sentence, poem, or story imposed on information in order to facilitate recall.

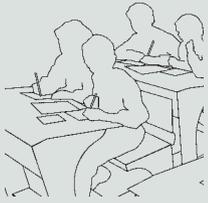
variety of stimulating and challenging activities. Furthermore, students should ideally practice new skills within the context of instruction and guidance that help them *improve* those skills. The Classroom Strategies box “Helping Students Acquire New Skills” provides examples of instructional strategies that can help students more effectively acquire procedural knowledge.

At the same time, teachers must be aware that automaticity has a downside.<sup>80</sup> In particular, students may quickly recall certain ideas or perform certain procedures

<sup>80</sup> Killeen, 2001; E. J. Langer, 2000; LeFevre, Bisanz, & Mrkonjic, 1988.

## Helping Students Acquire New Skills

## Classroom Strategies



- Help students understand the logic behind the procedures they are learning.

As a teacher demonstrates the correct way to swing a tennis racket, he asks his students, “Why is it important to have your feet apart rather than together? Why is it important to hold your arm straight as you swings?”

- Provide mnemonics that can help students remember a sequence of steps.

A math teacher presents this equation:

$$y = \frac{3(x + 6)^2}{2} + 5$$

“When  $x$  equals 4, what does  $y$  equal?” she asks. She gives students a mnemonic, *Please excuse my dear Aunt Sally*, that they can use to help them remember how to simplify such complex algebraic expressions. First, you simplify things within parentheses (this is the *P* in *Please*). Then, you simplify anything with an exponent (this is the

*e* in *excuse*). Then, you do any necessary multiplication and division (these are the *m* and *d* in *my dear*). Finally, you do any remaining addition and subtraction (these are the *A* and *S* in *Aunt Sally*).

- When skills are especially complex, break them into simpler tasks that students can practice one at a time.

Knowing how overwhelming the task of driving a car can initially be, a driver education teacher begins behind-the-wheel instruction by having students practice steering and braking in an empty school parking lot. Only later, after students have mastered these skills, does she have them drive in traffic on city streets.

- As students practice new skills, provide the feedback they need to help them improve.

A science teacher asks his students to write lab reports after each week’s lab activity. Many of his students have had little or no previous experience in scientific writing, so when he grades the reports, he writes numerous comments as well. Some comments describe the strengths that he sees, and others provide suggestions for making the reports more objective, precise, or clear.

when other, less automatic ideas or procedures are more useful. Students are far more flexible, and so far more likely to identify unique approaches to situations or creative solutions to problems, when they aren’t automatically “locked in” to a particular response. We’ll revisit this issue in our discussion of *mental set* in Chapter 4.

### Give hints that help students recall or reconstruct what they’ve learned.

Sometimes forgetting is simply a matter of retrieval difficulty: Students either can’t “find” knowledge that’s in long-term memory or else neglect to “look” for it altogether. In such situations retrieval cues are often helpful and appropriate. For example, if a student asks how the word *liquidation* is spelled, a teacher might say, “*Liquidation* means to make something liquid. How do you spell *liquid*?” Another example comes from one of my former teacher interns, Jesse Jensen. A student in her eighth-grade history class had been writing about the Battle of New Orleans, a decisive victory for the United States in the War of 1812. The following exchange took place:

**Student:** Why was the Battle of New Orleans important?

**Jesse:** Look at the map. Where is New Orleans?  
(The student locates New Orleans.)

**Jesse:** Why is it important?

**Student:** Oh! It’s near the mouth of the Mississippi. It was important for controlling transportation up and down the river.

