Consider everything that memory lets you do. Obviously there are the everyday tasks, such as passing tests, turning in a paper on time, or remembering a friend’s birthday. But go deeper: Think of the things memory lets you do that you take for granted. Because of memory, you can have favorite foods, favorite musicians, favorite movies, and favorite TV shows. Not only can you remember friends’ birthdays, you can also remember their typical behaviors and their preferences and then predict what they might want for their birthday.

You can go deeper still. If you did not somehow plant events and people in your mind, you would not know about anything that you were not directly sensing at that moment. You would only know what was in your line of sight and have no idea how the things that you were seeing connected to you or had any significance or meaning. Without memory, you would, like Leonard, be a stranger to yourself, unable to form the identity, or sense of self, that comes from linking one’s present to one’s past and using this information to make decisions about the future. By keeping a record of our past, our memory takes us out of an infinite present.
What Is Memory?

LEARNING OBJECTIVE 1 Define the basic activities of memory and describe two major models of memory.

Simply put, memory is the faculty for recalling past events and past learning. This definition is perhaps the only thing about memory that is simple. Although psychologists often differ in their ideas about memory, they generally agree that it involves three basic activities:

- **Encoding**—Getting information into memory in the first place
- **Storage**—Retaining memories for future use
- **Retrieval**—Recapturing memories when we need them

When, for example, you attend a musical concert, you may transform the sights and sounds produced by the performing band into a kind of memory code and record them in your brain (encoding). This information then remains stored in the brain until you retrieve it at later times—when, for example, you see photos of the band online, watch their music videos, or decide which of the band’s songs to download. At such times of retrieval, the original concert event, including the feelings of exhilaration and discovery that you experienced at the concert, may come rushing back.

How do we manage to encode, store, and retrieve information? Psychologists have developed a number of models of explanation, including the information-processing model and the parallel distributed-processing model, or connectionist model.

The information-processing model of memory holds that information must pass through three stages, or systems, of mental functioning in order to become a firmly implanted memory—sensory memory, working memory, and long-term memory (see Figure 8-1) (Dudai, 2011; Nee et al., 2008). When we first come across a stimulus, our brain retains a sensory image—or sensory memory—of it for less than a second. Sensory memories help us to keep alive a bit longer items that we have experienced briefly, so that we can, in a sense, decide whether to pay further attention to them. If, for example, we look up a person’s e-mail address, our sensory memory records the address and quickly passes it on to our working memory. We can help retain the new address in working memory by concentrating hard and repeating it over and over as we address...
What Is Memory?

271

Retrieval
Recalling memories when we need them

Storage
Retaining memories over the long term

Encoding
Entering information into memory

an e-mail or type it into our computer’s address book. But working memory itself can hold only so much information at a time. It will eventually fail us and the information will disappear unless it is further passed on to our long-term memory system—the system that can retain an enormous number of pieces of information for a seemingly endless period of time.

The three systems of memory proposed by the information-processing model operate like a computer (see Figure 8-2). Have you ever typed faster than your computer can process and then watched it spit out several characters at once? Sensory memory works in a similar way, giving us a quick copy of the information in our environment. In addition, information saved to working memory is like the information that a computer retains for as long as a document or website is open, but which disappears if you do not save it. And the final memory system, long-term memory, is the equivalent of the computer hard drive, storing information until something causes disruption or loss of the memory. These three systems are sometimes referred to as memory stores. The information-processing model has produced a great deal of research that we will explore further in the sections of this chapter that focus on encoding, storage, retrieval, and forgetting.

Although the information-processing model suggests that sensory memory, working memory, and long-term memory correspond roughly to computer memory structures, we need to be clear that this is but a metaphor (Silva, 2011). If you break open a computer, you can find clear modules where the various forms of memory are in operation. When we look at the human brain, however, there are no equivalent specific structures where short-term memory and long-term memory exist.

Unlike the information-processing model, which suggests that information is stored and retrieved piece by piece, an alternative model of memory, the parallel distributed-processing model (PDP), or connectionist model, holds that newly encountered pieces of information immediately join with other previously encountered pieces of information to help form and grow networks of information (McClelland, 2011). Such networks result in sophisticated memories, broad knowledge, and the ability to make better decisions and plans in life. Look, for example, at Figure 8-3. When the person in the figure sees an apple, connections to relevant kinds of information are activated—connections to information such as shape (roundness), color (red), and grandma (because of the apple tree in her backyard)—while other, less relevant connections are inhibited. These activated connections are all part of the network of information related to apples that this person has stored. When one part of the “apple” network is activated, related neurons throughout the brain also become active and

FIGURE 8-2 Memory as a computer In the information-processing model of memory, the basic memory stages are analogous to a computer: encoding allows us to enter information into our brain; storage to retain the information over the long term; and retrieval to call up the information as we need it.
richer memories spring forth. The PDP model of memory has gained many proponents, largely because its principles fit well with the field’s growing recognition that neurons throughout our brains form networks of association as we respond to repeated learning experiences and events in life (Changeux, 2011).

Before You Go On

What Do You Know?
1. What are encoding, storage, and retrieval?
2. What are the three memory stores suggested by the information-processing model of memory?

What Do You Think? Judging from your own experiences, do you think memory works more like a computer, with different memory stores, or more in a connectionist fashion? Could the two ideas both be useful in explaining some of your experiences?

How Do We Encode Information into Memory?

LEARNING OBJECTIVE 2 Describe how information is encoded and transferred among different memory stores and what we can do to enhance encoding.

How many steps are there from the front door of your building to your room? Can’t remember? How about an easier question: What was the first word you said yesterday morning? Most of us probably cannot recall the answer to either of these questions.

FIGURE 8-3 The PDP model of memory
The PDP, or connectionist, model of memory suggests that memories are stored in a network of associations throughout our brains.
Your lack of recall may be because the information was never encoded, or entered into your memory in the first place. Because we fail to encode many pieces of information that we come across in life, we do not actually remember most of the things that we experience. Encoding requires attention—that is, we need to focus on or notice the information. We can encode only what we attend to (Eysenck et al., 2010).

Amazing Recall... Not!
Contestants in the annual USA National Memory Championship are required to memorize thousands of numbers and words, pages of faces and names, and decks of cards (Schacter, 2001). Yet one winner considers herself dangerously forgetful? That’s right. “I’m incredibly absentminded,” winner Tatiana Cooley told a reporter. Fearful that she will forget to carry out everyday tasks, Cooley depends on to-do lists and notes scribbled on sticky pads, “I live by Post-Its,” she admitted.

Why does someone with a capacity for such amazing recall need to write down anything at all? Can’t she call on her extraordinary memory abilities and strategies—the ones on display during the memory championships—to help her remember that she needs to pick up a jug of milk at the store? Apparently not.

The kinds of everyday memory failures that Cooley seeks to remedy with Post-It notes—errands to run, appointments to keep, and the like—reflect absentmindedness. That is, like most of us, in her everyday life Cooley often is inattentive, encodes information improperly, and carelessly overlooks available information when she goes to retrieve memories—a phenomenon we’ll come across shortly.

Using Automatic and Effortful Processing to Encode
We are not always aware that we are attending to things in our environment. Sometimes we attend to information—particularly, information about time, space, or frequency—without much conscious awareness and indeed with little or no effort. Even though you might not know how many steps there are from the front door of your building to the door of your room, you probably do not get lost very often along the way and you probably did not need to practice the route to figure out how to get to your room. The encoding process that allowed you to learn this basic route is called automatic processing (Hassin, 2005).

Although we use automatic processing to encode many kinds of information, the encoding of other information requires that we make conscious efforts and pay very close attention (Gilchrist & Cowan, 2010). This is the type of processing you are engaging in right now as you read this chapter, whether you are preparing for tomorrow’s class or studying for a test. As you read through the present material, you are trying to find ways to bring this new information into your memory, because the facts won’t settle there without your careful attention. This kind of encoding—which is typically needed when a person learns new information, such as new names, songs, or tasks—is called effortful processing (Hassin, 2005).

Keep in mind that whether we are encoding information through automatic or effortful processing, we must be paying attention. Our attention might be less apparent in automatic processing, but if we do not attend sufficiently to information, in one way or another, we will simply not be able to encode it.

There are key differences between these two kinds of processing. First, the encoding of information by effortful processing tends to be disrupted when a person is forced to perform other tasks or to attend to other information while trying to encode the information at hand (Craik, 2001; Craik & Kester, 2000). You probably will not gather...
Chapter 8    Memory

much from this book if you try to read it while carrying on a lively text or phone conversation, for example. In contrast, automatic processing, being so effortless, is disrupted only slightly by the performance of other tasks.

Second, as the name might suggest, putting extra effort into effortful processing makes it more effective. Automatic processing is not greatly improved by a person’s extra efforts to attend and encode. You could go and rehearse the path from your front door to your room and count the steps, but it’s unlikely that you’ll know any more about the route than you knew this morning. In contrast, extra efforts can make a big difference in effortful processing. Reading over the material in this chapter again and again will affect considerably your ability to recall it on a test.

Encoding Information into Working Memory: Transferring from Sensory Memory into Working Memory

As we observed earlier, when we first come across a stimulus, our brains retain a very brief sensory image of it—an image called a sensory memory (Magnussen et al., 2010). If, for example, we are shown a photograph for just a moment, we retain a detailed image of all the shapes and items in the photograph for a few hundred milliseconds. Studies by researcher George Sperling in the late 1950s and early 1960s offered important clues about how sensory memories operate (Sperling, 1960).

Sperling wanted to demonstrate the presence of a brief visual storehouse—like the buffer memory of a computer—that would hold a picture of our environment for a very brief period of time. He also wanted to measure how long this buffer would last. To do so, he exposed participants to a list of random letters, similar to what you might see on an eye chart (although always the same size) (Figure 8-4). He presented those letters extremely quickly and found that, generally speaking, participants did a pretty good job reporting the letters if asked to do so right away. The longer Sperling waited after showing the letters, however, the more performance declined. After about half a second, participants had trouble remembering any letters from the grid.

If we do not pay much attention to our sensory memories, as is usually the case, they will disappear forever. Those that are attended to, however, may enter the working memory, the second system of memory. Working memory serves several important functions in our day-to-day lives (Hofmann et al., 2011). One of the most important is that of enabling us to hold on to information—such as a website address or a phone number—that we need for short periods. We use working memory in this way much of the time. Whenever we read, for example, our working memory enables us to keep the beginning of a sentence in mind while we are reading the last part of the sentence, so that the whole phrase will make sense to us (Just & Carpenter, 2002). It also enables us to relate new sentences, such as this one, to previous sentences we have just read. Similarly, in a conversation, working memory helps us link new comments to previous ones so that we can follow what we are hearing.

One way of helping to make sure that information is encoded into working memory is rehearsal, consciously repeating the information. As far back as 400 B.C.E., the ancient Greek philosophers recognized the value of rehearsal in memory. Assuming that hearing and saying the same things would transfer new information into memory, the philosophers advised students to repeat whatever they heard (Turkington & Harris, 2009, 2001). We are rehearsing when we keep repeating a phone number we’ve just heard until we can call it or add it to our phone’s contact list. Such rehearsal increases the likelihood that the information will indeed enter our working memory and be available to us as we punch in the phone number.

sensory memory memory involving detailed, brief sensory image or sound retained for a brief period of time.

working memory a short-term memory store that can hold about seven items at once.

rehearsal conscious repetition of information in an attempt to make sure the information is encoded.

FIGURE 8-4 Test of sensory memory In his study of the duration of sensory memory, George Sperling flashed a chart of letters, similar to this one, for 1/20 of a second. He found that participants could recall almost all the letters in a particular row if asked to do so immediately, but half a second later, their performance declined.
Encoding Information into Long-Term Memory: Transferring Working Memory into Long-Term Memory

Although concentrated efforts, such as rehearsal, can lengthen the availability of information in working memory, eventually that information is either passed on to the long-term memory system or lost (Jonides et al., 2008, 2003). It is in long-term memory that we hold all of the information we have gathered, available for use—often at a moment’s notice—in a new situation or task. When we remember past events, previously-gathered information, people we once met, past feelings, or acquired skills, we are using our long-term memory system.

