Unit VII

Cognition

Modules

I revised this unit's first three modules after collaborating with Janie Wilson, Professor of Psychology at Georgia Southern University and Vice President for Programming of the Society for the Teaching of Psychology.

Throughout history, we humans have both bemoaned our foolishness and celebrated our wisdom. The poet T. S. Eliot was struck by "the hollow men . . . Headpiece filled with straw." But Shakespeare's Hamlet extolled the human species as "noble in reason! . . . infinite in faculties! . . . in apprehension how like a god!" In the preceding units, we have likewise marveled at both our abilities and our errors.

Elsewhere in this text, we study the human brain—three pounds of wet tissue the size of a small cabbage, yet containing circuitry more complex than the planet's telephone networks. We appreciate the amazing abilities of newborns. We marvel at our sensory system, translating visual stimuli into nerve impulses, distributing them for parallel processing, and reassembling them into colorful perceptions. Little wonder that our species has had the collective genius to invent the camera, the car, and the computer; to unlock the atom and crack the genetic code; to travel out to space and into our brain's depths.

Yet we have also seen that our species is kin to the other animals, influenced by the same principles that produce learning in rats and pigeons. We have noted that we not-so-wise humans are easily deceived by perceptual illusions, pseudopsychic claims, and false memories.

In this unit, we encounter further instances of these two images of the human condition—the rational and the irrational. We will ponder our memory's enormous capacity, and the ease with which our two-track mind processes information, with and without our awareness. We will consider how we use and misuse the information we receive, perceive, store, and retrieve. We will look at our gift for language and consider how and why it develops. And we will reflect on how deserving we are of our species name, *Homo sapiens*—wise human.

Module 31

Studying and Building Memories


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Module Learning Objectives

31-1 Define *memory.*

31-2 Explain how psychologists describe the human memory system.

31-3 Distinguish between explicit and implicit memories.

31-4 Identify the information we process automatically.

31-5 Explain how sensory memory works.

31-6 Describe the capacity of our short-term and working memory.

31-7 Describe the effortful processing strategies that help us remember new information.

31-8 Describe the levels of processing and their effect on encoding.

Be thankful for memory. We take it for granted, except when it malfunctions. But it is our memory that accounts for time and defines our life. It is our memory that enables us to recognize family, speak our language, find our way home, and locate food and water. It is our memory that enables us to enjoy an experience and then mentally replay and enjoy it again. And it is our memory that occasionally pits us against those whose offenses we cannot forget.

AP® Exam Tip

The next three modules deal with memory. Not only is this a significant topic on the AP® exam, it is also one of the most practical topics in psychology, especially if you're a student! Some of your preconceptions about memory may be accurate and some may not. As you read, think about how you can apply what you're learning in order to be a better student.

In large part, we are what we remember. Without memory—our storehouse of accumulated learning—there would be no savoring of past joys, no guilt or anger over painful recollections. We would instead live in an enduring present, each moment fresh. But each person would be a stranger, every language foreign, every task—dressing, eating, biking—a new challenge. You would even be a stranger to yourself, lacking that continuous sense of self that extends from your distant past to your momentary present.

Studying Memory

31-1 What is memory?

memory the persistence of learning over time through the encoding, storage, and retrieval of information.

To a psychologist, **memory** is learning that has persisted over time; it is information that has been acquired, stored, and can be retrieved.

Research on memory's extremes has helped us understand how memory works. At age 92, my father suffered a small stroke that had but one peculiar effect. He was as mobile as before. His genial personality was intact. He knew us and enjoyed poring over family photo albums and reminiscing about his past. But he had lost most of his ability to lay down new memories of conversations and everyday episodes. He could not tell me what day of the week it was, or what he'd had for lunch. Told repeatedly of his brother-in-law's death, he was surprised and saddened each time he heard the news.

At the other extreme are people who would be gold medal winners in a memory Olympics. Russian journalist Shereshevskii, or S, had merely to listen while other reporters scribbled notes (Luria, 1968). You and I could parrot back a string of about 7—maybe even 9—digits. S could repeat up to 70, if they were read about 3 seconds apart in an otherwise silent room. Moreover, he could recall digits or words backward as easily as forward. His accuracy was unerring, even when recalling a list as much as 15 years later. "Yes, yes," he might recall. "This was a series you gave me once when we were in your apartment. . . . You were sitting at the table and I in the rocking chair. . . . You were wearing a gray suit. . . ."

Amazing? Yes, but consider your own impressive memory. You remember countless voices, sounds, and songs; tastes, smells, and textures; faces, places, and happenings. Imagine viewing more than 2500 slides of faces and places for 10 seconds each. Later, you see 280 of these slides, paired with others you've never seen. Actual participants in this experiment recognized 90 percent of the slides they had viewed in the first round (Haber, 1970). In a follow-up experiment, people exposed to 2800 images for only 3 seconds each spotted the repeats with 82 percent accuracy (Konkle et al., 2010).

