## Multiple-Choice Questions

1. Caitlin, a fifth grader, is asked to remember her second-grade teacher's name. What measure of retention will Caitlin use to answer this question?
   a. Storage
   b. Recognition
   c. Relearning
   d. Recall
   e. Encoding

2. Working memory is most active during which portion of the information-processing model?
   a. Short-term memory
   b. Sensory memory
   c. Retrieval
   d. Encoding
   e. Long-term memory

3. Your memory of which of the following is an example of implicit memory?
   a. What you had for breakfast yesterday
   b. The need to spend some time reviewing tomorrow for an upcoming psychology quiz
   c. Which way to turn the car key to start the engine
   d. That George Washington was the first President
   e. How exciting it was to get the best birthday present ever

4. Which of the following is the most accurate description of the capacity of short-term and working memory?
   a. Lasts for about 2 days in most circumstances
   b. Lasts for less than half a minute unless you rehearse the information
   c. Is thought to be unlimited—there is always room for more information
   d. Can handle about a half dozen items for each of the tasks you are working on at any time
   e. Can handle about a half dozen items total

5. Which of the following is most likely to lead to semantic encoding of a list of words?
   a. Thinking about how the words relate to your own life
   b. Practicing the words for a single extended period
   c. Breaking up the practice into several relatively short sessions
   d. Noticing where in a sentence the words appear
   e. Focusing on the number of vowels and consonants in the words

## Practice FRQs

1. To remember something, we must get information into our brain, retain the information, and later get the information back out. Making sure you use the terms for these three steps of the process, explain how this system would apply if you needed to learn the name of a new student who just enrolled in your school today.

### Answer

*1 point:* Encoding is the process of getting the new student's name into your brain.

*1 point:* Storage is keeping that name in your memory.

*1 point:* Retrieval is the process of using that name when greeting the new student later.

2. Last evening, Carlos' mom told him he needed to buy milk today. So, he hopped on his bicycle this morning and headed to the corner store to pick up a gallon. Explain how both implicit and explicit memories were involved in Carlos' errand.

*(4 points)*



# Module 32

## Memory Storage and Retrieval

Arthur Tilley/Getty Images

### Module Learning Objectives

32-1 Describe the capacity and location of our long-term memories.

32-2 Describe the roles of the frontal lobes and hippocampus in memory processing.

32-3 Describe the roles of the cerebellum and basal ganglia in our memory processing.

32-4 Discuss how emotions affect our memory processing.

32-5 Explain how changes at the synapse level affect our memory processing.

32-6 Explain how memory is measured.

32-7 Describe how external cues, internal emotions, and order of appearance influence memory retrieval.

## Memory Storage

32-1 What is the capacity of long-term memory? Are our long-term memories processed and stored in specific locations?

In Arthur Conan Doyle's *A Study in Scarlet,* Sherlock Holmes offers a popular theory of memory capacity:

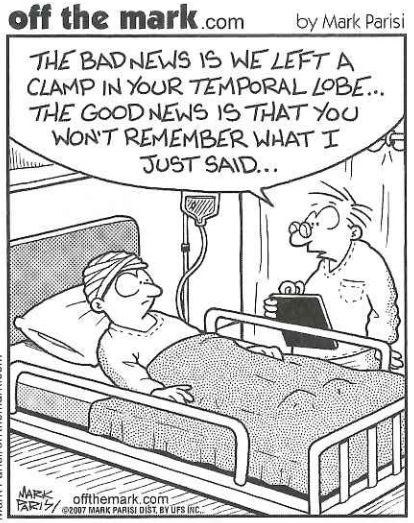
> I consider that a man's brain originally is like a little empty attic, and you have to stock it with such furniture as you choose. . . . It is a mistake to think that that little room has elastic walls and can distend to any extent. Depend upon it, there comes a time when for every addition of knowledge you forget something that you knew before.

Contrary to Holmes' "memory model," our capacity for storing long-term memories is essentially limitless. Our brains are not like attics, which once filled can store more items only if we discard old ones.

"Our memories are flexible and superimposable, a panoramic blackboard with an endless supply of chalk and erasers." -Elizabeth Loftus and Katherine Ketcham, *The Myth of Repressed Memory,* 1994

### Retaining Information in the Brain

I marveled at my aging mother-in-law, a retired pianist and organist. At age 88, her blind eyes could no longer read music. But let her sit at a keyboard and she would flawlessly play any of hundreds of hymns, including ones she had not thought of for 20 years. Where did her brain store those thousands of sequenced notes?




Mark Parisi/offthemark.com

For a time, some surgeons and memory researchers marveled at patients' seeming vivid memories triggered by brain stimulation during surgery. Did this prove that our whole past, not just well-practiced music, is "in there," in complete detail, just waiting to be relived? On closer analysis, the seeming flashbacks appeared to have been invented, not relived (Loftus & Loftus, 1980). In a further demonstration that memories do not reside in single, specific spots, psychologist Karl Lashley (1950) trained rats to find their way out of a maze, then surgically removed pieces of their brain's cortex and retested their memory. No matter which small brain section he removed, the rats retained at least a partial memory of how to navigate the maze.

*The point to remember:* Despite the brain's vast storage capacity, we do not store information as libraries store their books, in discrete, precise locations. Instead, many parts of the brain interact as we encode, store, and retrieve the information that forms our memories.