Just as rehearsal can help move information from the sensory memory system to the working memory system, it can help us move short-term, working memories into the long-term memory system (Neuschatz et al., 2005). Most of us rehearse information from a course’s textbook and lectures, for example, when we are studying for an examination. Information passes into long-term memory best when our rehearsal sessions are spread out over a period of time rather than attempting to take in a great deal of information all at once. As we observed in Chapter 7, this phenomenon is known as the spacing effect. Thus, distributed practice, such as studying material weekly, followed by reviews closer to the time of an exam, is usually more profitable than massed practice, such as studying in one “cram” session just before the exam.

As we also saw in Chapter 7, sleep can help or hurt rehearsal. Information acquired in the hours before falling asleep tends to be encoded into long-term memory, as long as we have time to process it before sleep sets in (Stickgold, 2011; Backhaus et al., 2008). Information learned just as sleep is approaching is rarely retained, however, partly because we fall asleep before we can rehearse. Furthermore, information that comes to us during sleep—a language CD, for example—does not typically enter our memories at all.

In What Form Is Information Encoded?

We must use some kind of code or representation to encode information. Different codes are available to us (Martin, 2009). When encoding information into working memory—for example, trying to keep a phone number in memory long enough to dial it—we can use a phonological code, repeating the sounds of the numbers again and again, or we can employ a visual code, holding an image of how the digits would look if written down.
Chapter 8  Memory

Research suggests that people tend to favor phonological codes when recording verbal information, such as digits, letters, and words. We rely more on visual codes for nonverbal information, such as a person’s face or a speeding car (Just & Carpenter, 2002).

Although adequate for most purposes, the phonological or visual codes that people use to record information in their working memory tend to be flawed. Some people, however, produce visual images with remarkable detail and near-perfect accuracy. When recalling an object or scene that they have just witnessed, these people almost seem to be looking at a photograph. Thus their detailed images are called eidetic memories, or photographic memories. Eidetic memories usually occur among children; as many as 5 percent of children encode images with this level of detail. The eidetic images can last for several minutes (Hochman, 2010, 2001).

When we encode nonverbal information into long-term memory, we once again tend to use phonological or visual codes. Similarly, we may use olfactory, gustatory, or tactile codes to help record smells, tastes, or physical sensations. Long after a concert, for example, audience members may remember its intensity by visualizing images of the stage and the lighting effects, re-experiencing the smells of the arena and the crowd, and calling to mind the sounds of the musical instruments, the performers’ voices, and the crowd’s cheers.

In contrast, to encode verbal information into long-term memory, people tend to use semantic codes, representations based on the meaning of information. Because we often rely on the meaning of information when transferring items into long-term memory, our later recall of events may be flawed to some degree. Many a family gathering has been spent sharing different versions of an important event—for example, the day Sarah received the news that she was accepted into medical school. Everyone at the gathering may remember the key elements of that special day, but the specific memories of each person—from the size and thickness of the envelope that bore the announcement to the wording of the announcement or the excited statements of various family members—may differ dramatically. Why? In part, because each member used semantic coding to record the important family happening into their long-term memory.

It is worth noting that the various codes may operate simultaneously when information is being encoded (Kessels & Postma, 2002). One of these codes—semantic, phonological, or visual—may be used more actively than the others in particular instances, but when we use multiple codes, the combined impact of the these codes increases the likelihood and strength of the memory.

Meaning and Encoding  Inasmuch as meaning often plays a key role in long-term memory, we should not be surprised that the more meaningful information is, the more readily it is encoded and later remembered. In one study, for example, people were asked to memorize 200 words of poetry, 200 nonsense syllables, and a 200-word prose passage (see Figure 8-5). The poetry took 10 minutes to learn and the prose less than 20 minutes, but the nonsense syllables took an hour and a half!

Similarly, the more meaningful a personal event, the more readily it is encoded and later remembered. Sarah’s acceptance into medical school was recognized by everyone in the family as a significant turning point in her life. Thus, Sarah, her parents, and her siblings all remembered the day of her acceptance. A lesser event, such as a day at the circus or a trip to a department store, might not be encoded as readily.

![What subway? Because people tend to use semantic codes (codes based on meaning) to record important events into long-term memory, everyone at this nontraditional wedding in Beijing may later remember the day’s events differently. A few may even leave out the fact that it took place on a subway platform!](image)

![FIGURE 8-5 Meaning matters in memory. Meaning helped people memorize poetry and prose much faster than nonsense syllables. (Based on Turkington & Harris, 2009, 2001)](image)
People can help ensure that less meaningful information proceeds into long-term memory by artificially adding meaning to it or by elaborating on the meaning of the information. Such efforts are known as mnemonic devices, cognitive techniques that impose additional or intensified meaning on various pieces of information (Cavallini et al., 2003). Throughout this book, we include relevant examples that we hope will make the information more applicable and more relevant and, in turn, make your memories more available.

**Tricks of the Trade**

Many a new music student has come to appreciate that the five lines of printed music of the treble clef are called E-G-B-D-F, by first tying those letters to the sentence “Every Good Boy Does Fine.” The first letter of each word in the sentence is the same as one of the lines of printed music. By giving more meaning to the musical language, the sentence helps the students to encode the information into their long-term memories.

One of the best ways to elaborate is by making the target information personally meaningful. For example, if you want to remember the difference between the spelling of the words dessert (a treat that follows a meal) and desert (a dry, hot, arid place), you might say to yourself, “I like something super sweet after dinner,” to remind you that the food item is spelled with a double s.

---

As we have seen, you can use mnemonic techniques—efforts at elaboration, or elaborative rehearsal, to impose meanings on seemingly unrelated pieces of information, such as the names of musical notes. Two other mnemonic techniques involve imagery, taking a mental picture of something meaningful to you and using information from the picture to increase your memory potential.

- **Key Word Method**
  This visualization method was developed by researcher Richard Atkinson (1975) for the learning of foreign-language words. A student trying to learn Spanish, for example, will think about an image that ties the Spanish word to an English key word that sounds similar to a portion of the foreign word. The Spanish word caballo, which means “horse,” sounds like eye in its middle syllable. So a student might imagine a horse kicking a giant eye. When confronted with the word caballo, the sound of the key word, eye, should cue the student to see the image in his or her mind and to retrieve the information that caballo means “horse.” In one experiment, students who were instructed to use this method of study scored an average of 88 percent correct on a test, while those who studied by repetition alone for the same duration scored only 28 percent correct (Pressley, Levin, & Delaney, 1982; Raugh & Atkinson, 1975). The method has also proven helpful in studying unfamiliar vocabulary within a student’s native language, such as medical terms (Troutt-Ervin, 1990).

- **Method of Loci**
  This method (loci is Latin for “places”) can help you remember information that must be recalled in a specific order, such as a list of words. First, imagine a place that you know well, such as your home. Visualize the layout of that place as you walk through it. At home, for example, you might imagine yourself walking through the front door, past a couch, toward a round table, then past a television set, and finally into the kitchen. Next, form a picture in your mind that connects each word or object to a location in the house. If the first word on a list to be remembered is cat, you might imagine a cat scratching at the front door, for example. Once you have tied the items on the list to these images and practiced them, you can mentally walk through the “place” and list the items one-by-one in the correct order.
Organization and Encoding

Another important variable that can enhance the encoding of information into long-term memory is organization. Actually, when people add to or elaborate on the meaning of certain pieces of information or events, they are organizing them. That is, they are giving the information a structure that is

In need of a schema This young patron seems confused about how things work at Round House Restaurant in Brno, Czech Republic. His previous restaurant schemas simply have not prepared him for the Round House’s unusual use of a model train to deliver food and drinks to its customers.
more familiar and available to them. As such, they are making it easier to encode into long-term memory. Typically, people do this intuitively. If we asked you to memorize a list of words that included FOX, BEAR, ITALY, ENGLAND, RABBIT, SPAIN, and MOUSE, you might naturally sort the words into rough categories of “Animals” and “European Countries.”

Organization by categories can be particularly useful in helping us to encode complicated situations. Cognitive psychologists have identified structures called schemas, bases of knowledge that we develop based on prior exposure to similar experiences or other bases of knowledge. Schemas can be helpful in allowing us to attend to and encode a lot of information in a hurry. Think about the first time you walked into a new restaurant. Did it feel awkward or strange because you weren’t sure of the rules or what to order? If you had visited other, similar restaurants before that one, the schemas you developed during your experiences at those restaurants probably helped you know what to do and what to order in the new restaurant with less effort than you would have needed if you had never been in a restaurant at all.

### Before You Go On

**What Do You Know?**

3. How does increased attention affect automatic and effortful processing?

4. Why is it more effective to study all term long, rather than in one massive session right before a final exam?

5. Which type of coding would most people use to remember someone’s face? Which type would most people use to remember a person’s name?

**What Do You Think?** As we noted earlier in the chapter, the author Samuel Johnson wrote, “The true art of memory is the art of attention.” Can you think of experiences from your own or others’ lives that bring this statement to life?

### How Do We Store Memories?

**LEARNING OBJECTIVE 3** Describe how we organize and store information in working and long-term memory and how we can enhance our long-term memories.

As you have seen, after entering the working memory system, information remains there for only a short period of time, sometimes only a matter of seconds. In contrast, when information moves on to the long-term memory system, it can remain there for hours or a lifetime. The retention of information—whether brief or long—in either of these memory systems is called **storage**.

### Storage in Working Memory

Information may enter working memory from two major sources. New information, as we have seen, can be encoded after a short trip through the sensory memory system. In addition, we can bring back into the working memory system information that previously has been encoded in the long-term memory system, for use in a current situation or task.

During the time that information from either of these sources is residing in the working memory system, it can, as we have seen, serve many important functions in our daily lives, from enabling us to read or carry on conversations to helping us solve current problems (Hofmann et al., 2011). The information stored in working memory also helps us do mental computations, such as mathematical problems (Maybery & Do,
We could not, for example, add together the numbers 12 plus 13 if our working memory were not reminding us that we are computing those particular numbers, that addition is the task at hand, and that 3 plus 2 equals 5 and 10 plus 10 equals 20. In fact, because working memory helps us do mental computations, it is often characterized as a “temporary notepad” that briefly holds intermediate information while we think and solve larger problems.

The Storage Limits of Working Memory Once information enters working memory, it can be stored for just a limited period of time (Courage et al., 2010). Concentrated efforts, such as rehearsal, can lengthen the availability of information in working memory, but eventually it is either passed on to the long-term memory system or lost (Jonides et al., 2008, 2003).

Just as striking as the limited duration of working memory is its limited capacity (Hofmann et al., 2011). On average, only five to nine items can be stored there at a given moment. This number was first uncovered in 1885 by the German researcher Hermann Ebbinghaus (1850–1909) who pioneered memory research by studying his own memory, and it was confirmed over 70 years later by psychologist George Miller (1956).

In a typical study of this phenomenon, researchers present people with a sequence of unrelated digits, letters, words, or the like, and then ask them to restate the items in the correct order. Because the items are unrelated and presented rapidly, it is likely that this procedure is tapping into working memory only, not into some related information that has been stored in long-term memory. In study after study, almost every adult can recall sequences that consist of five items, but very few can recall lists consisting of more than nine items. Each individual displays his or her own memory span—the maximum number of items that can be recalled in the correct order—but no memory span strays very far from seven. Because research shows that almost everyone has a working memory capacity in this range, Miller described it as the “magical number seven, plus or minus two.”

Enhancing Working Memory Actually, the storage capacity of working memory is not quite as limited as it may seem from the Ebbinghaus and Miller studies. Each of the seven or so items that working memory holds can consist of more than a single digit, letter, or word. An item can consist of a “chunk” of information. Chunking pieces of information together into larger units enables us to encode more information in our working memory system, and it also enables our working memory to store more information at a given moment.

Let us say that we are presented with a string of 23 letters, o-u-t-l-a-s-t-d-r-i-v-i-n-g-n-i-g-h-t-w-a-s-i. Because our capacity in working memory is only 7 ± 2 items, we would, on the face of it, be unable to store this entire sequence of items. If, however, we recognized that these letters can be chunked into words—“out,” “last,” “driving,” “night,” “was,” and “I”—our task changes. We now need to store only 6 items (that is, 6 words) in working memory, rather than 23, and the task becomes manageable. In fact, these words can be further chunked into one item: the sentence “Last night I was out driving.” If we store the information in this way, we still have room in our working memory for several other items. Similarly, without realizing it, we may be taking advantage of chunking when we first try to master a song’s lyrics. Rather than learn the song letter by letter or word by word, we may hold on to seven new lines at a time, repeating the lines again and again until we “nail” them.