In the early grades teachers typically provide many retrieval cues: They remind students about the tasks they need to do and when they need to do them (“I hear the fire alarm. Remember, we all walk quietly during a fire drill”; or “It’s time to go home. Do you all have the field trip permission slip to take to your parents?”). But as students grow older, they must develop greater independence, relying more on themselves and less on their teachers for the things they need to remember. At all grade levels, teachers can teach students ways of providing retrieval cues for *themselves*. For example, if first-grade teachers expect children to bring signed permission slips to school the following day, they might ask the children to write a reminder on a piece of masking tape that they attach to their jackets or lunch boxes. If junior high school teachers give students a major assignment due several weeks later, they might suggest that students help themselves remember the due date by taping a note to the bedside table or making an entry on the kitchen calendar. In such instances teachers are fostering *self-regulation*, a topic we’ll explore in Chapter 4.

### Regularly assess student’s understandings.

As we’ve learned, students construct their own versions of “reality,” and such constructions are not always accurate or productive. For example, the first day 8-year-old Darcy attended third grade at a new school, she accidentally got egg in her hair. Her teachers, Mrs. Whaley, brought her to the nurse’s office to have the egg washed out. In the journal entries in Figure 2.12, Darcy initially misinterpreted Mrs. Whaley’s comment about the situation. Not until five days later did she gain a more accurate understanding of what Mrs. Whaley had said.

Darcy’s misinterpretation of her teacher’s comment got her off to a rocky start at her new school. In other situations students may misinterpret material in classroom lessons—for example, thinking that a “round” earth must be shaped like a pancake or (as Barry did) believing that heavy egg containers fall faster than light ones despite evidence to the contrary—and so learn things that their teachers never anticipated.

Teachers must continually keep in mind that students won’t necessarily construct the meanings from classroom events and lessons that teachers intend for them to construct. Rather, students will each interpret classroom subject matter in their own, idiosyncratic ways. Accordingly, teachers should frequently monitor students’ understandings by asking questions, encouraging dialogue, and listening carefully to students’ ideas and explanations.

October 22nd, 2001

*I went to a new school today. My teacher’s name is Mrs. Whaley. I accidentally cracked an egg on my head. Mrs. Whaley told the nurse that I was a showoff and a nuisance. I got really sad and wanted to run away from school, but I didn’t leave.*

. . .

October 27th, 2001

*We presented our book reports today. I was the last one to present my book report. Whenever I did my book report, they laughed at me, but the teacher said they were laughing with me. I asked the teacher why she had called me a nuisance the first day. And she said, “Darcy, I didn’t call you a nuisance. I was saying to Mrs. Larson that it was a nuisance to try to wash egg out of your hair.” I was so happy. I decided to like Mrs. Whaley again.*

**Figure 2.12**

As you can see from her journal entries, 8-year-old Darcy initially interpreted a casual remark to the school nurse in a way very different from the teacher’s intended meaning. Fortunately, the teacher corrected the misunderstanding a few days later.

### Identify and address students’ misconceptions.

Teachers often present new information in class with the expectation that such information will replace students’ erroneous beliefs. Yet as we’ve seen, students of all ages can hold quite stubbornly to their existing misconceptions about the world, even after considerable instruction that explicitly contradicts them.<sup>81</sup> In some cases students never make the connection between what they are learning and what they already believe, perhaps because they engage in rote learning as they study academic subject matter.<sup>82</sup> In other instances students truly try to make sense of classroom material, but thanks to the process of elaboration, they interpret new information in light of what they already “know” about the topic, and they may reject or discredit something that doesn’t fit.<sup>83</sup> (Recall our earlier discussion of *confirmation bias*.)

When students hold scientifically inaccurate or in other ways counterproductive beliefs about the world, teachers must work actively and vigorously to help them revise their thinking. That is, teachers must encourage **conceptual change**. The Classroom Strategies box “Promoting Conceptual Change” presents and illustrates several potentially useful techniques.

Convincing students to replace long-held and well-engrained beliefs can be quite a challenge, and ultimately it may require addressing students’ *epistemological beliefs* and *motivation* as well as their long-term memory storage processes. We’ll explore these two topics in Chapters 4 and 6, respectively.