### EXPLICIT-MEMORY SYSTEM: THE FRONTAL LOBES AND HIPPOCAMPUS

**32-2** What roles do the frontal lobes and hippocampus play in memory processing?

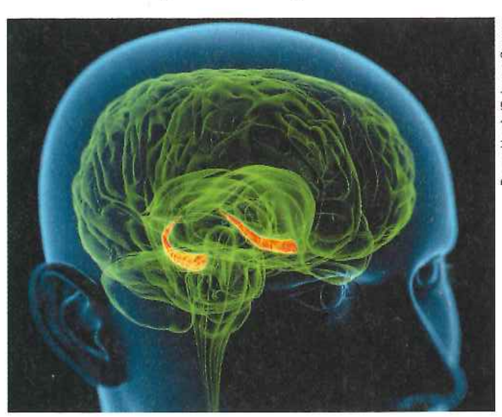
As with perception, language, emotion, and much more, memory requires brain networks. The network that processes and stores your explicit memories for facts and episodes includes your frontal lobes and hippocampus. When you summon up a mental encore of a past experience, many brain regions send input to your frontal lobes for working memory processing (Fink et al., 1996; Gabrieli et al., 1996; Markowitsch, 1995). The left and right frontal lobes process different types of memories. Recalling a password and holding it in working memory, for example, would activate the left frontal lobe. Calling up a visual party scene would more likely activate the right frontal lobe.

**hippocampus** a neural center located in the limbic system; helps process explicit memories for storage.

Cognitive neuroscientists have found that the **hippocampus,** a temporal-lobe neural center located in the limbic system, is the brain's equivalent of a "save" button for explicit memories (**FIGURE 32.1**). Brain scans, such as PET scans of people recalling words, and autopsies of people who had *amnesia* (memory loss) have revealed that new explicit memories of names, images, and events are laid down via the hippocampus (Squire, 1992).

Damage to this structure therefore disrupts recall of explicit memories. Chickadees and other birds can store food in hundreds of places and return to these unmarked caches months later—but not if their hippocampus has been removed (Kamil & Cheng, 2001; Sherry & Vaccarino, 1989). With left-hippocampus damage, people have trouble remembering verbal information, but they have no trouble recalling visual designs and locations. With right-hippocampus damage, the problem is reversed (Schacter, 1996).

**Figure 32.1**
**The hippocampus** Explicit memories for facts and episodes are processed in the hippocampus and fed to other brain regions for storage.



Roger Harris/Science Source

Subregions of the hippocampus also serve different functions. One part is active as people learn to associate names with faces (Zeineh et al., 2003). Another part is active as memory champions engage in spatial mnemonics (Maguire et al., 2003b). The rear area, which processes spatial memory, grows bigger the longer a London cabbie has navigated the maze of streets (Maguire et al., 2003a).

Memories are not permanently stored in the hippocampus. Instead, this structure seems to act as a loading dock where the brain registers and temporarily holds the elements of a remembered episode—its smell, feel, sound, and location. Then, like older files shifted to a basement storeroom, memories migrate for storage elsewhere.

Sleep supports memory consolidation. During deep sleep, the hippocampus processes memories for later retrieval. After a training experience, the greater the hippocampus activity during sleep, the better the next day's memory will be (Peigneux et al., 2004). Researchers have watched the hippocampus and brain cortex displaying simultaneous activity rhythms during sleep, as if they were having a dialogue (Euston et al., 2007; Mehta, 2007). They suspect that the brain is replaying the day's experiences as it transfers them to the cortex for long-term storage. Cortex areas surrounding the hippocampus support the processing and storing of explicit memories (Squire & Zola-Morgan, 1991).



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**Hippocampus hero** Among animals, one contender for champion memorist would be a mere birdbrain—the Clark's Nutcracker—which during winter and spring can locate up to 6000 caches of pine seed it had previously buried (Shettleworth, 1993).

### IMPLICIT-MEMORY SYSTEM: THE CEREBELLUM AND BASAL GANGLIA

**32-3** What roles do the cerebellum and basal ganglia play in our memory processing?

Your hippocampus and frontal lobes are processing sites for your *explicit* memories. But you could lose those areas and still, thanks to automatic processing, lay down *implicit* memories for skills and conditioned associations. Joseph LeDoux (1996) recounted the story of a brain-damaged patient whose amnesia left her unable to recognize her physician as, each day, he shook her hand and introduced himself. One day, she yanked her hand back, for the physician had pricked her with a tack in his palm. The next time he returned to introduce himself she refused to shake his hand but couldn't explain why. Having been *classically conditioned,* she just wouldn't do it.

The *cerebellum* plays a key role in forming and storing the implicit memories created by classical conditioning. With a damaged cerebellum, people cannot develop certain conditioned reflexes, such as associating a tone with an impending puff of air—and thus do not blink in anticipation of the puff (Daum & Schugens, 1996; Green & Woodruff-Pak, 2000). When researchers surgically disrupted the function of different pathways in the cerebellum of rabbits, the rabbits became unable to learn a conditioned eyeblink response (Krupa et al., 1993; Steinmetz, 1999). Implicit memory formation needs the cerebellum (**FIGURE 32.2**).

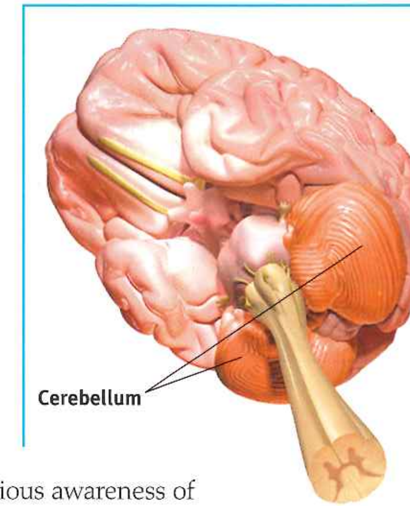



**Figure 32.2**
**Cerebellum** The cerebellum plays an important part in our forming and storing of implicit memories.

The *basal ganglia,* deep brain structures involved in motor movement, facilitate formation of our procedural memories for skills (Mishkin, 1982; Mishkin et al., 1997). The basal ganglia receive input from the cortex but do not return the favor of sending information back to the cortex for conscious awareness of procedural learning. If you have learned how to ride a bike, thank your basal ganglia.