Our ability to chunk actually comes from our long-term memory system (Cowan & Chen, 2009). Recall that information may enter working memory as either new information arriving from sensory memory or through retrieval from long-term memory. In chunking, we use our stored, long-term knowledge that certain letters spell certain words or that words can be organized to form sentences to guide us in chunking new information.

memory span maximum number of items that can be recalled in correct order.
chunking grouping bits of information together to enhance ability to hold that information in working memory.
Storage in Long-Term Memory

Whereas the sensory memory and working memory systems deal only with a limited number of short-term memories, our long-term memory system retains a seemingly unlimited number of pieces of information for an indefinite period of time, extending from minutes to a lifetime (Voss, 2009). Indeed, memory researcher Elizabeth Loftus has estimated that our long-term memory system may hold as many as one quadrillion separate pieces of information. This expansive capacity and duration is critical to our functioning, for it is in this vast memory store that we hold—ready for use—all of the information that we have ever gathered. When we remember previously gathered knowledge, past events and people, or acquired skills, we are using our long-term memory system.

Several factors influence whether particular events are stored in long-term memory. As we have observed, new information must first be attended to in order to have any chance of eventually winding up in this memory system. Furthermore, items that are attended to must be encoded and briefly stored in working memory and then encoded into long-term memory before they can be stored in this memory system (Baddeley, 2010). Any shortcomings in these attention and encoding activities may prevent the information from being stored in the long-term system (McGaugh, 2006, 2003). Moreover, even after information is successfully stored in long-term memory, some of it may become unavailable (Loftus & Loftus, 1980). That is, some of the information that we have previously acquired cannot be retrieved from long-term memory. Most of the research on long-term memory storage, including the loss of stored information, has been conducted in the biological realm, as we shall soon see.

We have observed that the number of items that can be stored in working memory is rather similar from person to person (7 ± 2). The capacity for long-term memory storage, while enormous for most of us, does, however, vary greatly among people.

What Types of Memories Do We Store in Long-Term Memory? Various kinds of information are stored in long-term memory, as shown in Figure 8-6. Explicit memories consist of the types of memories that you can consciously bring to mind, such as your mother’s birthday, or the movie discussed at the beginning of this chapter. But explicit memory memory that a person can consciously bring to mind, such as one’s date of birth.
there are other types of memories that we are not consciously aware of, such as learned reactions, learned motor behaviors, and perceptual information that help us to develop various skills. These implicit memories might include reacting with disgust when you are given a plate of food that made you sick sometime in the past—you might not recall the initial bad meal, but you remember to avoid the food.

**Remembering to Be Disgusted** In a series of studies, researchers Andrea Morales and Gavan Fitzsimons found not only that some products—trash bags, diapers, kitty litter, tampons—evoke a subconscious feeling of disgust, but they can also transfer their general ickiness to anything they come in contact with.

Where do feelings of disgust for certain products come from? In part from early life experiences with the products and perhaps, say the researchers, through evolution, from the negative experiences of our ancestors. Either way, the idea that negative qualities can be passed by a touch has become hardwired, says Fitzsimons. So he and Morales set out to see whether toilet paper and other products could psychologically contaminate food in a shopping basket. They used real shopping baskets and told shoppers that the study had to do only with product preference.

Strong preferences were just what the shoppers exhibited. Any food that touched something perceived to be disgusting became immediately less desirable itself, though all of the products were in their original wrapping. The appeal of the food fell even if the two products were merely close together; an inch seemed to be the critical distance. “It makes no sense if you think about it,” says Fitzsimons.

“We’d take cookies out of the basket and offer them to the subjects,” says Fitzsimons, “and we had some really tempting looking cookies.” No takers. Moreover, he says, “everything we did suggested that these feelings were below the level of awareness. If we told someone, ‘You didn’t take the cookie because it touched the kitty litter,’ they would say, ‘That’s ridiculous’” (Lemonick, 2007).

Neuroimaging studies of patients with brain damage suggest that these two kinds of information are stored in different brain regions (Mecklinger, Brunemann, & Kipp, 2011; Squire & Schacter, 2002). Explicit memories are converted into long-term...
memories in the hippocampus and then are stored permanently in various areas of the neocortex. (In a sense, the hippocampus serves as a temporary storage site within the long-term explicit memory system.) In contrast, the striatum, the region located toward the midline in the brain, plays a key role in the storage of implicit memories. As we observed in Chapters 4 and 7, when people need to call upon implicit memories to help them carry out various skills and habits, their striatum and its related structures become particularly active. In fact, an individual whose striatum is damaged by injury or disease may have great difficulty performing longtime skills and habits, yet retain most of his or her explicit memories.

To make things even a bit more complicated, there are two types of explicit memories: semantic memories, your general knowledge of the world, and episodic memories, knowledge of personal events or episodes from your own life. Some studies further hint that these two subgroups of explicit memories may, themselves, be stored in different ways from one another, but this possibility is far from certain (Christman & Propper, 2010; Markowitsch, Welzer, & Emmans, 2010).

How Are Long-Term Memories Organized? How does the long-term memory system organize the many pieces of information that are stored there? Is it set up like a bookstore in which the various items are organized first by broad categories, such as fiction and nonfiction, then by subcategories (in the case of nonfiction, for example, “art,” “health,” “nature,” “science,” or “travel”), and finally by sub-subcategories (for example, art books whose authors’ names begin with A, B, and so on). Despite years of study, we do not fully understand how pieces of information are organized when stored in long-term memory.

At the same time, psychologists do now know that, regardless of their precise organization, the pieces of information stored in long-term memory are indeed linked to each other, forming a network of interwoven associations. Thus, when we retrieve one piece of information from long-term memory, a related one will often spring forth, and that piece of information may, in turn, trigger another one. This web of associations enables us to travel rapidly through our long-term memory to retrieve much of the information we need for a current situation or task. As we saw earlier, the PDP, or connectionist, model of memory helps explain such networks by suggesting that our neurons also are activated in networks.

semantic memory  a person’s memory of general knowledge of the world.
episodic memory  a person’s memory of personal events or episodes from his or her life.
How Do We Retrieve Memories?

LEARNING OBJECTIVE 4 Describe how we retrieve information from memory and how retrieval cues, priming, context, and emotion can affect retrieval.

As we have noted, when information is successfully encoded from working memory into long-term memory, it is not only stored there, but is available for retrieval later. When we retrieve information from our long-term memory, it moves to the front and center of our thinking and becomes available once again for use in our working memory system. Upon its return to working memory, the retrieved information may be used to help clarify current issues, solve new problems, or simply re-experience past events (Baddeley, 2010; Hambrick & Engle, 2003). Retrieved memories of past political readings and experiences may, for example, enable us to push the right lever in a voting booth. Similarly, retrieved memories of learned math tables help us calculate new mathematical problems, and retrieved memories of how to drive guide us to park our cars in tight spaces. The kind or amount of information stored in long-term memory would mean little if we were unable to retrieve it. Like a library or the Internet, the information in long-term memory must be navigated efficiently and accurately in order to produce needed information.

Just as researchers do not fully understand how information is organized when stored in long-term memory, they do not know for sure how retrieval is carried out.
Some theorists propose that it is a kind of “search” process (Raaijmakers & Shiffrin, 2002, 1992). In other words, the person focuses on a specific question and scans his or her memory for the specific answer to that question. Other theorists believe that retrieval is more like an “activation” process in which the questions people pose to themselves activate relevant pieces of information that have been stored in long-term memory, after which this activation then spreads simultaneously to every other associated piece of information. The difference between these two operations is like the difference between the specific results you get on a Wikipedia search versus the hundreds of results you get from a Google search.

If we fail to locate a particular book in a library or bookstore, it can mean either that the book is not there or that we are looking for it in the wrong section. Similarly, our failure to locate a piece of information in our long-term memory may mean that it is not stored there (encoding failure or storage loss) or that we have committed a retrieval failure of some kind.

We experience many retrieval failures in our daily travels. Often we find ourselves unable to recall a face, an event, or a scheduled appointment, yet it comes to mind later. Obviously the information was available in our memory all along, or we would not recall it later. Similarly, all of us have experienced the frustration of being unable to recall the answer to an exam question, only to remember it soon after the test. And in some instances we may become particularly frustrated when a piece of information feels right at the edge of our consciousness, an experience called the tip-of-the-tongue phenomenon.

The retrieval of information from memory is aided by retrieval cues—words, sights, or other stimuli that remind us of the information that we need. Essentially, when we come across a retrieval cue, we enter our long-term memory system and activate a relevant piece of information. Because the pieces of information in this memory system are linked to each other in a network of associations, the activation of the first piece of information will trigger the activation of related pieces until a complete memory comes forth.

### Priming and Retrieval

If the pieces of information stored in long-term memory are indeed linked together in a network of associations, then the key to retrieving a specific memory is to locate one piece of information and follow associated pieces until arriving at the memory. This activation of one piece of information, which then triggers the activation of other pieces and leads to the retrieval of a specific memory, is called **priming** (Was, 2010; Schacter, 1999).
Ramponi et al., 2007). Sometimes we consciously try to prime a memory. If, for example, we are having trouble remembering the name of a woman whom we met last week, we may bring the letter M to mind, recalling vaguely that her name began with that letter and hoping that the M sound will lead to her name. Or we may try to recall our conversation with the nameless acquaintance, hoping that this recollection will eventually lead us back to her name.

Priming may also take place without our conscious awareness. Say you are in a store and you vaguely notice the classic jazz standard *Summertime* playing on the store’s sound system. If you were to walk out of the store and a friend were to ask you what song had just been playing on the store’s speaker, you might not be able to recall it. However, if a short while later, in an unlikely turn of events, a quiz show host were to pop up and ask you to name three classic jazz songs for $500, research suggests that you would be particularly likely to include *Summertime* in your answer. Although you had no choice in the matter and were not even aware that it was happening—and even if you dislike jazz and were trying to ignore the song while in the store—it would have served as a retrieval cue and primed you to recall *Summertime* when later quizzed about jazz hits.

Given the operation of priming, we should not be surprised that the more retrieval cues we encounter, or the more informative they are, the better our retrieval of memory. This is why people perform better on recognition tasks, ones in which they must report whether or not they have seen a particular item before, than on recall tasks, those in which they are forced to produce memories using no or few retrieval cues (Figure 8-7) (Wixted & Squire, 2010; Tulving, 1974).

**Memory-Friendly** If you are asked to name everyone who was enrolled in your tenth-grade history class—a recall task—you will probably be able to remember some of the individuals, but far from all of them. If, on the other hand, you are shown pictures one-by-one from your high school yearbook and asked to point to, identify, and name those individuals who were in your history class—a recognition task—you probably will perform better. The reason? The latter task offers more retrieval cues. Not surprisingly, students usually perform better on multiple-choice exams, which are recognition tasks, than on essay or short-answer exams, which are recall tasks.

### Context and Retrieval

It is often easier to retrieve particular information when we return to the setting or situation in which we first encoded it. Most of us have had personal experiences that attest to this. Upon returning to our old home or school, for example, we may find ourselves almost overrun by memories of events that we have not thought about for years. Similarly, a return to the scene of an argument or romantic encounter may bring forth detailed memories of the original event. Not surprisingly, then, some educators believe that people perform best on exams when the exams are administered in the same rooms where the material was taught.

Clearly, returning to or duplicating the context in which information was learned may help us to retrieve it (Postle, 2009, 2003). Why? Once again, the answer appears to be retrieval cues. The original context—the location or situation in which we learn material—is loaded with retrieval cues, each of which activates a piece of information, setting off the activation of related pieces and leading to memories of the original event. The likely impact of these many retrieval cues is an increase in the number, intensity, and accuracy of relevant memories.
How Do We Retrieve Memories?