### Be on the lookout for students who have unusual difficulty with certain cognitive processes.

Some students may show ongoing difficulties in processing and learning from academic (or in some cases social) situations. Students with **learning disabilities** have significant deficits in one or more specific cognitive processes. For instance, they

**conceptual change** Revision of one’s understanding of a topic in response to new information.

**learning disability** Deficiency in one or more specific cognitive processes despite relatively normal cognitive functioning in other areas.

<sup>81</sup> S. Carey, 1986; Chambliss, 1994; Chinn & Brewer, 1993; Eaton, Anderson, & Smith, 1984; Shuell, 1996

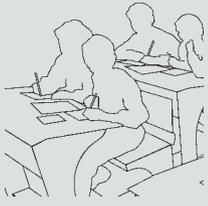
<sup>82</sup> Chambliss, 1994; Keil & Silberstein, 1996; Strike

& Posner, 1992.

<sup>83</sup> De Lisi & Golbeck, 1999; Gunstone & White, 1981; Hynd, 1998b; Kuhn, Amsel, & O’Loughlin, 1988.

## Promoting Conceptual Change

## Classroom Strategies



- Probe for prior misconceptions that may lead students to interpret new information incorrectly.

When a third-grade teacher asks, "What is gravity?" one of his students replies that it's "something that pulls you down." The teacher points to Australia on a globe and asks, "What do you mean by *down*? What do you think would happen if we traveled to Australia? Would gravity pull us off the earth and make us fall into space?"

- Provide information and experiences that explicitly contradict what students believe.



In a lesson about air, a first-grade teacher wants to address the common misconception that air has no substance. She asks students to predict what will happen when she submerges an upside-down glass in a large bowl of water, and the children have differing opinions about whether the "empty" glass will fill with water. The teacher stuffs the glass with a crumpled paper towel, turns it upside-down, and then pushes it straight down into the water. The paper towel remains dry, leading the class to a discussion of how air takes up space. (You can observe this lesson in the "Properties of Air" clip on Video CD 2.)

- Ask questions that challenge students' misconceptions.
 

A high school physics teacher has just begun a unit on inertia. Several students assert that when a baseball is thrown in the air, some force continues to act on the ball, pushing it upward until it begins to drop. The teacher asks, "What force in the air could possibly be pushing that ball upward once it leaves the thrower's hand?"
- Show students how an alternative explanation is more plausible and useful—how it makes more sense—than their original belief.
 

The same physics teacher points out that the baseball continues to move upward even though no force pushes it in that direction. He brings in the concept of *inertia*: The ball needs a force only to get it *started* in a particular direction. Once the force has been exerted, other forces (gravity and air resistance) alter the ball's speed and direction.
- Give students corrective feedback about responses that reflect misunderstanding.

A high school psychology teacher says to a student, "Hmmm, you just told me that you could learn a foreign language by playing audiotapes while you sleep. But didn't we just discover last week that attention is essential for most learning?"

- When pointing out misconceptions that students have, do so in a way that maintains their self-esteem.
 

A fourth-grade teacher begins a lesson on plants by asking, "Where do plants get their food?" Various students suggest that plants get their food from dirt, water, or fertilizer. The teacher responds, "You know, many children think exactly what you think. It's a very logical way to think. But actually, plants *make* their food, using sunlight, water, and things in the soil." The teacher continues by introducing the concept of photosynthesis.
- Engage students in discussions of the pros and cons of various explanations.
 

After students express the stereotypical belief that new immigrants to the country are "lazy," a middle school social studies teacher invites several recent immigrants to visit the class and describe their efforts to adjust to their new environment. The following day, he asks students to reflect on the guest speakers: "Several of you have told me that many immigrants are lazy. Do you think the people you met yesterday were lazy? Why or why not?" In the ensuing discussion the students begin to realize that most immigrants probably work very hard to adapt to and succeed in their new society and its culture.
- Ask students to apply their revised understandings to new situations and problems.