Our implicit memory system, enabled partly by the cerebellum and basal ganglia, helps explain why the reactions and skills we learned during infancy reach far into our future. Yet as adults, our conscious memory of our first three years is blank, an experience called *infantile amnesia.* In one study, events children experienced and discussed with their mothers at age 3 were 60 percent remembered at age 7 but only 34 percent remembered at age 9 (Bauer et al., 2007). Two influences contribute to infantile amnesia: First, we index much of our explicit memory using words that nonspeaking children have not learned. Second, the hippocampus is one of the last brain structures to mature.

## The Amygdala, Emotions, and Memory

**32-4** How do emotions affect our memory processing?

Our emotions trigger stress hormones that influence memory formation. When we are excited or stressed, these hormones make more glucose energy available to fuel brain activity, signaling the brain that something important has happened. Moreover, stress hormones provoke the *amygdala* (two limbic system, emotion-processing clusters) to initiate a memory

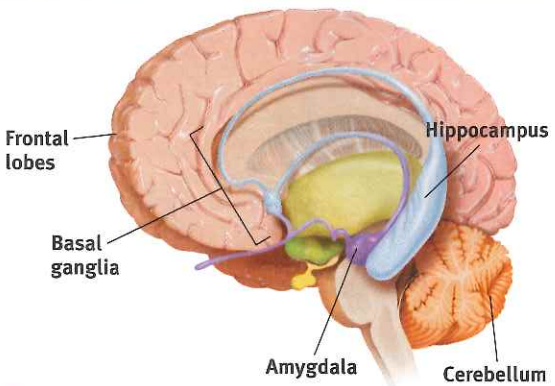



**Figure 32.3**
**Review key memory structures in the brain**
*Frontal lobes* and *hippocampus:* explicit memory formation
*Cerebellum* and *basal ganglia:* implicit memory formation
*Amygdala:* emotion-related memory formation

trace in the frontal lobes and basal ganglia and to boost activity in the brain's memory-forming areas (Buchanan, 2007; Kensinger, 2007) (**FIGURE 32.3**). The result? Emotional arousal can sear certain events into the brain, while disrupting memory for neutral events around the same time (Birnbaum et al., 2004; Brewin et al., 2007).

Emotions often persist without our conscious awareness of what caused them. In one ingenious experiment, patients with hippocampal damage (which left them unable to form new explicit memories) watched a sad film and later a happy film. After the viewing, they did not consciously recall the films, but the sad or happy emotion persisted (Feinstein et al., 2010).

Significantly stressful events can form almost indelible (unforgettable) memories. After traumatic experiences—a school shooting, a house fire, a rape—vivid recollections of the horrific event may intrude again and again. It is as if they were burned in: "Stronger emotional experiences make for stronger, more reliable memories," noted James McGaugh (1994, 2003). This makes adaptive sense. Memory serves to predict the future and to alert us to potential dangers. Conversely, weaker emotions mean weaker memories. People given a drug that blocked the effects of stress hormones later had more trouble remembering the details of an upsetting story (Cahill, 1994).

Emotion-triggered hormonal changes help explain why we long remember exciting or shocking events, such as our first kiss or our whereabouts when learning of a loved one's death. In a 2006 Pew survey, 95 percent of American adults said they could recall exactly where they were or what they were doing when they first heard the news of the 9/11 terrorist attacks. This perceived clarity of memories of surprising, significant events leads some psychologists to call them **flashbulb memories.** It's as if the brain commands, "Capture this!"

**flashbulb memory** a clear memory of an emotionally significant moment or event.

**Try This**

Which is more important—your experiences or your memories of them?

The people who experienced a 1989 San Francisco earthquake did just that. A year and a half later, they had perfect recall of where they had been and what they were doing (verified by their recorded thoughts within a day or two of the quake). Others' memories for the circumstances under which they merely *heard* about the quake were more prone to errors (Neisser et al., 1991; Palmer et al., 1991).

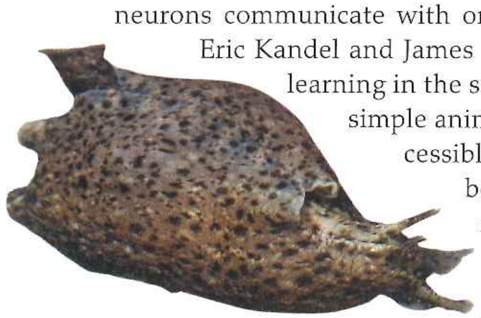
Our flashbulb memories are noteworthy for their vividness and the confidence with which we recall them. But as we relive, rehearse, and discuss them, these memories may come to err, as misinformation seeps in (Conway et al., 2009; Talarico & Rubin, 2003, 2007).

## Synaptic Changes

**32-5** How do changes at the synapse level affect our memory processing?

As you read this module and think and learn about memory characteristics and processes, your brain is changing. Given increased activity in particular pathways, neural interconnections are forming and strengthening.