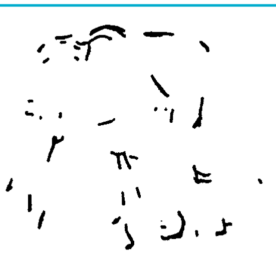


Figure 31.1
What is this? People who had, 17 years earlier, seen the complete image (in Figure 31.4 when you turn the page) were more likely to recognize this fragment, even if they had forgotten the earlier experience (Mitchell, 2006).

Or imagine yourself looking at a picture fragment, such as the one in **FIGURE 31.1.** Also imagine that you had seen the complete picture for a couple of seconds 17 years earlier. This, too, was a real experiment, and participants who had previously seen the complete drawings were more likely to identify the objects than were members of a control group (Mitchell, 2006). Moreover, the picture memory reappeared even for those who did not consciously recall participating in the long-ago experiment!

How do we accomplish such memory feats? How does our brain pluck information out of the world around us and tuck that information away for later use? How can we remember things we have not thought about for years, yet forget the name of someone we met a minute ago? How are memories stored in our brains? Why will you be likely, later in this module, to misrecall this sentence: *"The angry rioter threw the rock at the window"*? In this and the next two modules, we'll consider these fascinating questions and more, including tips on how we can improve our own memories.

Memory Models

31-2 How do psychologists describe the human memory system?

Architects make miniature house models to help clients imagine their future homes. Similarly, psychologists create memory models to help us think about how our brain forms and retrieves memories. *Information-processing models* are analogies that compare human memory to a computer's operations. Thus, to remember any event, we must

- *get information into our brain,* a process called **encoding.**
- *retain that information,* a process called **storage.**
- later *get the information back out,* a process called **retrieval.**

Like all analogies, computer models have their limits. Our memories are less literal and more fragile than a computer's. Moreover, most computers process information sequentially, even while alternating between tasks. Our dual-track brain processes many things simultaneously (some of them unconsciously) by means of **parallel processing**. As you enter the lunchroom, you simultaneously—in parallel—process information about the people you see, the sounds of voices, and the smell of the food.

To focus on this complex, simultaneous processing, one information-processing model, *connectionism,* views memories as products of interconnected neural networks. Specific memories arise from particular activation patterns within these networks. Every time you learn something new, your brain's neural connections change, forming and strengthening pathways that allow you to interact with and learn from your constantly changing environment.

To explain our memory-forming process, Richard Atkinson and Richard Shiffrin (1968) proposed another model, with three stages:

1. We first record to-be-remembered information as a fleeting **sensory memory.**
2. From there, we process information into **short-term memory,** where we encode it through *rehearsal.*
3. Finally, information moves into **long-term memory** for later retrieval.

Other psychologists have updated this model (**FIGURE 31.2**) to include important newer concepts, including *working memory* and *automatic processing*.

WORKING MEMORY

Alan Baddeley and others (Baddeley, 2001, 2002; Engle, 2002) challenged Atkinson and Shiffrin's view of short-term memory as a small, brief storage space for recent thoughts and experiences. Research shows that this stage is not just a temporary shelf for holding incoming information. It's an active desktop where your brain processes information, making sense of new input and linking it with long-term memories. Whether we hear *eye-screem* as "ice cream" or "I scream" will depend on how the context and our experience guide us in interpreting and encoding the sounds.

encoding the processing of information into the memory system—for example, by extracting meaning.

storage the process of retaining encoded information over time.

retrieval the process of getting information out of memory storage.

parallel processing the processing of many aspects of a problem simultaneously; the brain's natural mode of information processing for many functions. Contrasts with the step-by-step (serial) processing of most computers and of conscious problem solving.

sensory memory the immediate, very brief recording of sensory information in the memory system.

short-term memory activated memory that holds a few items briefly, such as the seven digits of a phone number while dialing, before the information is stored or forgotten.

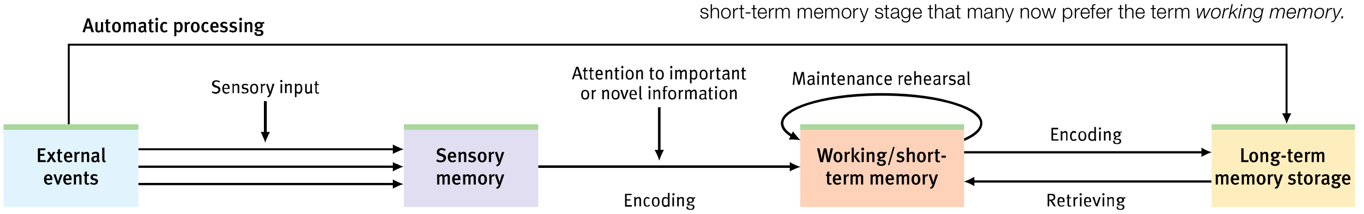
long-term memory the relatively permanent and limitless storehouse of the memory system. Includes knowledge, skills, and experiences.

AP® Exam Tip

You will see several versions of Figure 31.2 as you work your way through Modules 31, 32, and 33. Pay attention! This model may look confusing now, but will make more and more sense as its components are described in more detail.