Emotion: A Special Retrieval Cue

Just as a letter, word, song, or setting may serve as a retrieval cue and lead to specific memories, so may an emotional state, or mood. If people learn something while in a particular state of mind, they may recall it more readily when they are in that state again. Gordon Bower was one of the first psychologists to recognize this phenomenon, called state-dependent memory (Bower, 2008, 1981; Forgas, 2008). In one study, he had people learn a list of words while they were in a hypnotically induced happy state of mind. He found that they remembered the words better if they were in a happy mood when tested later than if they were in a sad mood. Conversely, those who learned the words when in a sad mood recalled them better if they were sad during later testing than if they were happy. Apparently, a feeling can serve as a cue for retrieving information that was encoded while experiencing that feeling.

Some theorists further believe that a person’s emotions may be more than just another retrieval cue (Rolls, 2011; McGaugh, 2003). As we shall see in the following sections, they suggest that strong emotions may enhance memories by leading to increased rehearsal, elaboration, and organization of a particular event, or that intense emotions may trigger a special memory mechanism, producing emotional memories.

Emotional Memory: Rehearsal, Elaboration, and Organization

If an event makes us particularly happy, or for that matter, very upset, we will probably think about it again and again. We are likely to talk about highly emotional events with relatives, perhaps text friends, maybe write about the events in a personal journal, or even try to revisit the scene. Such behaviors are commonly displayed by people who have achieved a special personal accomplishment, observers of exciting sporting events, or victims of accidents, hurricanes, or other catastrophes. Together, responses of this kind amount to repeated rehearsals, elaborations, and organization of the emotionally-charged events. Think back to Sarah’s medical school acceptance. Talking about the day with her relatives not only helped Sarah repeat the event, but probably also helped her link it to other important events in the family and to organize her recall of the event, perhaps chronologically from the moment the acceptance letter arrived until the moment she read it. We have seen already that rehearsal, elaboration, and organization all are ways to improve the encoding and storage of memories; thus, we should not be surprised that exciting or upsetting events tend to be retrieved more readily than ordinary ones (McGaugh, 2006, 2003).
Special Emotional Memory Mechanisms: Flashbulb Memories

If we were asked where we were at 9:00 A.M. a few Tuesdays back, what we were doing, and who we were talking to, few of us would be able to answer off the top of our heads. Yet, if we were asked the same questions about our whereabouts on September 11, 2001, at 9:00 A.M., the fateful hour when two planes crashed into and brought down the twin towers of the World Trade Center, many of us could state with apparent accuracy and great confidence these and other details (Denver, Lane, & Cherry, 2010). Such detailed and near-permanent memories of emotionally significant events, or of the circumstances surrounding our learning of the events, are called flashbulb memories. Beyond widely shared events, such as the 9/11 attacks, people also have flashbulb memories of emotional events that have more personal significance, such as the birth or death of a loved one.

The kinds of details retained in flashbulb memories seem unavailable to us in our memories of other events (Edery-Halpern & Nachson, 2004). What is it about these special events that enables us to retrieve such details? According to some theorists, it is the extraordinary level of emotionality that we experience during the event. Specifically, our intense emotions may help trigger a special memory mechanism—a mechanism above and beyond the usual memory processes—that produces a near-permanent record and more likely retrieval of nearly everything we experienced during the event (McGaugh, 2006, 2003).

Psychologists have yet to fully identify this proposed memory mechanism, but certain studies do support the notion that emotionally-charged memories involve mechanisms beyond those operating for more neutral memories (LeDoux & Doyère, 2011; Kensinger & Corkin, 2003). In one study, for example, some participants were given a tranquilizer drug while hearing an emotional story about a boy who received emergency surgery, whereas other participants were given a placebo drug during the same story (Cahill et al., 1994). One week later, the participants who had been tranquilized—and due to the tranquilizer, had experienced little emotionality during the intense story—remembered less about the story than did the placebo participants, whose emotions had been allowed to rise during the story. In contrast, when the study’s participants were asked to recall a more neutral story, participants from both groups showed equal accuracy in their later recollections (Figure 8-8).

On the other hand, some recent research has called into question whether flashbulb memories are, in fact, as highly accurate as previously believed. One study, for example, compared undergraduates’ memories of the 9/11 attacks with their memories of everyday events (Talarico & Rubin, 2009, 2007, 2003). Although the participants in the study reported a high level of confidence in the accuracy of their 9/11 memories, the data indicated that, in fact, such memories were no more accurate than those of more neutral events.
Why Do We Forget and Misremember?

LEARNING OBJECTIVE 5 Summarize key theories of why we forget information and sometimes distort or manufacture memories.

Throughout most of this chapter, we have considered which variables help us to accurately remember events and information. But as you well know, people do not always remember things as well as they would like (Tsukiura et al., 2011). The elusive name, the missed meeting, and the overlooked birthday of a friend or relative are all instances of **forgetting**—the inability to recall information that was previously encoded. Sometimes we not only forget information, we distort or manufacture memories. We recall events differently from the way in which they occurred or we remember things that never occurred at all.

**Theories of Forgetting**

As we have observed, some apparent losses of memory are not really instances of forgetting at all, but rather failures of attention. If our mind is elsewhere when we are putting down our set of keys or our treasured remote control, we simply cannot encode such acts. Correspondingly, the location of such items will not be stored in memory and available for later retrieval. At the other end of the spectrum, some material is indeed stored and available, but has weak or few retrieval cues attached to it, making it difficult for people to activate—or prime—the relevant memories from storage.

Beyond these common causes of forgetting, theorists have uncovered a number of variables that may actively interfere with memory and, in turn, produce forgetting (Macleod, Saunders, & Chalmers, 2010; Wixted, 2010, 2004). Each of today’s leading explanations of forgetting has received some research support, but as you will see, each also has key limitations and raises important questions.

**Decay** As we observed earlier, German researcher Hermann Ebbinghaus pioneered the study of forgetting over a century ago by systematically testing his own memory of lists of syllables (for example, *lin, wee, sul*). After rehearsing and mastering a particular list, Ebbinghaus would measure how well he had retained the syllables after various intervals of time: twenty minutes, two days, a month later, and so on. He found that there was a huge drop in his memory of a list soon after learning it. However, the amount that he forgot eventually leveled off; in fact, most of the information that had been retained ten hours after first memorizing a list remained in his memory three weeks later. Known as the “**forgetting curve**” (see **Figure 8-9**), this pattern of rapid memory...
**decay theory**  theory of forgetting, suggesting memories fade over time due to neglect or failure to access over long period of time.

**interference theory**  theory that forgetting is influenced by what happens to people before or after they take information in.

**proactive interference**  competing information that is learned before the forgotten material, preventing its subsequent recall.

**retroactive interference**  learning of new information that disrupts access to previously recalled information.

loss followed by a stable retention of the remaining information has been supported again and again by research (Erdelyi, 2010).

Many theorists explain patterns of forgetting, such as that observed by Ebbinghaus, by pointing to decay. According to the decay theory, memories often fade away on their own simply because they are neglected or not used for a long period of time (Wixted, 2010, 2004; McGaugh, 2006, 2003). This theory is built on the notion that memories leave a physical trace in the brain—a so-called memory trace—when they are acquired. Theoretically, these traces fade away over time if the person does not use them.

Decay theory is not as popular an explanation for forgetting as it once was. It cannot account for the repeated finding that people learn seemingly forgotten information or skills much more rapidly the second time around than the first time. In other words, relearning is faster than initial learning. If forgotten information has, in fact, worn away because of lack of use—that is, if memory traces have been lost—relearning should be occurring from scratch, and it should take just as long as the initial learning did.

**Interference**  According to the interference theory, forgetting is affected mainly by what happens to people before or after they learn information. This theory holds that information will be retained in memory as long as competing, similar information does not interfere with it (Tillman, Peretz, & Samson, 2011; Wixted, 2010, 2004). Suppose your friend moves to a new house and receives a new landline phone number in which the first three digits are the same as the old number. Perhaps when dialing the new number, you find yourself mistakenly dialing her old number. According to the interference theory, the new landline number was forgotten because competing information—the old number—interfered with its retrieval.

When the competing information that prevents recall has been learned before the forgotten item, as in the case of the forgotten phone number, the process is called proactive interference. Alternatively, retroactive interference occurs when new information prevents the retrieval of previously learned information (see Figure 8-10). Suppose, for example, you wish to call your friend’s old number—perhaps to reach her mother who is still living at the old location—but you mistakenly dial the new number. In this scenario, you forgot the old number because competing information—the new number—interfered with its retrieval.

Can you spell “anxiety”? Two children each await their turn at the annual Scripps National Spelling Bee. Both are fully prepared, but their emotional states are another story. Who is likely to perform better?
Why Do We Forget and Misremember?

We should keep in mind that old information does not always interfere with the learning or remembering of new information. Sometimes it can even help us learn and hold on to new information. People who know how to roller skate often pick up ice skating faster than other people. Speakers of Spanish may have an easier time learning to speak Portuguese. Interference occurs only when old and new information conflict with one another.

We have observed how emotions—both positive and negative—often improve memory by either providing powerful retrieval cues, setting up additional rounds of rehearsal, or triggering special memory mechanisms. At the same time, all of us have had experiences in which negative emotions, such as anxiety, actually interfere with memory and cause us to forget (Hawley, Grissom, & Dohanich, 2011; Eysenck, 2010, McGaugh, 2006, 2003).

Messing with Memory Many students experience severe test anxiety. They may prepare fully for an examination, retain all of the necessary information, and score high on practice tests. Yet, on the day of the examination, they experience feelings of anxiety that grow from butterflies in their stomach to a persistent fear that they will "not do well on the exam . . . not pass the course . . . perhaps not even complete college." Their anxiety grows so out of control as the test sits in front of them that they are unable to retrieve many of the answers that had been so available to them during practice exams the evening before. Many counselors who work with such individuals suggest that the negative thoughts accompanying their anxiety (for example, "I will not pass this course") interfere with the retrieval of memories and cause the students to forget.

Motivated Forgetting Sometimes we seem to almost purposely forget information that is unpleasant, embarrassing, or painful (Erdelyi, 2010; Mather, 2009; Kennedy, Mather, & Carstensen, 2004). Suppose, for example, that during your freshman year, you completely bungle a conversation with a classmate on whom you have a crush. Humiliated, you give up all hopes of pursuing the relationship, and by the end of the semester, the two of you are hardly acknowledging each other. Fast-forward three years. By now, you have become much smoother, and, as it turns out, you and your former crush meet again at a graduation party. As the two of you laugh together, talk comfortably, and discover shared tastes, you wonder aloud how it is that you never got together during your four years at college. Taken aback by your comment, your new friend recalls for you the freshman year bungling incident. You are shocked by this
distortion. On reflection, you recall vaguely that a discussion took place three years ago, but, for the life of you, you have no recollection of the stammering, falling, and other embarrassing moves you made. In fact, you do not even recall having been all that interested in this person in the first place.

Clearly, you have forgotten an incident and related information that was unpleasant. But why? One possibility is that because the event was so painful, you actively worked to forget it. You avoided opportunities for rehearsal, such as discussing the terrible experience with relatives or friends, sending a tweet about it, or writing about it in your personal journal. You may have even avoided retrieval cues, such as the walkway where the catastrophic interaction occurred. In short, you avoided rehearsing, elaborating, or organizing the information, making it less available for later retrieval from memory.

Of course, anyone who has actively tried to forget an upsetting event knows that this is not so easy to do. Even if we do not share the event with others, we often find ourselves thinking about it (that is, privately rehearsing it) again and again. Moreover, like a flashbulb memory, the special emotional component of such an event often increases, rather than decreases, the likelihood of our remembering it (Payne & Corrigan, 2007).

How then might we manage to forget certain unpleasant events or information? The leading explanation of such motivated forgetting is Sigmund Freud’s theory of repression. Freud held that all people employ repression on occasion, a process in which we unconsciously prevent some traumatic events from entering our awareness, so that we do not have to experience the anxiety or blows to our self-concept that the memories would bring. According to Freud, the repressed material is not lost, but rather hidden from consciousness. He believed that our experiences, especially childhood experiences, are too rich and powerful to slip away altogether. In fact, the hidden material may influence later decisions or behaviors, although we are not aware of its impact in such cases. In short, the repressed information takes on the form of an implicit memory.