The quest to understand the physical basis of memory—how information becomes embedded in brain matter—has sparked study of the synaptic meeting places where neurons communicate with one another via their neurotransmitter messengers. Eric Kandel and James Schwartz (1982) observed synaptic changes during learning in the sending neurons of the California sea slug, *Aplysia*, a simple animal with a mere 20,000 or so unusually large and accessible nerve cells. Module 26 noted how the sea slug can be classically conditioned (with electric shock) to reflexively withdraw its gills when squirted with water, much as a shell-shocked soldier jumps at the sound of a snapping twig. By observing the slug's neural connections before and after conditioning, Kandel and Schwartz pinpointed changes. When learning occurs, the slug releases more of the neurotransmitter *serotonin* into certain synapses. Those synapses then become more efficient at transmitting signals.



Art Directors & TRIP/Alamy

**Aplysia** The California sea slug, which neuroscientist Eric Kandel studied for 45 years, has increased our understanding of the neural basis of learning.



In experiments with people, rapidly stimulating certain memory-circuit connections has increased their sensitivity for hours or even weeks to come. The sending neuron now needs less prompting to release its neurotransmitter, and more connections exist between neurons (**FIGURE 32.4**). This increased efficiency of potential neural firing, called **long-term potentiation (LTP),** provides a neural basis for learning and remembering associations (Lynch, 2002; Whitlock et al., 2006). Several lines of evidence confirm that LTP is a physical basis for memory:

- Drugs that block LTP interfere with learning (Lynch & Staubli, 1991).
- Mutant mice engineered to lack an enzyme needed for LTP couldn't learn their way out of a maze (Silva et al., 1992).
- Rats given a drug that enhanced LTP learned a maze with half the usual number of mistakes (Service, 1994).
- Injecting rats with a chemical that blocked the preservation of LTP erased recent learning (Pastalkova et al., 2006).

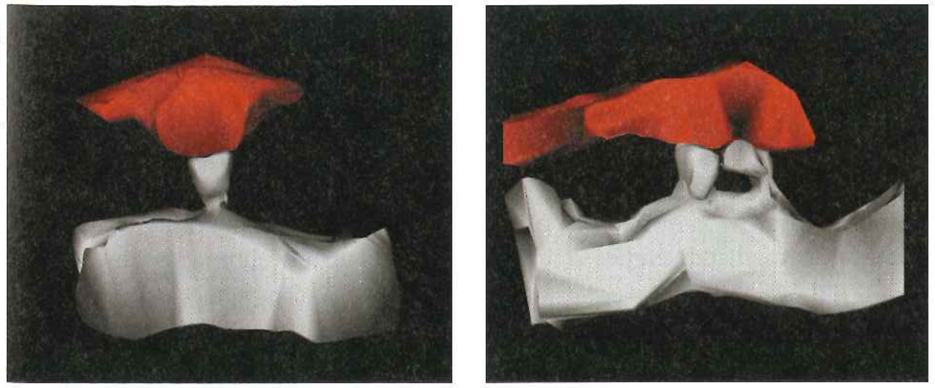
"The biology of the mind will be as scientifically important to this [new] century as the biology of the gene [was] to the twentieth century." -Eric Kandel, acceptance remarks for his 2000 Nobel Prize

**long-term potentiation (LTP)** an increase in a cell's firing potential after brief, rapid stimulation. Believed to be a neural basis for learning and memory.

After long-term potentiation has occurred, passing an electric current through the brain won't disrupt old memories. But the current will wipe out very recent memories. Such is the experience both of laboratory animals and of severely depressed people given *electroconvulsive therapy* (see Module 73). A blow to the head can do the same. Football players and boxers momentarily knocked unconscious typically have no memory of events just before the knockout (Yarnell & Lynch, 1970). Their working memory had no time to consolidate the information into long-term memory before the lights went out.

Some memory-biology explorers have helped found companies that are competing to develop memory-altering drugs. The target market for memory-boosting drugs includes millions of people with Alzheimer's disease, millions more with *mild neurocognitive disorder* that often becomes Alzheimer's, and countless millions who would love to turn back the clock on age-related memory decline. From expanding memories perhaps will come bulging profits.

In your lifetime, will you have access to safe and legal drugs that boost your fading memory without nasty side effects and without cluttering your mind with trivia best forgotten? That question has yet to be answered. But in the meantime, one safe and free memory enhancer is already available for high schoolers everywhere: effective study techniques followed by adequate *sleep!* (You'll find study tips in Module 2 and at the end of this module, and sleep coverage in Modules 23 and 24.)



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(a) (b)

**Figure 32.4**
**Doubled receptor sites** Electron microscope image (a) shows just one receptor site (gray) reaching toward a sending neuron before long-term potentiation. Image (b) shows that, after LTP, the receptor sites have doubled. This means that the receiving neuron has increased sensitivity for detecting the presence of the neurotransmitter molecules that may be released by the sending neuron. (From Toni et al., 1999.)

**FIGURE 32.5** summarizes the brain's two-track memory processing and storage system for implicit (automatic) and explicit (effortful) memories.