Figure 31.2

A modified three-stage processing model of memory Atkinson and Shiffrin's classic three-step model helps us to think about how memories are processed, but today's researchers recognize other ways long-term memories form. For example, some information slips into long-term memory via a "back door," without our consciously attending to it (*automatic processing*). And so much active processing occurs in the short-term memory stage that many now prefer the term *working memory.*



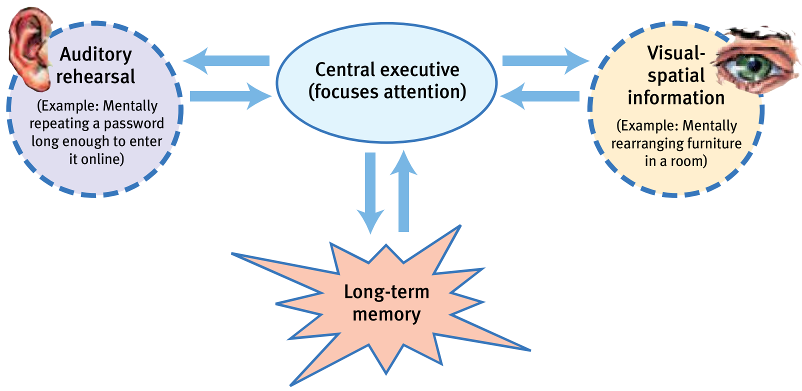


Figure 31.3
Working memory Alan Baddeley's (2002) model of working memory, simplified here, includes *visual* and *auditory rehearsal* of new information. A hypothetical *central executive* (manager) focuses attention and pulls information from long-term memory to help make sense of new information.

To emphasize the active processing that takes place in this middle stage, psychologists use the term **working memory.** Right now, you are using your working memory to link the information you're reading with your previously stored information (Cowan, 2010; Kail & Hall, 2001).

The pages you are reading may enter working memory through vision. You might also repeat the information using auditory rehearsal. As you integrate these memory inputs with your existing long-term memory, your attention is focused. Baddeley (2002) suggested a *central executive* handles this focused processing (**FIGURE 31.3**).

Without focused attention, information often fades. In one experiment, people read and typed new information they would later need, such as "An ostrich's eye is bigger than its brain." If they knew the information would be available online, they invested less energy in remembering, and they remembered the trivia less well (Sparrow et al., 2011). Sometimes Google replaces rehearsal.

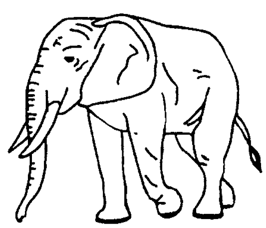


Figure 31.4
Now you know People who had seen this complete image were, 17 years later, more likely to recognize the fragment in Figure 31.1.

Before You Move On

▶ ASK YOURSELF

How have you used the three parts of your memory system (encoding, storage, and retrieval) in learning something new today?

▶ TEST YOURSELF

Memory includes (in alphabetical order) long-term memory, sensory memory, and working/short-term memory. What's the correct order of these three memory stages?

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

working memory a newer understanding of short-term memory that focuses on conscious, active processing of incoming auditory and visual-spatial information, and of information retrieved from long-term memory.

explicit memory memory of facts and experiences that one can consciously know and "declare." (Also called *declarative memory.*)

effortful processing encoding that requires attention and conscious effort.

automatic processing unconscious encoding of incidental information, such as space, time, and frequency, and of well-learned information, such as word meanings.

implicit memory retention independent of conscious recollection. (Also called *nondeclarative memory.*)

Building Memories: Encoding

Dual-Track Memory: Effortful Versus Automatic Processing

31-3 How do explicit and implicit memories differ?

As we have seen throughout this text, our mind operates on two tracks:

- Atkinson and Shiffrin's model focused on how we process our **explicit memories**—the facts and experiences we can consciously know and declare (thus, also called *declarative memories*). We encode explicit memories through conscious, **effortful processing.**
- Behind the scenes, outside the Atkinson-Shiffrin stages, other information skips the conscious encoding track and barges directly into storage. This **automatic processing,** which happens without our awareness, produces **implicit memories** (also called *nondeclarative memories*).

Automatic Processing and Implicit Memories

31-4 What information do we automatically process?

Our implicit memories include *procedural* memory for automatic skills (such as how to ride a bike) and classically conditioned *associations* among stimuli. Visiting your dentist, you may, thanks to a conditioned association linking the dentist's office with the painful drill, find yourself with sweaty palms. You didn't plan to feel that way when you got to the dentist's office; it happened *automatically*.

Without conscious effort you also automatically process information about

- *space.* While studying, you often encode the place on a page or in your notebook where certain material appears; later, when you want to retrieve information about automatic processing, for example, you may visualize the location of that information on this page.
- *time.* While going about your day, you unintentionally note the sequence of its events. Later, realizing you've left your backpack somewhere, the event sequence your brain automatically encoded will enable you to retrace your steps.
- *frequency.* You effortlessly keep track of how many times things happen, as when you suddenly realize, *This is the third time I've run into her today.*

Our two-track mind engages in impressively efficient information processing. As one track automatically tucks away many routine details, the other track is free to focus on conscious, effortful processing. This reinforces an important principle introduced in Module 18's description of parallel processing: Mental feats such as vision, thinking, and memory may seem to be single abilities, but they are not. Rather, we split information into different components for separate and simultaneous processing.