When several students express the belief that rivers always run from north to south, a middle school geography teacher reminds them that water travels from higher elevations to lower elevations, not vice versa. She then pulls out a map of Africa. "Let's look at the Nile River," she says. "One end of the Nile is here [she points to a spot on Egypt's Mediterranean coast] and the other end is here [she points to a spot in Uganda]. In which direction must the Nile be flowing?"

Sources: Chan, Burtis, & Bereiter, 1997; Chinn & Brewer, 1993; Hynd, 1998b; Pine & Messer, 2000; Pintrich, Marx, & Boyle, 1993; Posner, Strike, Hewson, & Gertzog, 1982; Prawat, 1989; Putnam, 1992; K. J. Roth, 1990; K. J. Roth & Anderson, 1988; Slusher & Anderson, 1996; Vosniadou & Brewer, 1987.

may have trouble remembering verbal instructions, recognizing words in print (*dyslexia*), or thinking about and remembering information involving numbers (*dyscalculia*). Students with **attention-deficit hyperactivity disorder (ADHD)** may show marked deficits in attention, have trouble inhibiting inappropriate thoughts and behaviors, or both. Most experts believe that learning disabilities and ADHD have a biological basis and are in many cases inherited.<sup>84</sup>

When students have been officially identified as having a learning disability or ADHD, specialists are often called upon to assist them in their learning. Even so, most of these students are in general education classrooms for much or all of the school day. Strategies for working effectively with them include the following:

- Identify and capitalize on the times of day when students learn best.
- Minimize distractions.
- Use multiple modalities to present information.

**attention-deficit hyperactivity disorder (ADHD)** Disorder marked by inattention, inability to inhibit inappropriate thoughts and behaviors, or both.

<sup>84</sup> Barkley, 1998; J. G. Light & Defries, 1995; Manis, 1996; Purdie, Hattie, & Carroll, 2002.

- Actively address students' areas of weakness (e.g., in reading or math).
- Teach mnemonics for specific facts.
- Help students organize and use their time effectively.
- Teach general learning and memory strategies.
- Provide a structure to guide students' learning efforts (e.g., present a partially filled-in outline for taking notes, or suggest questions to answer while reading a textbook chapter).
- Continually assess students' recall and understanding.<sup>85</sup>

Some of these strategies should look familiar, as you've seen them at earlier points in the chapter. We'll revisit others in our discussion of metacognition and self-regulation in Chapter 4. By and large, the most effective strategies for students with special educational needs are the same ones that are effective with *all* learners.

As you have discovered, effective instruction involves a lot more than simply telling students what they need to learn. In our discussion of cognitive processes and memory in this chapter, we've focused primarily on things that happen inside the learner when learning takes place. However, we can better understand how human beings learn when we look at *social processes* as well as internal, mental processes. We'll consider the social nature of learning as we address "Learning in Context" in Chapter 3.

## SUMMARY

Learning is not simply a process of "absorbing" information from the environment. Rather, it is a process of actively *constructing* meaning from both informal experiences and formal instruction. In their attempts to make sense of the world, learners combine some (but not all) of what they observe with their existing knowledge and beliefs to create an ever-expanding and distinctly idiosyncratic understanding of the world.

At the most basic level, learning probably involves changes in neurons and synapses in the brain. Different parts of the brain specialize in different tasks, but many parts of the brain in both hemispheres tend to work closely together in everyday tasks.

The results of many psychological studies of human learning and behavior indicate that human memory may have three distinct components. One component, often called the *sensory register*, holds incoming sensory information for two or three seconds at the very most. What a learner pays attention to moves on to *working memory*, where it is held for a somewhat longer period while the learner actively thinks about, manipulates, and interprets it. Yet working memory can hold only a small amount of information at one time, and information that is not actively being thought about tends to disappear quickly (typically, in less than half a minute) unless the learner processes it sufficiently that it is stored in long-term memory.