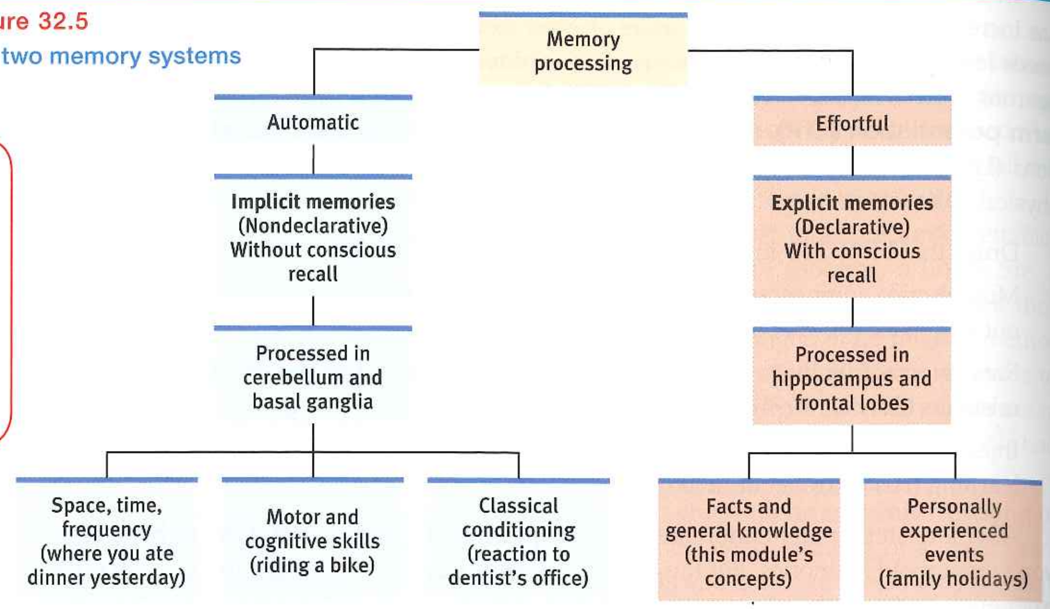



**Figure 32.5**
**Our two memory systems**

**AP® Exam Tip**

Figure 32.5 is an excellent summary. Why don't you review it for a few minutes and then see how much of it you can reproduce on a piece of paper? That will give you a good assessment of which parts of the memory process you know and which parts you still need to work on.

## Before You Move On

**▶ ASK YOURSELF**

Can you name an instance in which stress has helped you remember something, and another instance in which stress has interfered with remembering something?

**▶ TEST YOURSELF**

Your friend tells you that her father experienced brain damage in an accident. She wonders if psychology can explain why he can still play checkers very well but has a hard time holding a sensible conversation. What can you tell her?

*Answers to the Test Yourself questions can be found in Appendix E at the end of the book.*

## Retrieval: Getting Information Out

After the magic of brain encoding and storage, we still have the daunting task of retrieving the information. What triggers retrieval? How do psychologists study this phenomenon?

### Measuring Retention

**32-6** How is memory measured?

To a psychologist, evidence of memory includes these three *measures of retention:*

- **recall**—retrieving information that is not currently in your conscious awareness but that was learned at an earlier time. A fill-in-the-blank question tests your recall.
- **recognition**—identifying items previously learned. A multiple-choice question tests your recognition.
- **relearning**—learning something more quickly when you learn it a second or later time. When you study for a final exam or engage a language used in early childhood, you will relearn the material more easily than you did initially.

**recall** a measure of memory in which the person must retrieve information learned earlier, as on a fill-in-the-blank test.

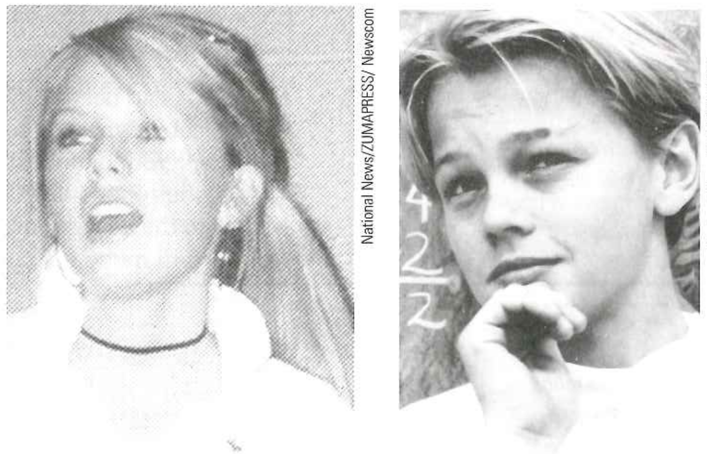
**recognition** a measure of memory in which the person need only identify items previously learned, as on a multiple-choice test.

**relearning** a measure of memory that assesses the amount of time saved when learning material again.



Long after you cannot recall most of the people in your high school graduating class, you may still be able to recognize their yearbook pictures from a photographic lineup and pick their names from a list of names. In one experiment, people who had graduated 25 years earlier could not *recall* many of their old classmates, but they could *recognize* 90 percent of their pictures and names (Bahrick et al., 1975). If you are like most students, you, too, could probably recognize more names of Snow White's Seven Dwarfs than you could recall (Miserandino, 1991).

Our recognition memory is impressively quick and vast. "Is your friend wearing a new or old outfit?""Old.""Is this 5-second movie clip from a film you've ever seen?""Yes.""Have you ever seen this person before—this minor variation on the same old human features (two eyes, one nose, and so on)?""No." Before the mouth can form our answer to any of millions of such questions, the mind knows, and knows that it knows.




**Remembering things past** Even if Taylor Swift and Leonardo DiCaprio had not become famous, their high school classmates would most likely still recognize their high school photos.

Our speed at *relearning* also reveals memory. Hermann Ebbinghaus showed this more than a century ago, in his learning experiments, using nonsense syllables. He randomly selected a sample of syllables, practiced them, and tested himself. To get a feel for his experiments, rapidly read aloud, eight times over, the following list (from Baddeley, 1982), then look away and try to recall the items:

JIH, BAZ, FUB, YOX, SUJ, XIR, DAX, LEQ, VUM, PID, KEL, WAV, TUV, ZOF, GEK, HIW.

The day after learning such a list, Ebbinghaus could recall few of the syllables. But they weren't entirely forgotten. As **FIGURE 32.6** portrays, the more frequently he repeated the list aloud on day 1, the fewer repetitions he required to *relearn* the list on day 2. Additional rehearsal *(overlearning)* of verbal information increases retention, especially when practice is distributed over time. For students, this means that it is important to continue to rehearse course material even after you know it.