Effortful Processing and Explicit Memories

Automatic processing happens so effortlessly that it is difficult to shut off. When you see words in your native language, perhaps on the side of a delivery truck, you can't help but read them and register their meaning. *Learning* to read wasn't automatic. You may recall working hard to pick out letters and connect them to certain sounds. But with experience and practice, your reading became automatic. Imagine now learning to read reversed sentences like this:

.citamotua emoceb nac gnissecorp luftroffE

At first, this requires effort, but after enough practice, you would also perform this task much more automatically. We develop many skills in this way. We learn to drive, to text, to speak a new language with effort, but then these tasks become automatic.

SENSORY MEMORY

31-5 How does sensory memory work?

Sensory memory (recall Figure 31.2) feeds our active working memory, recording momentary images of scenes or echoes of sounds. How much of this page could you sense and recall with less exposure than a lightning flash? In one experiment (Sperling, 1960), people viewed three rows of three letters each, for only one-twentieth of a second (**FIGURE 31.5**). After the nine letters disappeared, they could recall only about half of them.

Was it because they had insufficient time to glimpse them? *No.* The researcher, George Sperling, cleverly demonstrated that people actually *could* see and recall all the letters, but only momentarily. Rather than ask them to recall all nine letters at

Figure 31.5

Total recall—briefly When George Sperling flashed a group of letters similar to this for one-twentieth of a second, people could recall only about half the letters. But when signaled to recall a particular row immediately after the letters had disappeared, they could do so with near-perfect accuracy.

K	Z	R
Q	B	T
S	G	N

iconic memory a momentary sensory memory of visual stimuli; a photographic or picture-image memory lasting no more than a few tenths of a second.

echoic memory a momentary sensory memory of auditory stimuli; if attention is elsewhere, sounds and words can still be recalled within 3 or 4 seconds.

once, he sounded a high, medium, or low tone immediately *after* flashing the nine letters. This tone directed participants to report only the letters of the top, middle, or bottom row, respectively. Now they rarely missed a letter, showing that all nine letters were momentarily available for recall.

Sperling's experiment demonstrated **iconic memory,** a fleeting sensory memory of visual stimuli. For a few tenths of a second, our eyes register a photographic or picture-image memory of a scene, and we can recall any part of it in amazing detail. But if Sperling delayed the tone signal by more than half a second, the image faded and participants again recalled only about half the letters. Our visual screen clears quickly, as new images are superimposed over old ones.

We also have an impeccable, though fleeting, memory for auditory stimuli, called **echoic memory** (Cowan, 1988; Lu et al., 1992). Picture yourself in class, as your attention veers to thoughts of the weekend. If your mildly irked teacher tests you by asking, "What did I just say?" you can recover the last few words from your mind's echo chamber. Auditory echoes tend to linger for 3 or 4 seconds.

CAPACITY OF SHORT-TERM AND WORKING MEMORY

31-6 What is the capacity of our short-term and working memory?

FYI

The Magical Number Seven has become psychology's contribution to an intriguing list of magic sevens—the Seven Wonders of the Ancient World, the seven seas, the seven deadly sins, the seven primary colors, the seven musical scale notes, the seven days of the week—seven magical sevens.

George Miller (1956) proposed that short-term memory can retain about seven information bits (give or take two). Other researchers have confirmed that we can, if nothing distracts us, recall about seven digits, or about six letters or five words (Baddeley et al., 1975). How quickly do our short-term memories disappear? To find out, researchers asked people to remember three-consonant groups, such as *CHJ* (Peterson & Peterson, 1959). To prevent rehearsal, the researchers asked them, for example, to start at 100 and count aloud backward by threes. After 3 seconds, people recalled the letters only about half the time; after 12 seconds, they seldom recalled them at all (**FIGURE 31.6**). Without the active processing that we now understand to be a part of our working memory, short-term memories have a limited life.

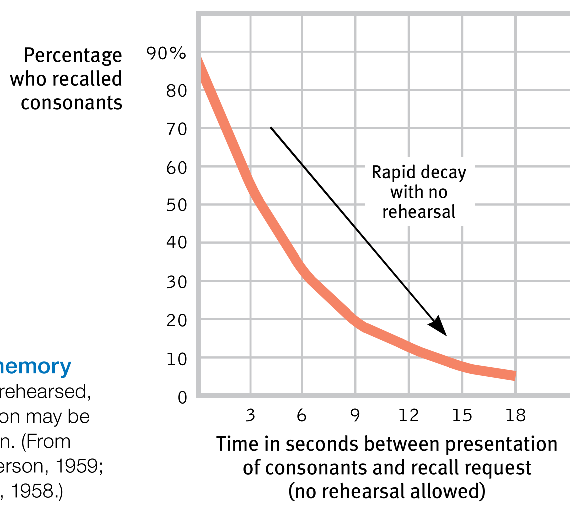


Figure 31.6
Short-term memory decay Unless rehearsed, verbal information may be quickly forgotten. (From Peterson & Peterson, 1959; see also Brown, 1958.)