*Long-term memory* appears to have as much capacity as human beings could ever need. In fact, the more information learners already have there, the more easily they can store new material. Effective storage typically involves *meaningful learning*—that is, connecting new information with existing knowledge and beliefs. By making such connections, learners make better sense of their experience, retrieve what they've learned more easily, and create an increasingly organized and integrated body of knowledge that helps them interpret new experiences. In some instances, however, meaningful learning leads learners to distort new information, such that they construct inaccurate and potentially counterproductive understandings.

Knowledge about the brain tells us little about how teachers can best help students learn. Fortunately, psychological and educational research provides considerable guidance. Teachers must continually emphasize the importance of *understanding* classroom subject matter—making sense of it, drawing inferences from it, seeing how it all ties together, and so on—rather than simply memorizing it in a rote, "thoughtless"

<sup>85</sup> Barkley, 1998; Brigham & Scruggs, 1995; Buchoff, 1990; Eilam, 2001; E. S. Ellis & Friend, 1991; Heward, 2003; Mastropieri & Scruggs, 1992;

Wilder & Williams, 2001; J. W. Wood, 1998; J. W. Wood & Rosbe, 1985.

manner. Such an emphasis must be reflected not only in teachers' words but also in their instructional activities, classroom assignments, and assessment practices. For instance, rather than just presenting important ideas in classroom lectures and asking students to take notes, teachers might ask thought-provoking questions that require students to evaluate, synthesize, or apply what they are learning. As an alternative to asking students to memorize procedures for adding two-digit numbers, teachers might ask them to suggest at least three different ways they might solve problems such as  $15 + 45$  or  $29 + 68$  and to justify their reasoning. Rather than assessing students' knowledge of history by asking them to recite names, places, and dates, teachers might ask them to explain why certain historical events happened and how those events altered the course of subsequent history. At the same time, teachers must also be alert to the misconceptions that students either bring with them to the classroom or acquire from instructional activities, and then make a concerted effort to convince and motivate them to change their beliefs.

## PRACTICE FOR YOUR LICENSURE EXAM

### Vision Unit

Ms. Kontos is teaching a unit on human vision to her fifth-grade class. She shows her students a diagram of the various parts of the human eye: lens, cornea, retina, and so on. She then explains that people can see objects because light from the sun or another light source bounces off those objects and into the eye. To illustrate this idea, she shows them the picture to the right.

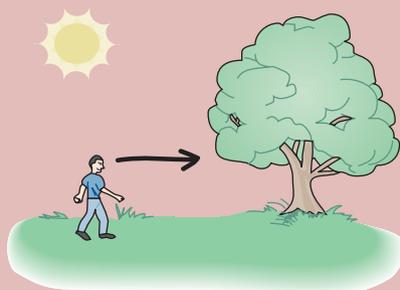


"Do you all understand how our eyes work?" she asks. Her students nod that they do.

The next day Ms. Kontos gives her students this picture:



She asks them to draw how light travels so that the child can see the tree. More than half of the students draw lines something like this:<sup>86</sup>



### 1. Constructed-response question

Obviously, most of Ms. Kontos's students have not learned what she thought she had taught them about human vision.

- Explain why many students believe the *opposite* of what Ms. Kontos has taught them. Base your response on contemporary principles and theories of learning and cognition.
- Describe two different ways in which you might improve on the lesson to help students gain a more accurate understanding of human vision. Base your strategies on contemporary principles and theories of learning and cognition.

### 2. Multiple-choice question

Many elementary school children think of human vision in the way that Ms. Kontos's fifth graders do—that is, as a process that originates in the eye and goes outward toward objects that are seen. When students revise their thinking to be more consistent with commonly accepted scientific explanations, they are said to be:

- Acquiring a new script
- Developing automaticity
- Undergoing conceptual change
- Acquiring procedural knowledge

Once you have answered these questions, compare your responses with those presented in Appendix A.

<sup>86</sup> The Case presented in the exercise is based on a study by J. F. Eaton et al., 1984.