*The point to remember:* Tests of recognition and of time spent relearning demonstrate that *we remember more than we can recall.*

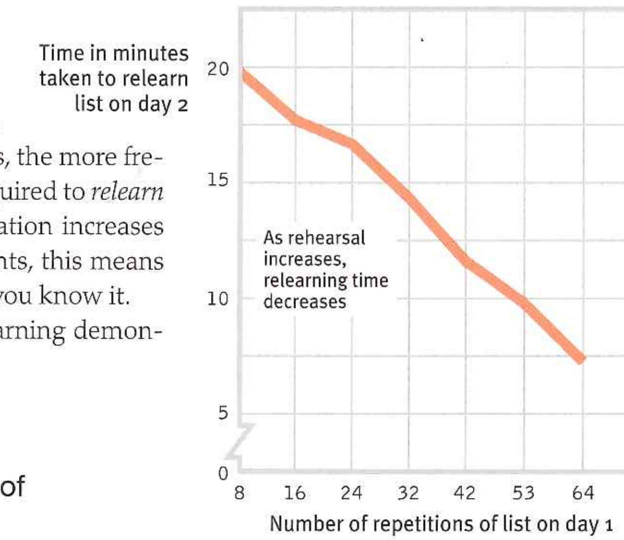



**Figure 32.6**
**Ebbinghaus' retention curve** Ebbinghaus found that the more times he practiced a list of nonsense syllables on day 1, the fewer repetitions he required to relearn it on day 2. Speed of relearning is one measure of memory retention. (From Baddeley, 1982.)

### Retrieval Cues

**32-7** How do external cues, internal emotions, and order of appearance influence memory retrieval?

Imagine a spider suspended in the middle of her web, held up by the many strands extending outward from her in all directions to different points. If you were to trace a pathway to the spider, you would first need to create a path from one of these anchor points and then follow the strand down into the web.

The process of retrieving a memory follows a similar principle, because memories are held in storage by a web of associations, each piece of information interconnected with others. When you encode into memory a target piece of information, such as the name of the person sitting next to you in class, you associate with it other bits of information about your surroundings, mood, seating position, and so on. These bits can serve as *retrieval cues* that you can later use to access the information. The more retrieval cues you have, the better your chances of finding a route to the suspended memory.

"Memory is not like a container that gradually fills up; it is more like a tree growing hooks onto which memories are hung." -Peter Russell, *The Brain Book*, 1979

#### PRIMING

The best retrieval cues come from associations we form at the time we encode a memory—smells, tastes, and sights that can evoke our memory of the associated person or event. To call up visual cues when trying to recall something, we may mentally place ourselves in the

**priming** the activation, often unconsciously, of particular associations in memory.

original context. After losing his sight, British scholar John Hull (1990, p. 174) described his difficulty recalling such details:

> I knew I had been somewhere, and had done particular things with certain people, but where? I could not put the conversations . . . into a context. There was no background, no features against which to identify the place. Normally, the memories of people you have spoken to during the day are stored in frames which include the background.

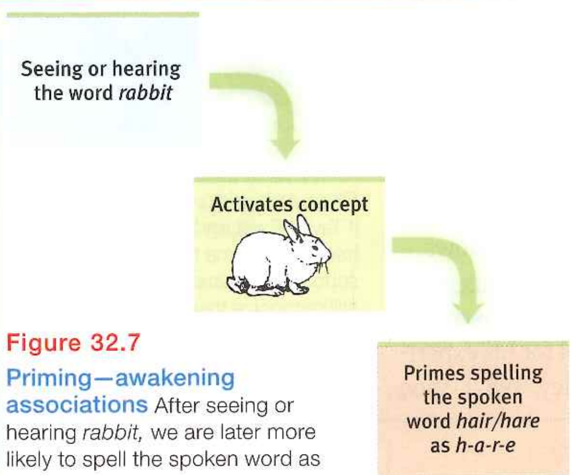



**Figure 32.7**
**Priming—awakening associations** After seeing or hearing *rabbit*, we are later more likely to spell the spoken word as *h-a-r-e*. The spreading of associations unconsciously activates related associations. This phenomenon is called priming. (Adapted from Bower, 1986.)

Often our associations are activated without our awareness. The philosopher-psychologist William James referred to this process, which we call **priming,** as the "wakening of associations." Seeing or hearing the word *rabbit* primes associations with *hare,* even though we may not recall having seen or heard *rabbit* (**FIGURE 32.7**).

Priming is often "memoryless memory"—invisible memory, without your conscious awareness. If, walking down a hallway, you see a poster of a missing child, you may then unconsciously be primed to interpret an ambiguous adult-child interaction as a possible kidnapping (James, 1986). Although you no longer have the poster in mind, it predisposes your interpretation.

Priming can influence behaviors as well. In one study, participants primed with money-related words were less likely to help another person when asked (Vohs et al., 2006). In such cases, money may prime our materialism and self-interest rather than the social norms that encourage us to help (Ariely, 2009).

## CONTEXT-DEPENDENT MEMORY

Putting yourself back in the context where you experienced something can prime your memory retrieval. As **FIGURE 32.8** illustrates, when scuba divers listened to a word list in two different settings (either 10 feet underwater or sitting on the beach), they recalled more words if retested in the same place (Godden & Baddeley, 1975).

You may have experienced similar context effects. Consider this scenario: While taking notes from this book, you realize you need to sharpen your pencil. You get up and walk into another room, but then you cannot remember why. After returning to your desk it hits you: "I wanted to sharpen this pencil!" What happens to create this frustrating experience?