Working-memory capacity varies, depending on age and other factors. Compared with children and older adults, young adults have more working-memory capacity, so they can use their mental workspace more efficiently. This means their ability to multitask is relatively greater. But whatever our age, we do better and more efficient work when focused, without distractions, on one task at a time. "One of the most stubborn, persistent phenomenon of the mind," notes cognitive psychologist Daniel Willingham (2010), "is that when you do two things at once, you don't do either one as well as when you do them one at a time." *The bottom line:* It's probably a bad idea to try to watch TV, text your friends, and write a psychology paper all at the same time!

EFFORTFUL PROCESSING STRATEGIES

31-7 What are some effortful processing strategies that can help us remember new information?

Research shows that several effortful processing strategies can boost our ability to form new memories. Later, when we try to retrieve a memory, these strategies can make the difference between success and failure.

CHUNKING Glance for a few seconds at row 1 of **FIGURE 31.7,** then look away and try to reproduce what you saw. Impossible, yes? But you can easily reproduce the second row, which is no less complex. Similarly, you will probably find row 4 much easier to remember than row 3, although both contain the same letters. And you could remember the sixth cluster more easily than the fifth, although both contain the same words. As these units demonstrate, **chunking** information—organizing items into familiar, manageable units—enables us to recall it more easily. Try remembering 43 individual numbers and letters. It would be impossible, unless chunked into, say, seven meaningful chunks, such as "Try remembering 43 individual numbers and letters."☺

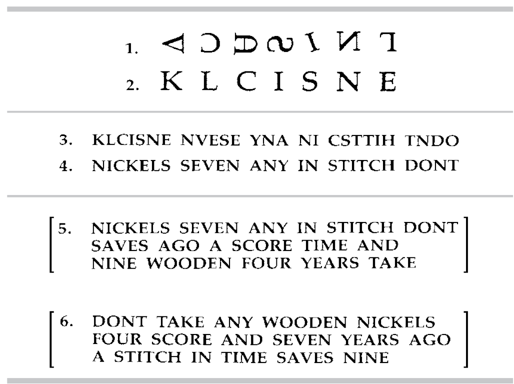


Figure 31.7
Effects of chunking on memory When we organize information into meaningful units, such as letters, words, and phrases, we recall it more easily. (From Hintzman, 1978.)

Chunking usually occurs so naturally that we take it for granted. If you are a native English speaker, you can reproduce perfectly the 150 or so line segments that make up the words in the three phrases of item 6 in Figure 31.7. It would astonish someone unfamiliar with the language. I am similarly awed at a Chinese reader's ability to glance at **FIGURE 31.8** and then reproduce all the strokes; or of a varsity basketball player's recall of the positions of the players after a 4-second glance at a basketball play (Allard & Burnett, 1985). We all remember information best when we can organize it into personally meaningful arrangements.

春
夏
秋
冬

Figure 31.8
An example of chunking—for those who read Chinese After looking at these characters, can you reproduce them exactly? If so, you are literate in Chinese.

MNEMONICS To help them encode lengthy passages and speeches, ancient Greek scholars and orators also developed **mnemonics** (nih-MON-iks). Many of these memory aids use vivid imagery, because we are particularly good at remembering mental pictures. We more easily remember concrete, visualizable words than we do abstract words. (When I quiz you later, in Module 33, which three of these words—*bicycle, void, cigarette, inherent, fire, process*—will you most likely recall?) If you still recall the rock-throwing rioter sentence, it is probably not only because of the meaning you encoded but also because the sentence painted a mental image.

The *peg-word system* harnesses our superior visual-imagery skill. This mnemonic requires you to memorize a jingle: *"One is a bun; two is a shoe; three is a tree; four is a door; five is a hive; six is sticks; seven is heaven; eight is a gate; nine is swine; ten is a hen."* Without much effort, you will soon be able to count by peg words instead of numbers: *bun, shoe, tree* . . . and then to visually associate the peg words with to-be-remembered items. Now you are ready to challenge anyone to give you a grocery list to remember. Carrots? Stick them into the imaginary bun. Milk? Fill the shoe with it. Paper towels? Drape them over the tree branch. Think *bun, shoe, tree* and you see their associated images: carrots, milk, paper towels. With few errors, you will be able to recall the items in any order and to name any given item (Bugelski et al., 1968). Memory whizzes understand the power of such systems. A study of star performers in the World Memory Championships showed them not to have exceptional intelligence, but rather to be superior at using mnemonic strategies (Maguire et al., 2003).