According to Freud, repressed memories may be jogged and brought forth under certain circumstances. Indeed, as we saw in Chapter 1, a key feature of psychoanalytic therapy, the treatment approach first developed by Freud, is to help clients rediscover their repressed memories of past traumas and, in turn, open the door to more effective functioning. Despite the wide influence of this theory and of psychoanalytic therapy, it is important to recognize that research has failed to demonstrate consistently that people repress unpleasant events (Erdelyi, 2010; Kihlström, 2006).

Distorted or Manufactured Memories

Our memories can be subject to distortions. In large part, this is because, as we observed earlier, we tend to rely on semantic codes when we encode information into long-term memory. That is, we encode the meaning of an event, rather than its specific words or images. In turn, when we later retrieve the memory, we have to reconstruct it. We must fill in details from our earlier recollection. Thus, when five persons later try to remember the same event—for example, when Sarah and her family members recall her acceptance into medical school—they may each recall the details of the event quite differently.

A number of factors may contribute to faulty reconstructions of memory—that is, to the distortion or manufacture of memories (Erdelyi, 2010). Three of the most common are source misattributions, exposure to misinformation, and the effects of imagination (Table 8-1).

Source Misattributions When we encode and store information in long-term memory, we often forget or are confused about where it came from originally.
Dubious Source  Years ago, millions of viewers watched a popular television game show named To Tell the Truth each evening. On this show, three persons would claim to be an individual who was famous for a particular skill or accomplishment, for example, a famous dog trainer. Only one of the three was, in fact, the real expert; the other two were imposters. A celebrity panel would fire questions at the three individuals. They might ask questions about dogs, dog instincts, effective training techniques, and the like. Then, on the basis of the answers, they would try to decide who the real expert was. Finally, the expert would stand up and identify himself or herself.

During the questioning period, television viewers were exposed to a good deal of information. In the case of a famous dog trainer, for example, viewers would hear answers about which breeds are easier to train, which training techniques are most effective, how long training typically takes, and so on. The problem was that only one-third of this information was necessarily accurate. Only the actual trainer was “sworn to tell the truth.” The two impostors were making up answers. Later, it was often impossible for viewers to remember whether a particular piece of information came from the expert (and was therefore accurate) or from one of the impostors (and was inaccurate). Unable to remember that the information came from a dubious source, many viewers carried away from each program false information, which they continued to believe for months or years.

Source misattributions can produce memories that are distorted, or in some cases, manufactured (Lindsay et al., 2004). Is our detailed recollection of getting lost at the mall when we were 6 years old a direct memory of that event? Or, are we actually remembering our parents’ many stories about the event? Or are we confusing our own life with that of one of the kids in the 1999 cult TV series Freaks and Geeks? We may have supreme confidence in our memory of the event and even “remember” vivid details about it, yet the memory may be inaccurate or even entirely false. We are remembering something, but it may not be the event itself.

Exposure to Misinformation  Earlier we noted that retroactive interference often causes us to forget something when we are later exposed to new competing information. For example, an old phone number may be lost from memory when a fairly similar, new phone number is mastered. Similarly, exposure to new information, particularly misinformation, can lead to the distortion or the manufacture of memories (Wixted, 2010, 2004).

Consider a situation in which a man witnesses a robbery. If a week later the eyewitness is asked, “Could you please describe the robber,” he is being called upon to rely exclusively on his memory for a description. If, however, the eyewitness is told in passing, as part of the questioning process, “We’ve had a number of sim

<table>
<thead>
<tr>
<th>TABLE 8-1  Common Reasons Why We Distort or Manufacture Memories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source misattribution</td>
</tr>
<tr>
<td>Exposure to misinformation</td>
</tr>
<tr>
<td>Effects of imagination</td>
</tr>
</tbody>
</table>

source misattribution  remembering information, but not the source it came from; can lead to remembering as true information from unreliable sources.

Why Do We Forget and Misremember?  293
lar robberies lately, involving a heavy, blond-haired guy with a beard,” this new information may greatly influence the witness’s recall of the robber and the robbery. Such exposures to new information—often misinformation—are of great concern in police cases. Many a defendant has been accused or even convicted of a crime based on testimony from witnesses whose memories were unintentionally distorted or manufactured (Devenport et al., 2009; Wells & Loftus, 2003). (See “Your Brain and Behavior: Giving Eyewitness Testimony” at the end of this section.)

The impact of misinformation on memory has received considerable study in psychology laboratories. How do researchers “plant” misinformation in memory studies? A clever investigation by psychologist Elizabeth Loftus and her colleagues (1978) illustrates how this is done. Participants in her study observed a film of a traffic accident and were then asked to remember certain details of the accident. One group of participants was asked, “How fast were the cars going when they smashed into each other?” A second group was asked, “How fast were the cars going when they hit each other?” The experimenter’s use of the word smash implies a very severe accident, whereas the word hit implies a milder accident. Not surprisingly, people who heard smash remembered the cars going at a faster speed than did those who heard hit. The researchers also asked, “Did you see any broken glass?” Those who heard smash were much more likely to say yes than those who heard hit. In fact, there had been no broken glass in the film.

Study after study has demonstrated the distorting effects of misinformation on memory. In each, participants first observe an event and later receive from experimenters new, misleading information about the event (Zhu et al., 2010; Loftus, 2005). A short while after observing an uneventful interaction between two spouses, for example, participants in a study may be told, in passing, that one of the spouses is a rather hostile person, or passionate, or devious. Sure enough, in their later recollections of the observed interaction, many participants “remember” hostile, passionate, or devious acts by the spouse in question. Similarly, people have been misled by subsequent exposures to misinformation, to “remember” objects—glasses, paintings, revolvers—that were not actually present in an observed event.

A particularly powerful way of being exposed to misinformation is through hypnosis. As we first saw in Chapter 6, people who are hypnotized enter a sleeplike state in which they become very suggestible. While in this state, they can be led to behave, perceive, and think in ways that would ordinarily seem impossible. They may, for example, become temporarily blind, deaf, or insensitive to pain. Hypnosis can also help people remember events that occurred and were forgotten years ago, a capability used by many psychotherapists. On the other hand, in recent years, it has come to the attention of researchers that hypnosis can also make people forget, distort, or manufacture memories by supplying misinformation (Erdelyi, 2010; Mazzoni, Heap, & Scoboria, 2010; Barnier et al., 2004). Witnesses who are hypnotized to help them remember an observed crime are, in fact, likely to remember details offered or implied by the hypnotist. These details, such as the time of the crime, the clothes worn by the perpetrator, or the presence of a weapon, may be inconsistent with their actual observations. For this reason, police hypnotists must be very careful when questioning witnesses. Even so, state courts across the United States no longer admit as evidence eyewitness recollections that have been gathered initially under hypnosis.
The Effect of Imagination  It turns out that our memories can be distorted not only by misinformation supplied by others, but also by false information that comes from within, from our imaginations. Researchers have found repeatedly that when people are instructed to imagine the occurrence of certain events, many come to believe that they have in fact experienced the events (Richardson, 2011; Thomas et al., 2007).

In one study, a team of researchers asked the parents of college students to list events that had, in fact, occurred during the students’ childhoods (Hyman & Kleinknecht, 1999). In later interviews, the students themselves were instructed to recall those real events, along with another event, one that had not actually occurred according to the parents’ reports. The students were not told that this event was false. A student might, for example, be instructed to recall the false event of accidentally knocking over a table at a wedding, as well as a number of events that actually had occurred. When interviewed some days later, about one-fourth of the students fully believed that the false events had occurred during their childhood, and, in fact, they could “remember” many details of the unfortunate experiences. Clearly, misinformation from others or from our own imaginations, or from a combination of the two, can greatly influence our recollections, leading at times to forgetting, distortions, or even the manufacture of memories.

Before You Go On

What Do You Know?

11. How does the decay theory explain forgetting?

12. What is repression?

13. A late night TV comedy show host suggests that members of one political party have better sex lives than members of the others. Although this person is obviously unqualified to know, your friends have started to tell you it’s proven that members of this party have more fun, so they’re thinking of switching parties. What might be happening to your friends’ memories?

14. The saying, “Elementary, my dear Watson,” did not appear in any of the writings of Sir Arthur Conan Doyle, the author of the Sherlock Holmes series, yet millions of fans vividly remember reading these words. What processes can explain this manufactured memory?

What Do You Think?  What examples of proactive and retroactive interference or memory distortions have you experienced in your own life?
Giving Eyewitness Testimony

Imagine you have witnessed a car accident where someone was injured. You dialed 911 and stayed at the scene to tell the police officer what happened. A few months later, you were called to testify as an eyewitness at the trial. How accurate do you think your memory would be?

When people give eyewitness testimony, many regions of their brains are involved, including the hippocampus, amygdala, prefrontal cortex, visual cortex, thalamus, and mamillary bodies, among others. Let’s see how several of these regions are involved in such eyewitness testimony.

DISTORTING THE MEMORY

Memories are often susceptible to distortions when they are recalled. Wrong information can be incorporated into an eyewitness’s memory if leading questions are asked or if circumstances surrounding the inquiry are particularly frightening.
RECALLING THE EVENT
Eyewitness retrieval and recall of the observed event depends largely on neuron activity in the cerebral cortex, shown here in this image of a fluorescent pyramidal neuron. In addition, protein synthesis in the pyramidal neurons of the prefrontal cortex enables memories to be stored again after they have been used.

RETRIEVING AN INCORRECT MEMORY
Different parts of the visual cortex are activated when eyewitnesses remember an observed event accurately versus when they remember it inaccurately. Association parts of the visual cortex are at work in both true and false memories (orange areas on the left brain scan) whereas only true memories activate the primary visual cortex (orange areas on the right).

STORING THE MEMORY
A major role in the formation and storage of memories about the observed event is played by the hippocampus, shown here in this image of neurons genetically engineered to make fluorescent dyes. The synapses in this brain region are changed by experience and are activated when we remember.
LEARNING OBJECTIVE 6 Describe how the brain is involved in memory.

Much of what we know about the biology of memory has come from studies of people who have suffered injuries to specific locations of the brain (Matthews, 2011). Important information has also been gained through experiments in which researchers surgically or chemically change the brains of animals and then observe the effects on old memories and new learning (Schwarting, 2003). In addition, over the past decade, studies using brain scans have enabled investigators to observe brain activity and structure at the very moment that people are thinking and remembering (Matthews, 2011). Finally, molecular biology studies have shed light on specific changes that may occur in our brain cells as memories form (Sweatt, 2010).

What Is the Anatomy of Memory?

Memories are difficult to locate. Recall from Chapter 4 that back in the 1920s, neurological researcher Karl Lashley undertook a series of experiments with rats, in search of the specific places in the brain where memories are stored (Lashley, 1948). He would train a rat to run through a maze, then cut out a snippet of its brain tissue and set the rat loose in the maze again, checking to see whether it still remembered how to navigate through the maze. Lashley operated on many, many rats, cutting out different sections of brain tissue for each one. He found that all rats retained at least some memory of the maze, no matter what part of the brain he removed.

Based on studies such as this, researchers have concluded that there is no single place—no storehouse—in the brain where memories reside (Dudai, 2011), that information in the brain is encoded across various neurons throughout the brain. As we have seen, for example, connectionist theorists see memory as a process rather than a place, an activity that involves changes in networks of multiple neurons throughout the brain. When such networking is activated, a memory is triggered and comes forth. This conclusion that there is no single place in the brain where memories reside is similar to the Chapter 7 conclusion that a single learning center in the brain does not exist. Indeed, because memory and learning go hand in hand, you’ll see that several of the brain structures and activities that were discussed in Chapter 7 to account for learning are pointed to again here as we examine the neuroscience of memory.

Although today’s theorists believe that neurons located throughout the brain are involved in memory, research has clarified that some brain areas are particularly important in the formation and retrieval of memories. Among the most important structures in working memory, for example, is the prefrontal cortex, a key structure within the neocortex that is located just behind the forehead (Öztekin et al., 2009; Wang, 2005). When animals or humans acquire new information, the prefrontal cortex becomes more active (Chein, Moore, & Conway, 2011). Apparently this activity enables them to hold information temporarily and to continue working with the information as long as it is needed. To refer back to our analogy between the brain and a computer, the neurons in the prefrontal cortex seem to operate like a computer’s random access memory (RAM), drawing information from various parts of the brain and holding it temporarily for use in a task, yet able to switch whenever necessary to other information and tasks.