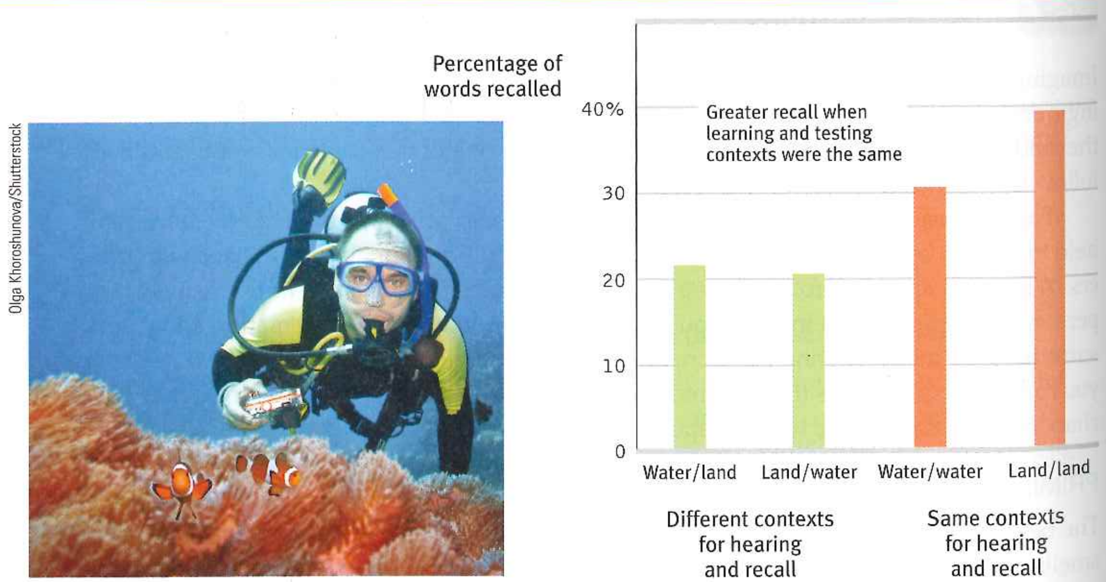



**Figure 32.8**
**The effects of context on memory** In this experiment, words heard underwater were best recalled underwater. Words heard on land were best recalled on land. (Adapted from Godden & Baddeley, 1975.)



In one context (desk, reading psychology), you realize your pencil needs sharpening. When you go to the other room and are in a different context, you have few cues to lead you back to that thought. When you are once again at your desk, you are back in the context in which you encoded the thought (*"This pencil is dull"*).

In several experiments, one researcher found that a familiar context could activate memories even in 3-month-olds (Rovee-Collier, 1993). After infants learned that kicking a crib mobile would make it move (via a connecting ribbon from the ankle), the infants kicked more when tested again in the same crib with the same bumper than when in a different context.

**Try This**

Ask a friend two rapid-fire questions: (a) How do you pronounce the word spelled by the letters s-h-o-p? (b) What do you do when you come to a green light? If your friend answers "stop" to the second question, you have demonstrated priming.

## STATE-DEPENDENT MEMORY

Closely related to context-dependent memory is *state-dependent memory*. What we learn in one state—be it drunk or sober—may be more easily recalled when we are again in that state. What people learn when drunk they don't recall well in *any* state (alcohol disrupts storage). But they recall it slightly better when again drunk. Someone who hides money when drunk may forget the location until drunk again.



*"I can't remember what we're arguing about, either. Let's keep yelling, and maybe it will come back to us."*

Our mood states provide an example of memory's state dependence. Emotions that accompany good or bad events become retrieval cues (Fiedler et al., 2001). Thus, our memories are somewhat **mood congruent.** If you've had a bad evening—your date never showed, your Chicago Cubs hat disappeared, your TV went out 10 minutes before the end of a show—your gloomy mood may facilitate recalling other bad times. Being depressed sours memories by priming negative associations, which we then use to explain our current mood. In many experiments, people put in a buoyant mood—whether under hypnosis or just by the day's events (a World Cup soccer victory for German participants in one study)—have recalled the world through rose-colored glasses (DeSteno et al., 2000; Forgas et al., 1984; Schwarz et al., 1987). They judged themselves competent and effective, other people benevolent, happy events more likely.

Knowing this mood-memory connection, we should not be surprised that in some studies *currently* depressed people have recalled their parents as rejecting, punitive, and guilt promoting, whereas *formerly* depressed people's recollections more closely resembled the more positive descriptions given by those who never suffered depression (Lewinsohn & Rosenbaum, 1987; Lewis, 1992). Similarly, adolescents' ratings of parental warmth in one week gave little clue to how they would rate their parents six weeks later (Bornstein et al., 1991). When teens were down, their parents seemed inhuman; as their mood brightened, their parents morphed from devils into angels. In a good or bad mood, we persist in attributing to reality our own changing judgments, memories, and interpretations. In a bad mood, we may read someone's look as a glare and feel even worse. In a good mood, we may encode the same look as interest and feel even better. Passions exaggerate.

"When a feeling was there, they felt as if it would never go; when it was gone, they felt as if it had never been; when it returned, they felt as if it had never gone." -George MacDonald, *What's Mine's Mine*, 1886

This retrieval effect helps explain why our moods persist. When happy, we recall happy events and therefore see the world as a happy place, which helps prolong our good mood. When depressed, we recall sad events, which darkens our interpretations of current events. For those of us with a predisposition to depression, this process can help maintain a vicious, dark cycle.