Chunking and mnemonic techniques combined can be great memory aids for unfamiliar material. Want to remember the colors of the rainbow in order of wavelength? Think of the mnemonic ROY G. BIV (*r*ed, *o*range, *y*ellow, *g*reen, *b*lue, *i*ndigo, *v*iolet). Need to recall the names of North America's five Great Lakes? Just remember HOMES (*H*uron, *O*ntario, *M*ichigan, *E*rie, *S*uperior). In each case, we chunk information into a more familiar form by creating a word (called an *acronym*) from the first letters of the to-be-remembered items.

chunking organizing items into familiar, manageable units; often occurs automatically.

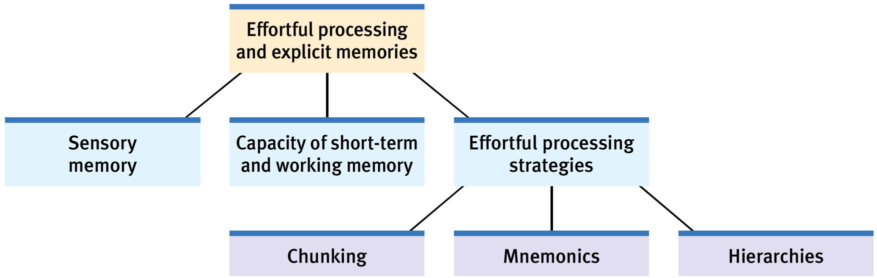
mnemonics [nih-MON-iks] memory aids, especially those techniques that use vivid imagery and organizational devices.

HIERARCHIES When people develop expertise in an area, they process information not only in chunks but also in *hierarchies* composed of a few broad concepts divided and subdivided into narrower concepts and facts. This section, for example, aims to help you organize some of the memory concepts we have been discussing (**FIGURE 31.9**).

Organizing knowledge in hierarchies helps us retrieve information efficiently, as Gordon Bower and his colleagues (1969) demonstrated by presenting words either randomly or grouped into categories. When the words were organized into categories, recall was two to three times better. Such results show the benefits of organizing what you study—of giving special attention to the module objectives, headings, and Ask Yourself and Test Yourself questions. Taking class and text notes in outline format—a type of hierarchical organization—may also prove helpful.

Figure 31.9

Hierarchies aid retrieval When we organize words or concepts into hierarchical groups, as illustrated here with some of the concepts from this section, we remember them better than when we see them presented randomly.



"The mind is slow in unlearning what it has been long in learning."
-Roman philosopher Seneca (4 B.C.E.–65 C.E.)

AP® Exam Tip

It's not the studying you do in May that will determine your success on the AP® exam; it's the studying you do now. It's a good idea to take a little time each week to quickly review material from earlier in the course. When was the last time you looked at information from the previous units?

spacing effect the tendency for distributed study or practice to yield better long-term retention than is achieved through massed study or practice.

testing effect enhanced memory after retrieving, rather than simply rereading, information. Also sometimes referred to as a *retrieval practice effect* or *test-enhanced learning*.

shallow processing encoding on a basic level based on the structure or appearance of words.

DISTRIBUTED PRACTICE

We retain information (such as classmates' names) better when our encoding is distributed over time. More than 300 experiments over the last century have consistently revealed the benefits of this **spacing effect** (Cepeda et al., 2006). *Massed practice* (cramming) can produce speedy short-term learning and a feeling of confidence. But to paraphrase pioneer memory researcher Hermann Ebbinghaus (1885), those who learn quickly also forget quickly. *Distributed practice* produces better long-term recall. After you've studied long enough to master the material, further study at that time becomes inefficient (Rohrer & Pashler, 2007). Better to spend that extra reviewing time later—a day later if you need to remember something 10 days hence, or a month later if you need to remember something 6 months hence (Cepeda et al., 2008).

Spreading your learning over several months, rather than over a shorter term, can help you retain information for a lifetime. In a 9-year experiment, Harry Bahrick and three of his family members (1993) practiced foreign language word translations for a given number of times, at intervals ranging from 14 to 56 days. Their consistent finding: The longer the space between practice sessions, the better their retention up to 5 years later.

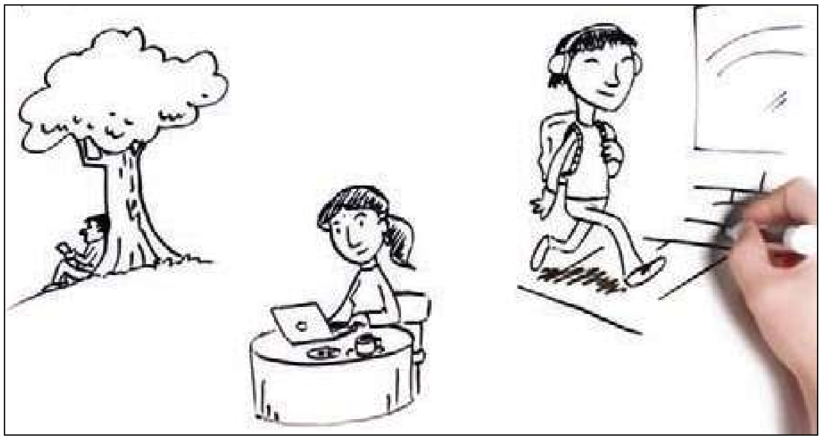
One effective way to distribute practice is *repeated self-testing,* a phenomenon that researchers Henry Roediger and Jeffrey Karpicke (2006) have called the **testing effect.** In this text, for example, the testing questions interspersed throughout and at the end of each module and unit offer such opportunities. Better to practice retrieval (as any exam will demand) than merely to reread material (which may lull you into a false sense of mastery).