Among the most important structures in long-term memory are the hippocampus (see Figure 8-11) and other parts of the neocortex (Tsukiura et al., 2011). In our earlier discussion of explicit memories, we noted that the hippocampus converts such memories into long-term status, stores the memories temporarily and then sends them on to various areas of the neocortex for genuine long-term storage. As we saw in Chapter 4,
destruction of the hippocampus in adulthood does not wipe out all long-term memories, only those that occurred just prior to the brain damage (Jeneson et al., 2010; Wixted & Squire, 2010). In contrast, destruction of certain parts of the neocortex results in the loss of older memories. These findings suggest that the hippocampus is indeed an important temporary storage site for long-term memories and a key player in the transfer of such memories into genuine long-term status in the neocortex.

What Is the Biochemistry of Memory?

As we have discussed, the PDP, or connectionist, model of memory describes the storage of information in long-term memory as a network of associations (McClelland, 2011). When we activate one piece of information, related ones spring into action, enabling us to travel through our long-term memory system rapidly and retrieve particular memories. But how, in fact, does the brain manage to link such pieces of information to each other? Research increasingly points to biochemical and electrical changes in certain neurons, particularly those neurons located in the key brain regions that we have just noted.

Neural Circuits As we observed in Chapter 4, communication throughout the brain proceeds from neuron to neuron in a particular way. A given message arrives at a neuron as an impulse, travels down the axon of the neuron, and is then carried by a chemical—a neurotransmitter—across the synaptic space to another neuron. The next neuron is then triggered and, like the preceding neuron, passes along a message to yet another neuron, and so on. When we talk about certain pieces of information being closely linked to other pieces of information in the long-term memory system, we are really saying that certain neurons in the brain become predisposed to trigger other neurons.

The question for memory researchers is how such neural circuits form (Changeux, 2011). How is it that some neurons become predisposed to trigger other neurons, enabling us to retrieve a given memory? It appears that the repeated stimulation of certain neurons greatly increases the likelihood that these neurons will respond—and respond strongly—to future stimulation of the same kind, a phenomenon called long-term potentiation (LTP) (Wixted, 2006, 2004). The effects of LTP can last quite a long time (hence the name long-term potentiation), long enough to be a key factor in the formation and retrieval of memories. Think of many sleds ridden one after another down a snowy slope, creating a groove that later sledgers can easily find. LTP seems to create a kind of groove that helps memories form, so a person can more easily retrieve a memory later by following the well-worn path.

You already know from Chapter 7 that LTP plays a role in learning. Researchers have gathered considerable evidence that it also plays a role in long-term memory. If experimental animals are given substances known to block the development of LTP, they have difficulty transferring information from their working memory into their long-term memory (Glaser et al., 2010; Sanberg et al., 2006; Lynch et al., 1991). Conversely, drugs that increase the development of LTP seem to improve the acquisition of long-term memories. In one study, for example, rats that were given an LTP-enhancing drug learned and remembered a maze better than rats that were not given the drug.

Many of the neurons and neural circuits that use glutamate as their neurotransmitter are particularly likely to exhibit LTP. Correspondingly, glutamate is a key neurotransmitter in the formation of memories, as you shall soon see. Moreover, neurons that display LTP are commonly located in the hippocampus and neocortex, brain regions that play such important roles in the formation of long-term memories, as we have just observed (Glaser et al., 2010; Thompson, 2000).

Proteins Still other memory researchers have tried to identify biochemical changes that occur within neurons as memories are forming (Matthews, 2011; Sweatt, 2010; long-term potentiation (LTP) repeated stimulation of certain nerve cells in the brain greatly increases the likelihood that the cells will respond strongly to future stimulation. Memory isn’t like reading a book; it’s more like writing a book from fragmentary notes.” —John Kihlström, psychologist
Rosenzweig, 1996). When neurons receive neurotransmitters at their receptor sites, chemical changes immediately begin to occur within the neurons, including the manufacture of proteins (Fioravante & Byrne, 2011). Proteins are believed to help memories form. Although researchers have yet to identify all of the proteins involved in memory formation, they have found that disruptions in the production of proteins often interfere with the proper encoding, storage, or retrieval of memories (Chen et al., 2010)

All of these findings suggest that memory occurs as a result of changes both within and among neurons. Clearly, although no one has yet discovered all of the biological changes that account for memory, researchers are shedding more and more light on how the brain manages to provide this critical faculty.

**Memories in the Young and Old**

**LEARNING OBJECTIVE 7** Describe the kinds of memories and memory changes that characterize early life and later life.

As you have seen in previous chapters, the brains of infants and young children seem to soak up information like sponges. Indeed, from the word go, the very young begin acquiring information, learn vocabularies and motor skills, and so on. Such learning tasks all require the use of memory of one kind or another.

Young babies can remember what certain objects look like (even if they don’t know what they are) and can discriminate between a new object and a familiar one. Researchers assess this type of memory by measuring the amount of time a baby spends looking at an object. Babies prefer to look at, and so focus longer on, objects that they haven’t seen before. This task, called *preferential looking*, is a useful way to study memory in babies who are too young to speak or to perform complex motor tasks that might otherwise reveal what they remember. Based on such research, we now know that the ability to remember objects increases from several minutes in the very young infant to several days in the toddler.

As babies gain control over their movements, they become able to learn new skills—skills that also require memory, although a different kind of memory. Memories of skills form during the first year of life as well. For example, one-year-olds can remember how to stack blocks or to successfully play with toys that require specific movements, such as winding a crank handle to get the jack in the box to pop up. Once learned—even in very early life—this type of procedural knowledge is rarely forgotten. That is why you will never forget how to tie your shoelaces, even if you go for years wearing only flip flops. Procedural knowledge is stored, among other places, in the brain region called the striatum. The early ability to store procedural information for the long term suggests that the striatum matures quickly.
In short, babies and toddlers demonstrate lots of memories—from memories of faces, places, and objects, to memories of skills and procedures. As a result, they can recognize a particular face as dad, a particular house as grandma’s, and a particular animal as a giraffe. Similarly, once they get going, they can remember how to walk and get from here to there, how to use a fork, and, often, how to get their way. On the other hand, their specific memories of the events that occur in their lives are not very impressive. Prior to the age of 4 years, children do not hold onto memories of life events for very long. Correspondingly, most adults do not have any recollections of the events that occurred during their first 3½ to 4 years of life. Small wonder that the early years of life are often referred to as a period of “infantile amnesia.”

Why is it that young children can remember factual information, like the names of animals, from one day to the next, and remember how to play games and perform often complex motor skills, but they cannot form a permanent memory of life events? The answer to this question is that brain regions holding different types of memories do not develop at the same rate. That is, the brain circuits responsible for storing memories of events seem to develop more slowly than the brain regions responsible for storing information about language, motor skills, and simple associations.

As you learned in the previous section, in adults, memories about life events, often called episodic memories, are initially stored in the hippocampus. Only after temporary storage in the hippocampus is that information then distributed more widely throughout neocortical regions for long-term storage. We know that the hippocampus is a late developing brain structure, and this late development might contribute to the inability to form episodic memories early on. Alternatively, it may not be a late-maturing hippocampus that is responsible for infantile amnesia, but rather the brain’s early inability to transfer information out of the hippocampus to other locations in the neocortex.

Of course, if you spend any time with talkative 2-year-olds, you will notice they have a lot to say about what has been happening in their lives. They may tell you what a friend said at nursery school, that a sibling took their toy, or that they are expecting their mom to come home from work later in the day. This shows that young children are in fact forming memories of life events but that the information is not being stored permanently. If you ask those same two-year-olds a few months later about the same life events, unless the events have been repeated over and over, the children will not recall them.

Think back to your earliest memory of a childhood event. If the memory is accurate (and not a manufactured one), it probably has an emotional component. The emotionally-charged event that you remember may be positive, such as receiving a special birthday present, going on an exciting vacation, or experiencing the arrival of your younger brother or sister. Or the remembered event may be negative, such as traveling to the emergency room after a fall off a scooter, being the victim of bullying in a preschool class, or experiencing the arrival of your younger brother or sister (depending on how you viewed this event initially!). It is unlikely that the earliest event you remember is a neutral one, particularly if it occurred before the age of 4 years. The fact that most early life memories are emotional suggests that the episodic memory system is helped along at early stages by brain regions that process emotional information, particularly the amygdala (LeDoux & Doyère, 2011).

Too Scary to Forget  “One of my first, scariest memories I can recall, was when I got stuck in my dress. It was super scary—I was playing with my gigantic doll who had a very nice dress on that used to belong to me at some point in time—I remembered that I used to wear it and thought that it would be a great idea to put it on—I didn’t realize that I was way too big for that dress and kept squeezing it on until I got stuck—I could not take it off or put it on—my hands were stretched up and my elbows were somewhere by my ears—I felt very uncomfortable and it was dark, since the material of the dress was covering my head. I thought I would have to stay in that position forever—that was scary!! My mommy rescued me.”

Research suggests that memory and related cognitive functions peak at approximately age 25 (Cansino et al., 2010; McGaugh, 2003, 1999).
Having looked at memory during the earliest years of life, let’s take a look at memory during the later years. As we travel through middle adulthood and old age, we become more susceptible to forgetting, distortions, and misremembering. Studies suggest that in the normal course of aging, elderly people are likely to experience declines in their working memories, their ability to encode new memories, their episodic memories (recollections of past events), certain types of short-term memory, and the sources of information that they remember (Berry et al., 2010; Hedden & Gabrieli, 2004; Nilsson, 2003). Researchers also have found that older adults tend to remember positive information while ignoring the negative (Park & Reuter-Lorenz, 2009; Jacoby et al., 2005). Perhaps for these reasons, some older individuals fall prey to scams. On the other hand, the implicit (procedural) memories of aging people show little decline, several types of short-term memory remain strong throughout aging, and the semantic memories (general knowledge) of older people may actually improve (Backman & Nyberg, 2010; Fleischman et al., 2004; Verhaeghen, 2003).

An area of memory decline that is particularly upsetting to many aging people is in the operation of their prospective memories. A prospective memory involves remembering to perform a future intended action, as opposed to a retrospective memory, which involves the recall of past actions, events, or knowledge. Prospective memories help us to carry out our plans and move through the day effectively. They include, for example, remembering to pick up clothing at the cleaners, to call a family member, to send a birthday card, to take a prescribed medication at the right time, or to share a “juicy” piece of information with a friend. Studies find that older people perform more poorly on prospective memory tasks than do younger adults, especially when the tasks become more demanding, distracting, or complex (Einstein & McDaniel, 2010, 2005, 1990). Declines in prospective memory can often be worked around by using strategies such as to-do lists. However, the frustration that often accompanies a growing sense of absentmindedness is harder for aging people to address.

Although the age-related changes in the way our memory functions are gradual, they actually begin in our twenties (Park & Reuter-Lorenz, 2009). Certain parts of the brain, such as the hippocampus, begin to shrink. A study of the brains of elderly individuals found that the hippocampus was about 20 percent larger in those with excellent memories than those suffering from Alzheimer’s disease (Winningham, 2010; Erten-Lyons et al., 2009), a finding that also may have implications for the memory losses that accompany normal aging.

As the elderly population continues to grow in our society, an increasing amount of research is focusing on how to improve memory and prevent, or at the very least, lessen the impact of memory disorders such as Alzheimer’s disease. Brain fitness approaches—using computer exercises and various mental games to keep the mind “in shape”—have become very popular and are often recommended to elderly patients by health-care professionals. Although this approach has received support in a few studies (Basak et al., 2008), many of today’s researchers remain skeptical about whether brain puzzles and the like can in fact prevent memory decline. On the other hand, as we observed in Chapter 4, research has demonstrated repeatedly that physical exercise does indeed help to prevent or slow down deficiencies and impairments of memory and other forms of cognitive functioning (Hoveida et al., 2011; Smith et al., 2011).
Disorders of Memory

LEARNING OBJECTIVE 8 Describe physical and psychological disorders that disrupt memory.

At times, each of us has been inconvenienced by flawed memories or by outright forgetting. When our memories fail to operate as we would like, we may experience dismay, frustration, or embarrassment. Imagine how upsetting and confusing life would be if memory failure were the rule rather than the exception, as it became for Leonard, the character in the movie Memento. This is the experience of people who have memory disorders (McGaugh, 2003).