## SERIAL POSITION EFFECT

Another memory-retrieval quirk, the **serial position effect,** can leave us wondering why we have large holes in our memory of a list of recent events. Imagine it's your first day in a new job, and your manager is introducing co-workers. As you meet each person, you silently repeat everyone's name, starting from the beginning. As the last person smiles and turns away, you feel confident you'll be able to greet your new co-workers by name the next day.

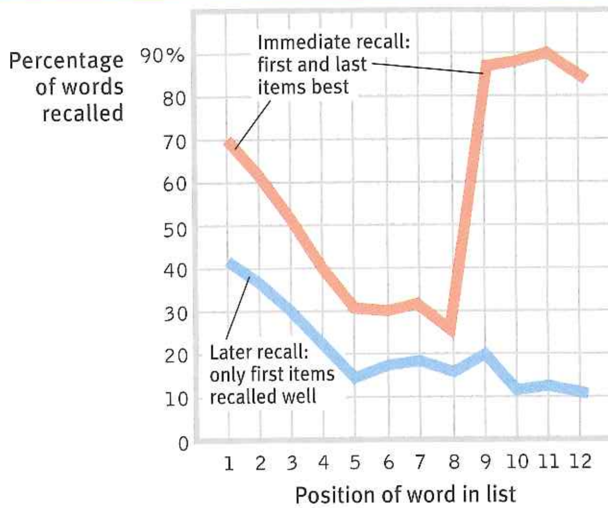
Don't count on it. Because you have spent more time rehearsing the earlier names than the later ones, those are the names you'll probably recall more easily the next day.

**mood-congruent memory** the tendency to recall experiences that are consistent with one's current good or bad mood.

**serial position effect** our tendency to recall best the last (a *recency effect*) and first items (a *primacy effect*) in a list.

Figure 32.9

**The serial position effect** Immediately after the royal newlyweds, William and Kate, made their way through the receiving line of special guests, they would probably have recalled the names of the last few people best. But later they may have been able to recall the first few people best.





In experiments, when people view a list of items (words, names, dates, even odors) and immediately try to recall them in any order, they fall prey to the serial position effect (Reed, 2000). They briefly recall the last items especially quickly and well (*a recency effect*), perhaps because those last items are still in working memory. But after a delay, when they have shifted their attention away from the last items, their recall is best for the first items (*a primacy effect;* see **FIGURE 32.9**).

## Before You Move On

**▶ ASK YOURSELF**

What sort of mood have you been in lately? How has your mood colored your memories, perceptions, and expectations?

**▶ TEST YOURSELF**

You have just watched a movie that includes a chocolate factory. After the chocolate factory is out of mind, you nevertheless feel a strange urge for a chocolate bar. How do you explain this in terms of priming?

*Answers to the Test Yourself questions can be found in Appendix E at the end of the book.*

# Module 32 Review

### 32-1 What is the capacity of long-term memory? Are our long-term memories processed and stored in specific locations?

- Our long-term memory capacity is essentially unlimited.
- Memories are not stored intact in the brain in single spots. Many parts of the brain interact as we form and retrieve memories.

### 32-2 What are the roles of the frontal lobes and hippocampus in memory processing?

- The frontal lobes and *hippocampus* are parts of the brain network dedicated to explicit memory formation.
  - Many brain regions send information to the frontal lobes for processing.
  - The hippocampus, with the help of surrounding areas of cortex, registers and temporarily holds elements of explicit memories before moving them to other brain regions for long-term storage.



### 32-3 What roles do the cerebellum and basal ganglia play in our memory processing?

- The cerebellum and basal ganglia are parts of the brain network dedicated to implicit memory formation.
  - The cerebellum is important for storing classically conditioned memories.
  - The basal ganglia are involved in motor movement and help form procedural memories for skills.
- Many reactions and skills learned during our first three years continue into our adult lives, but we cannot consciously remember learning these associations and skills, a phenomenon psychologists call "infantile amnesia."

### 32-4 How do emotions affect our memory processing?

- Emotional arousal causes an outpouring of stress hormones, which lead to activity in the brain's memory-forming areas. Significantly stressful events can trigger very clear *flashbulb memories.*

### 32-5 How do changes at the synapse level affect our memory processing?

- *Long-term potentiation (LTP)* appears to be the neural basis for learning and memory. In LTP, neurons become more efficient at releasing and sensing the presence of neurotransmitters, and more connections develop between neurons.

### 32-6 How is memory measured?

- Evidence of memory may be seen in an ability to *recall* information, *recognize* it, or *relearn* it more easily on a later attempt.

### 32-7 How do external cues, internal emotions, and order of appearance influence memory retrieval?

- External cues activate associations that help us retrieve memories; this process may occur without our awareness, as it does in *priming.*
- Returning to the same physical context or emotional state *(mood congruency)* in which we formed a memory can help us retrieve it.
- The *serial position effect* accounts for our tendency to recall best the last items (which may still be in working memory) and the first items (which we've spent more time rehearsing) in a list.

## Multiple-Choice Questions

**1.** What two parts of the brain are most involved in explicit memory?

a. Frontal lobes and basal ganglia
b. Amygdala and hippocampus
c. Amygdala and cerebellum
d. Cerebellum and basal ganglia
e. Frontal lobes and hippocampus

**2.** Which of the following statements most accurately reflects the relationship between emotions and memory?

a. Emotion blocks memory, and it is generally true that we are unable to recall highly emotional events.
b. Excitement tends to increase the chance that an event will be remembered, but stress decreases the chance that an event will be remembered.
c. Stress tends to increase the chance that an event will be remembered, but excitement decreases the chance that an event will be remembered.
d. The effect of emotion on memory depends on the interpretation of the event in the frontal lobes.
e. Emotion enhances memory because it is important for our survival to remember events that make us emotional.