The point to remember: Spaced study and self-assessment beat cramming and rereading. Practice may not make perfect, but smart practice—occasional rehearsal with self-testing—makes for lasting memories.

LEVELS OF PROCESSING

31-8 What are the levels of processing, and how do they affect encoding?

Memory researchers have discovered that we process verbal information at different levels, and that depth of processing affects our long-term retention. **Shallow processing** encodes on a very basic level, such as a word's letters or, at a more intermediate level, a word's sound.



Making things memorable
For suggestions on how to apply the *testing effect* to your own learning, watch this 5-minute YouTube animation: tinyurl.com/HowToRemember.

Deep processing encodes *semantically,* based on the meaning of the words. The deeper (more meaningful) the processing, the better our retention.

In one classic experiment, researchers Fergus Craik and Endel Tulving (1975) flashed words at people. Then they asked the viewers a question that would elicit different levels of processing. To experience the task yourself, rapidly answer the following sample questions:

deep processing encoding semantically, based on the meaning of the words; tends to yield the best retention.

Sample Questions to Elicit Processing	Word Flashed	Yes	No
1. Is the word in capital letters?	CHAIR	______	______
2. Does the word rhyme with train?	brain	______	______
3. Would the word fit in this sentence? The girl put the __________ on the table.	doll	______	______

Which type of processing would best prepare you to recognize the words at a later time? In Craik and Tulving's experiment, the deeper, semantic processing triggered by the third question yielded a much better memory than did the shallower processing elicited by the second question or the very shallow processing elicited by question 1 (which was especially ineffective).

MAKING MATERIAL PERSONALLY MEANINGFUL

If new information is not meaningful or related to our experience, we have trouble processing it. Put yourself in the place of the students whom John Bransford and Marcia Johnson (1972) asked to remember the following recorded passage:

> The procedure is actually quite simple. First you arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. . . . After the procedure is completed one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is part of life.

When the students heard the paragraph you have just read, without a meaningful context, they remembered little of it. When told the paragraph described washing clothes (something meaningful to them), they remembered much more of it—as you probably could now after rereading it.

AP® Exam Tip

Are you often pressed for time? The most effective way to cut down on the amount of time you need to spend studying is to increase the meaningfulness of the material. If you can relate the material to your own life—and that's pretty easy when you're studying psychology—it takes less time to master it.

Try This

Here is another sentence I will ask you about later (in Module 33): "The fish attacked the swimmer."

Can you repeat the sentence about the rioter that I gave you at this module's beginning? ("The angry rioter threw . . .") Perhaps, like those in an experiment by William Brewer (1977), you recalled the sentence by the meaning you encoded when you read it (for example, "The angry rioter threw the rock *through* the window") and not as it was written ("The angry rioter threw the rock *at* the window"). Referring to such mental mismatches, researchers have likened our minds to theater directors who, given a raw script, imagine the finished stage production (Bower & Morrow, 1990). Asked later what we heard or read, we recall not the literal text but *what we encoded*. Thus, studying for a test, you may remember your class notes rather than the class itself.

We can avoid some of these mismatches by rephrasing what we see and hear into meaningful terms. From his experiments on himself, German philosopher Hermann Ebbinghaus (1850–1909) estimated that, compared with learning nonsense material, learning meaningful material required one-tenth the effort. As memory researcher Wayne Wickelgren (1977, p. 346) noted, "The time you spend thinking about material you are reading and relating it to previously stored material is about the most useful thing you can do in learning any new subject matter."

Psychologist-actor team Helga Noice and Tony Noice (2006) have described how actors inject meaning into the daunting task of learning "all those lines." They do it by first coming to understand the flow of meaning: "One actor divided a half-page of dialogue into three [intentions]: 'to flatter,' 'to draw him out,' and 'to allay his fears.'" With this meaningful sequence in mind, the actor more easily remembered the lines.

We have especially good recall for information we can meaningfully relate to ourselves. Asked how well certain adjectives describe someone else, we often forget them; asked how well the adjectives describe us, we remember the words well. This tendency, called the *self-reference effect,* is especially strong in members of individualist Western cultures (Symons & Johnson, 1997; Wagar & Cohen, 2003). Information deemed "relevant to me" is processed more deeply and remains more accessible. Knowing this, you can profit from taking time to find personal meaning in what you are studying.

The point to remember: The amount remembered depends both on the time spent learning and on your making it meaningful for deep processing.

Before You Move On

▶ ASK YOURSELF

Can you think of three ways to employ the principles in this section to improve your own learning and retention of important ideas?

▶ TEST YOURSELF

What would be the most effective strategy to learn and retain a list of names of key historical figures for a week? For a year?