As you will see in Chapter 16, there are two basic groups of memory disorders: organic memory disorders, in which physical causes of memory impairment can be identified, and dissociative disorders, in which the disruptions in memory lack a clear physical cause.

Organic Memory Disorders

Some changes in memory have clear organic causes, such as brain injuries or medical conditions. These injuries or conditions damage one or more of the brain regions or brain chemicals that are important in the formation, storage, or retrieval of memories (Matthews, 2011). The most common kinds of organic memory disorders are amnestic disorders, which primarily affect memory, and dementias, which affect both memory and other cognitive functions.

Amnestic Disorders People with amnestic disorders, organic disorders in which memory loss is the primary symptom, experience retrograde amnesia, anterograde amnesia, or both (Figure 8-12). Retrograde amnesia is an inability to remember things that occurred before the organic disorder or event that triggered amnesia. Anterograde amnesia is an ongoing inability to form new memories after the onset of the disorder or event.

In severe forms of anterograde amnesia, such as that suffered by Leonard, the main character in the film Memento, new acquaintances are forgotten almost immediately and problems solved one day must be tackled again the next. The person may not remember anything that has happened since the physical problem first occurred. A middle-aged patient who suffered a physical trauma more than 25 years ago, for example, may still believe that Ronald Reagan is president of the United States.

Head injuries are a common cause of amnestic disorders. Although mild head injuries—for example, a mild concussion—rarely cause much memory loss, almost half of all severe head injuries do cause some permanent learning and memory problems (King & Kirwilliam, 2011; Zeckey et al., 2011). Brain surgery can also cause amnestic disorders. The most famous case of memory loss as a result of brain surgery is that of H.M., a man whose identity was protected for decades until his death in 2008 (Milner, 2010; Kensinger et al., 2001; Corkin, 1984). H.M. suffered from severe epilepsy, a disorder that produced seizures in his temporal lobes. To reduce his symptoms, doctors performed surgery in 1953 that removed parts of both his temporal lobes, the amygdala, and the hippocampus. At that time, the role of these brain areas in the formation of memories was not known. (Today temporal lobe surgery is usually done on only the right or left side of the brain.) H.M. experienced severe amnestic disorders organic disorders in which memory loss is the primary symptom. retrograde amnesia inability to remember things that occurred before an organic event. anterograde amnesia ongoing inability to form new memories after an amnesia-inducing event.
Part of the sport? Increasingly aware that hard hits to the head often lead to brain injuries and learning problems, the National Football League now hands out severe fines for hits to the head and restricts how quickly players can return to action after experiencing a concussion. As many as 350,000 athletes, across all sports and levels, endure consciousness-losing injuries each year (Gioia, 2007).

Dementia severe memory problems combine with losses in at least one other cognitive function, such as abstract thinking or language.

Alzheimer’s disease most common form of dementia, usually beginning with mild memory problems, lapses of attention, and problems in language and progressing to difficulty with even simple tasks and recall of long-held memories.

neurofibrillary tangles twisted protein fibers found within the cells of the hippocampus and certain other brain areas.

Senile plaques sphere-shaped deposits of a protein that form in the spaces between cells in the hippocampus, cerebral cortex, and certain other brain regions, as well as in some nearby blood vessels.

Dementias In dementia, severe memory problems combine with losses in at least one other cognitive function, such as abstract thinking or language (Ringman & Winters, 2011; APA, 2000). Between 3 and 9 percent of the world’s adult population suffer from some form of dementia (Berr et al., 2005). Among people 65 years of age, the prevalence of dementia is around 1 to 2 percent, increasing to as much as 50 percent of those over the age of 85 (Ames et al., 2010; Apostolova & Cummings, 2008).

Alzheimer’s disease, named after Alois Alzheimer, the German physician who first identified it in 1907, is the most common form of dementia (Farlow, 2010). This gradually progressive disease usually begins with mild memory problems, lapses of attention, and difficulties in language and communication. As symptoms worsen over the years, patients also have difficulty with simple tasks and forget distant memories. Eventually, they may lose almost all knowledge of the past and fail to recognize the faces of even close relatives.

People with Alzheimer’s disease form far more than ordinary numbers of neurofibrillary tangles and senile plaques, brain changes that are normal features of aging up to a point (Fandrich et al., 2011; Selkoe, 2011, 2000, 1991). Neurofibrillary tangles are twisted protein fibers found within the cells of the hippocampus and several other brain areas. Senile plaques are sphere-shaped deposits of a protein that form in the spaces between cells in the hippocampus, cerebral cortex, and several other brain regions, as well as in some nearby blood vessels. The presence of so many tangles and plaques indicates that very destructive processes take place in the brains of Alzheimer victims (Meyer-Luehmann et al., 2008; O’Connor et al., 2008). Researchers do not yet fully understand what those processes are, but they have begun to zero in on several possibilities.

A leading theory suggests that two proteins, beta-amyloid protein and tau protein, run amok in people with Alzheimer’s disease, contributing to the formation of plaques and tangles in the hippocampus and other brain areas (Ramirez et al., 2011; Apostolova & Cummings, 2008). Why might these proteins act so abnormally? According to research, around 30 percent of the population is born with a particular gene variation called ApoE-4, located on chromosome 19, which puts them at higher risk for the development of Alzheimer’s disease (Hollingsworth et al., 2011). Apparently, the ApoE-4 gene form promotes the excessive formation of beta-amyloid proteins, which helps to spur the formation of plaques. The formation of so many plaques, in turn, sets in motion the breakdown of the tau protein, the production of numerous tangles, the death of many neurons, and, finally, Alzheimer’s disease.

Although the ApoE-4 gene form appears to be a major contributor to the development of Alzheimer’s disease, it is important to recognize that not everyone with this gene form develops the disease. Apparently, other factors—perhaps environmental, lifestyle, or stress-related—also have a significant impact in the development of Alzheimer’s disease (Nation et al., 2011; Tran et al., 2011).

Gender and Dementia How We Differ Depending on whether you are a male or a female, you may be susceptible to different risk factors for dementia and Alzheimer’s disease. Older women are more likely to develop dementia than men. Although this may be because women tend to live longer, natural age-related declines in estrogen, which is known to have a protective effect in the brain, could also be a factor (Sun, 2007).

As we age, certain conditions in men and women may increase the likelihood of developing dementia. A study of adults with mild cognitive impairment showed that stroke in men and depression in women increase the risk for dementia (Artero et al., 2008).
In addition to risk factors, Alzheimer’s disease also may “look” different in men and women. The brains of women with the disease, for example, typically have many more neurofibrillary tangles than do those of men (Barnes et al., 2005). Also, men with Alzheimer’s disease tend to be more aggressive, while women are more likely to become depressed (Lovheim et al., 2009).

**Dissociative Disorders**

People with dissociative disorders experience major losses of memory without any clear physical causes. Many memorable books and movies have portrayed such disorders (Vidal, 2011). Some clinicians, however, believe that they are quite rare. There are several different kinds of dissociative disorders, including dissociative amnesia, dissociative fugue, and dissociative identity disorder:

- **Dissociative amnesia** People with dissociative amnesia are unable to recall important information, usually of an upsetting nature, about their lives (APA, 2000). The loss of memory is much more extensive than instances of normal forgetting and is often triggered directly by a traumatic event—typically a serious threat to health and safety—as in wartime and natural disasters (Hunt, 2010; Kikuchi et al., 2010; Cardena & Gleaves, 2007).

- **Dissociative fugue** In addition to forgetting their personal identities and details of their past lives, people with dissociative fugue flee to an entirely different location. Although some individuals travel but a short distance and make few social contacts in the new setting, others travel far from home, take new names and establish new identities, develop new relationships, and even seek new lines of work (Kihlström, 2001; APA, 2000).

- **Dissociative identity disorder** People with dissociative identity disorder, formerly known as multiple personality disorder, develop two or more distinct personalities—called subpersonalities—each having a unique set of memories, behaviors, thoughts, and emotions. Often one of the subpersonalities has little or no recall of the experiences, thoughts, feelings, or behaviors of the others. During activities and interactions, one of the subpersonalities takes center stage and dominates the person’s functioning. Women receive this diagnosis at least three times as often as men (APA, 2000).

**Divided Memories** In the famous case of “Eve White,” depicted in the book and movie The Three Faces of Eve, a woman had three subpersonalities—Eve White, Eve Black, and Jane (Thigpen & Cleckley, 1957). Eve White, the primary personality, was quiet and serious; Eve Black was carefree and mischievous; and Jane was mature and intelligent. According to the book, these three subpersonalities eventually merged into a single, integrated personality named Evelyn. However, in an autobiography decades later, this woman revealed that altogether twenty-two subpersonalities had come forth during her life, including nine subpersonalities after Evelyn (Sizemore, 1991).

A variety of theories have been proposed to explain dissociative disorders, but none of them has received much research support. Some psychologists in fact suggest that the symptoms of dissociative disorders may originate not from within the individual, but in a therapist’s office. We have seen how easy it is for people to distort or manufacture memories based on even casual suggestions. Perhaps therapists unintentionally create dissociative disorders, particularly dissociative identity disorders, by subtly suggesting to their clients over the course of treatment that they may have other personalities or by asking the clients to produce different personalities while in a hypnotic state (Lynn & Deming, 2010; Loewenstein, 2007; Piper & Merskey, 2005, 2004).

dissociative disorders psychological disorder characterized by major loss of memory without a clear physical cause.
dissociative amnesia psychological disorder characterized by inability to recall important information, usually of an upsetting nature, about one’s life.
dissociative fugue psychological disorder characterized by loss of memory of personal identities and details of one’s past life and flight to an entirely different location.
dissociative identity disorder psychological disorder characterized by the development of two or more distinct personalities.
subpersonalities alternate personalities developed in dissociative identity disorder, each with a unique set of memories, behaviors, thoughts, and emotions.
Before You Go On

What Do You Know?
19. Compare and contrast retrograde and anterograde amnesia. What are the likely causes of both?
20. What changes happen in the brains of people with Alzheimer’s disease?
21. How do dissociative disorders differ from organic memory disorders?

What Do You Think? Do you think that media portrayals of dissociative disorders have actually influenced psychotherapists and members of the public to increase the number of diagnoses of these conditions? What other reasons might explain increased diagnoses?

Tying It Together: Memory

The study of memory is closely connected to the study of all other areas of psychology. Throughout this chapter, we have stressed how memory interfaces with psychology’s various subfields, including our highlighted sections on brain functioning, individual differences, abnormal functioning, and development. To remind you of how memory is tied to other psychology subfields and issues, we’ve selected some interesting points from throughout the chapter.

What Happens in the Brain?
• In his pioneering studies, Karl Lashley found that rats retained at least some memory of their mazes, even when he removed large parts of their brains.
• Memory is not confined to any single area of the brain, although the prefrontal cortex and hippocampus play particularly important roles.
• If experimental animals are given substances that block the development of long-term potentiation (LTP) in their neurons, they cannot transfer information from working memory into long-term memory.
• The brains of people with Alzheimer’s disease form an unusually large number of plaques and tangles.

How We Differ
• The storage capacity of everyone’s working memory is about the same, but storage capacity in long-term memory varies greatly from person to person.
• Everyone uses phonological, visual, and semantic codes to encode information, but individuals may differ in how much they use each of these codes.
• The hippocampus size of elderly adults with normal memories is, on average, 20 percent larger than that of people with Alzheimer’s disease.
• Women are somewhat more likely than men to develop dementia.

When Things Go Wrong
• Head injuries are a common cause of organic memory loss.
• From the moment that he had both of his temporal lobes surgically removed, the famous patient H.M. was never again able to form new long-term memories.
• Only 1 to 2 percent of 65-year-olds experience dementia, compared to as many as 50 percent of those over the age of 85.
What Is Memory?

Learning Objective 1 Define the basic activities of memory and describe two major models of memory.

- Memory is our faculty for holding onto past events and past learning. It involves three basic activities: encoding, storage, and retrieval.
- Researchers typically take an information-processing approach to memory, talking about different memory stores that work together in a similar way to parts of a computer, each serving particular functions and holding information for varying lengths of time.
- PDP or connectionist models of memory suggest that information is stored not in a particular neuron or location in the brain, but instead across a network of connections.

How Do We Encode Information Into Memory?

Learning Objective 2 Describe how information is encoded and transferred among different memory stores and what we can do to enhance encoding.

- Encoding refers to taking information in and putting it into memory.
- Encoding can happen either automatically or through effortful processing. Either way, however, a person must attend to something to put it into memory.
- One of the most common means of effortful processing is rehearsal of material.
- Encoding takes place in the form of phonological, sound, or visual codes.

How Do We Retrieve Memories?

Learning Objective 4 Describe how we retrieve information from memory and how retrieval cues, priming, context, and emotion can affect retrieval.

- The access of information from memory is known as retrieval. Information can be stored in memory for anywhere from fractions of a second to a lifetime.
- Sensory memory is the equivalent of the small buffer on your computer, holding a very brief visual or auditory copy of information so you can decide whether or not to encode it into working or long-term memory. Sensory memory may also help maintain the continuity of your sensory input.
- Working memory is a short-term store of slightly more information that allows us to conduct simple calculations, such as memorizing a phone number so we can dial it immediately, or remembering the beginning of a sentence as we come to the end of the sentence.
- It appears that, without rehearsal, we can hold 7 ± 2 pieces of information in working memory, although we can expand that capacity through techniques, such as chunking.
- Long-term memory appears to be both infinite in capacity and storage time.
- Information taken from working memory into long-term memory appears to be organized according to its meaningfulness and relation to other concepts in long-term storage.
- Information in long-term memory may be stored in the form of explicit memories of facts or in implicit memories, knowledge about how to do something. A person cannot always articulate implicit knowledge.

How Do We Store Memories?

Learning Objective 3 Describe how we organize and store information in working and long-term memory and how we can enhance our long-term memories.

- The retention of information in memory is known as storage. Information can be stored in memory for anywhere from fractions of a second to a lifetime.
- Sensory memory is the equivalent of the small buffer on your computer, holding a very brief visual or auditory copy of information so you can decide whether or not to encode it into working or long-term memory. Sensory memory may also help maintain the continuity of your sensory input.
- Working memory is a short-term store of slightly more information that allows us to conduct simple calculations, such as memorizing a phone number so we can dial it immediately, or remembering the beginning of a sentence as we come to the end of the sentence.
- It appears that, without rehearsal, we can hold 7 ± 2 pieces of information in working memory, although we can expand that capacity through techniques, such as chunking.
- Long-term memory appears to be both infinite in capacity and storage time.
- Information taken from working memory into long-term memory appears to be organized according to its meaningfulness and relation to other concepts in long-term storage.
- Information in long-term memory may be stored in the form of explicit memories of facts or in implicit memories, knowledge about how to do something. A person cannot always articulate implicit knowledge.
Why Do We Forget and Misremember?

**Learning Objective 5** Summarize key theories of why we forget information and sometimes distort or manufacture memories.

- Forgetting is the inability to recall information that has previously been encoded.
- Initially, researchers believed that failure to access information regularly led to its loss from awareness, a theory known as decay theory. This theory is less popular now, and researchers instead emphasize other problems with remembering.
- Interference theory suggests that information gets in the way of proper encoding of information, preventing it from being remembered later. Retroactive interference comes from new information that interferes with previous memories. Proactive interference comes from earlier memories that interfere with new ones.
- Motivated forgetting hypothesizes that we try to purposely forget information that is unpleasant, embarrassing, or painful.
- In addition to being forgotten, memories can also be distorted or manufactured. We can make source misattributions, where we forget where information came from. We can also be exposed to new information that distorts previous information (as described in interference theory). Also, our own imaginations can play a role in distorting how our memories play out.

**Disorders of Memory When Things Go Wrong**

**Learning Objective 8** Describe physical and psychological disorders that disrupt memory.

- Disorders of memory can come about through aging, brain trauma, or the experience of traumatic events. Organic memory disorders, involving physical causes, include amnestic disorders and dementia. Major losses of memory without a clear physical cause are known as **dissociative disorders**.
- People with amnestic disorder are unable to remember things that have occurred before (retrograde amnesia) or after (anterograde amnesia) an organic event, such as a head injury or brain surgery.
- The other major class of organic memory disorders is dementia, characterized by severe memory problems combined with losses in at least one other cognitive function, such as abstract thinking or language.
- The most common form of dementia is Alzheimer’s disease, a severe progressive form of dementia that accounts for at least half of all dementia cases.
- The brains of people with Alzheimer’s disease have an extraordinarily high number of neurofibrillary tangles and senile plaques. The disease may stem in part from a particular gene variation called ApoE-4, inherited by 30 percent of the population. ApoE-4 promotes the excessive formation of beta-amyloid proteins, which lead, in turn, to plaques formations, the breakdown of tau proteins, tangle formations, and finally, the death of many cells. Environmental, lifestyle, and stress-related factors may also play key roles in the development of Alzheimer’s disease.
- Most of the time, dissociative disorders are triggered by a serious trauma or upsetting event and the memory loss is specifically related to that trauma.
- Dissociative amnesia refers to the inability to remember important, upsetting information about one’s life.
- Dissociative fugue involves the complete loss of one’s identity, combined with a flight to another location.
- Dissociative identity disorder describes a disorder in which a person develops two or more distinct personalities, each with a unique set of memories, behaviors, thoughts, and emotions.
- Some theorists suspect that dissociative identity disorder may be inadvertently triggered by therapy discussions or events.

**Memory What Happens in The Brain**

**Learning Objective 6** Describe how the brain is involved in memory.

- Because scientists have not been able to pinpoint the place where memories are stored in the brain, they have concluded that there is no single storehouse. Instead, memory appears to be a process, resulting from activation patterns throughout the brain.
- However, structures like the prefrontal cortex are extremely important in helping people hold information in working memory and to work with it as long as it is needed. Also, the hippocampus and other parts of the neocortex appear to be important in the transfer of memories into long-term memory.
- Memory itself appears to be a neural circuit, a network of neurons predisposed to trigger one another whenever one is activated. Through a phenomenon called long-term potentiation, repeated stimulation of certain nerve cells increases the likelihood that the neurons will respond strongly whenever stimulated.

**Memories in the Young and Old How We Develop**

**Learning Objective 7** Describe the kinds of memories and memory changes that characterize early life and later life.

- Babies and toddlers display many memories—from memories of faces, places, and objects, to memories of skills and procedures. But they do not retain memories of life events for very long.
- The slow development of the hippocampus may be responsible for the slow development of life event memories.
- Physical exercise seems to help prevent or slow down memory decline more than cognitive exercise does.
Key Terms

memory 270
encoding 270
storage 270
retrieval 270
information-processing model 270
parallel distributed-processing (PDP) (or connectionist) model 271
automatic processing 273
effortful processing 273
sensory memory 274
working memory 274
rehearsal 274
long-term memory 275
spacings effect 275
semantic code 277
mnemonic devices 277
schemas 279
storage 279
memory span 280
chunking 280
explicit memory 281
implicit memory 282
semantic memory 283
episodic memory 283
retrieval cues 285
priming 285
recognition tasks 286
recall tasks 286
state-dependent memory 287
flashbulb memory 289
forgetting 289
decay theory 290
interference theory 290
proactive interference 290
retroactive interference 290
repression 292
source misattribution 293
prefrontal cortex 298
long-term potentiation (LTP) 299
amnestic disorders 303
retrograde amnesia 303
anterograde amnesia 303
dementia 304
Alzheimer’s disease 304
neurofibrillary tangles 304
senile plaques 304
dissociative disorders 305
dissociative amnesia 305
dissociative fugue 305
dissociative identity disorder 305
subpersonalities 305

Practice Questions

Multiple Choice

1. Which of the following sequences best reflects the order of stages in the three-stage memory model, from first to last?
   a) sensory memory → long-term memory → working memory
   b) sensory memory → working memory → long-term memory
   c) working memory → long-term memory → sensory memory
   d) working memory → sensory memory → long-term memory

2. For encoding to occur, individuals need to focus on environmental stimuli. This “focus” refers to what cognitive process?
   a) attention
   b) invigoration
   c) retrieval
   d) storage

3. An experimenter is reading a series of digits aloud for a respondent to recite back from memory in the order they were read. The experimenter is testing the capacity of ______ memory, and the longest string the respondent is likely to be able to repeat correctly is ______ digits.
   a) sensory; 4
   b) sensory; 7
   c) working; 4
   d) working; 7

4. Multiple choice test is to essay test as ______ is to ______.
   a) cueing; priming
   b) explicit memory; implicit memory
   c) recall; recognition
   d) recognition; recall

5. What does the forgetting curve discovered by Ebbinghaus tell us about the way we forget material over time?
   a) At first, we forget very little of what we have learned, but as time passes, the rate of forgetting accelerates.
   b) Most forgetting happens immediately after we learn material; the rate of forgetting slows down as time goes by.
   c) We forget information at a constant rate as time passes.
   d) We forget information at a variable and unpredictable rate as time passes.

6. The need to reconstruct rather than simply retrieve memories stems from the ______ code used in long-term memory.
   a) orthographic
   b) phonological
   c) semantic
   d) visual

7. How do the results of Lashley’s research on maze memory among rats inform an evaluation of connectionist models of memory?
   a) They cast serious doubt on connectionist models of memory.
   b) They offer strong support for connectionist models of memory.
   c) They pose a challenge for connectionist models of memory.
   d) They say little with respect to connectionist models of memory.

8. Which statement best describes the role of the hippocampus in memory?
   a) The hippocampus helps encode procedural memories, but not semantic ones.
   b) The hippocampus is a “staging area” for the encoding of material into long-term memory.
   c) The hippocampus is the final repository for long-term memories.
   d) The hippocampus serves to transfer material from sensory to working memory.
9. In terms of helping to slow or prevent memory loss in older adults, which strategy has received the most research support?
   a) Completing puzzles
   b) Engaging in physical exercise
   c) Playing computer games
   d) Taking vitamins

10. How are organic memory disorders, amnesic disorders, and dementias related?
   a) Amnesic disorders and dementias are types of organic memory disorders.
   b) Organic memory disorders, amnesic disorders, and dementias are all types of dissociative disorders.
   c) Organic memory disorders and amnesic disorders are examples of dementias.
   d) Organic memory disorders and dementias are types of amnesic disorders.

Fill-in-the-Blank

1. According to the information processing model of memory, ________ is the first stage in which an image is retained by the brain for less than 1 second.
2. The ________ model of memory emphasizes how memories are formed and stored in a network of connections throughout the brain.
3. ________, or consciously repeating information, increases the likelihood of information being encoded into working memory.
4. Remembering a fact based on general knowledge requires ________ memory.
5. A stimulus reminding us of the information we need to retrieve from memory is termed a retrieval ________.
6. In ________ interference, information learned earlier disrupts the recall of information learned more recently; in ________ interference, recently learned information disrupts the recall of information learned earlier.

Your Brain and Behavior Questions

Giving Eyewitness Testimony

1. Imagine a person who has witnessed a bank robbery. Provide an example of a leading question that might alter this person’s memory, and a non-leading question that is more likely to preserve the original memory.

2. Explain how the visual cortex is activated differently when a person is remembering a witnessed event accurately versus inaccurately.

3. Discuss the role of the prefrontal cortex and the hippocampus in the storage and recall of eyewitness memory.
Psychology Around Us

Recalling Flashbulb Memories

Memory plays a big role in our lives and in psychology. Generally, most people believe that they can remember things pretty well. Indeed, retrieving past memories, including “buried” memories, is a major part of daily functioning.

We all retain special memories of particularly significant events, called “flashbulb memories,” which can be recalled with vivid, near perfect detail. We tend to be very confident about the accuracy of these memories because of the strong emotionality experienced during that event. But do the special memory mechanisms triggered by these emotions always result in the precise memories? In this lab exercise, you’ll test your powers of recall surrounding the details of the attack on the World Trade Center on September 11, 2001.

Should we have great confidence in our flashbulb memories, let alone our recollections of everyday events or childhood experiences? With this lab in hand, you’ll be able to provide an insider’s answer.

As you are working on this online exercise, consider the following questions . . .

• What do you think this lab exercise says about the accuracy of our memories?
• How does our state of mind influence our mechanisms of memory, or explain why we misremember and forget?
• What implications might this lab exercise hold for the field of psychology’s assumptions, techniques, and interpretations?