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

Module 31 Review

31-1 What is memory?

- *Memory* is learning that has persisted over time, through the storage and retrieval of information.

31-2 How do psychologists describe the human memory system?

- Psychologists use memory models to think and communicate about memory.
- Information-processing models involve three processes: *encoding, storage,* and *retrieval.*
- The connectionism information-processing model views memories as products of interconnected neural networks.
- The three processing stages in the Atkinson-Shiffrin model are *sensory memory, short-term memory,* and *long-term memory.* More recent research has updated this model to include two important concepts: (1) *working memory,* to stress the active processing occurring in the second memory stage; and (2) automatic processing, to address the processing of information outside of conscious awareness.

31-3 How do explicit and implicit memories differ?

- Through *parallel processing,* the human brain processes many things simultaneously, on dual tracks.
- *Explicit* (declarative) *memories*—our conscious memories of facts and experiences—form through *effortful processing,* which requires conscious effort and attention.
- *Implicit* (nondeclarative) *memories*—of skills and classically conditioned associations—happen without our awareness, through *automatic processing.*

31-4 What information do we automatically process?

- In addition to skills and classically conditioned associations, we automatically process incidental information about space, time, and frequency.

31-5 How does sensory memory work?

- Sensory memory feeds some information into working memory for active processing there.
- An *iconic memory* is a very brief (a few tenths of a second) sensory memory of visual stimuli; an *echoic memory* is a three- or four-second sensory memory of auditory stimuli.

31-6 What is the capacity of our short-term and working memory?

- Short-term memory capacity is about seven items, plus or minus two, but this information disappears from memory quickly without rehearsal.
- Working memory capacity varies, depending on age, intelligence level, and other factors.

31-7 What are some effortful processing strategies that can help us remember new information?

- Effective effortful processing strategies include *chunking, mnemonics,* hierarchies, and distributed practice sessions.
- The *testing effect* is the finding that consciously retrieving, rather than simply rereading, information enhances memory.

31-8 What are the levels of processing, and how do they affect encoding?

- Depth of processing affects long-term retention.
  - In *shallow processing,* we encode words based on their structure or appearance.
  - Retention is best when we use *deep processing,* encoding words based on their meaning.
- We also more easily remember material that is personally meaningful—the self-reference effect.

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.

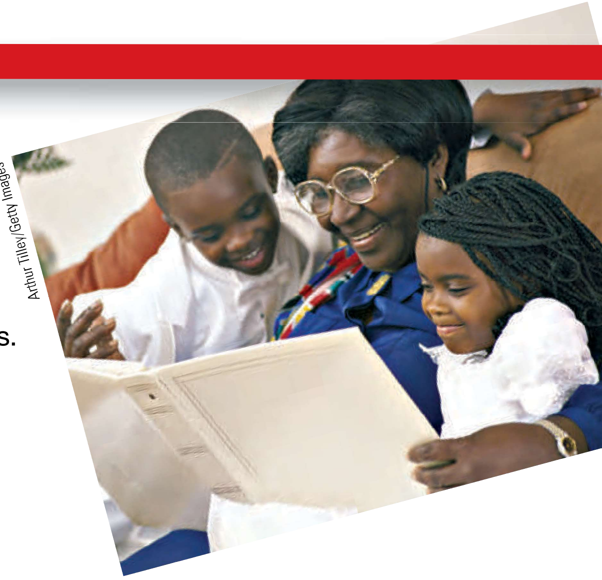
1 point: Retrieval is the process of using that name when greeting the new student later.

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



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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?

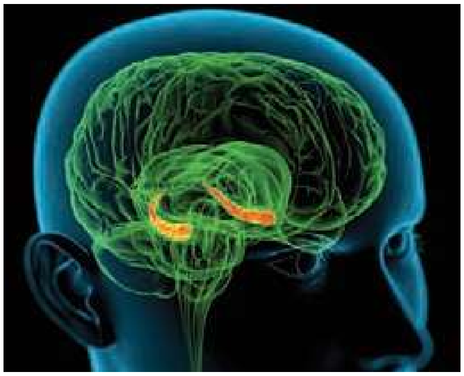
As with perception, language, emotion, and much more, memory requires brain networks. The network that processes and stores your explicit memories for facts and episodes includes your frontal lobes and hippocampus. When you summon up a mental encore of a past experience, many brain regions send input 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).

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**).

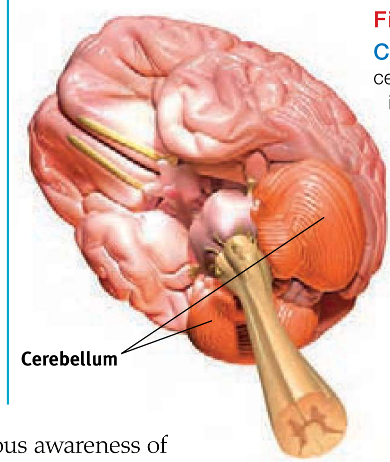


Figure 32.2 **Cerebellum** The cerebellum plays an important part in our forming and storing of implicit memories.

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

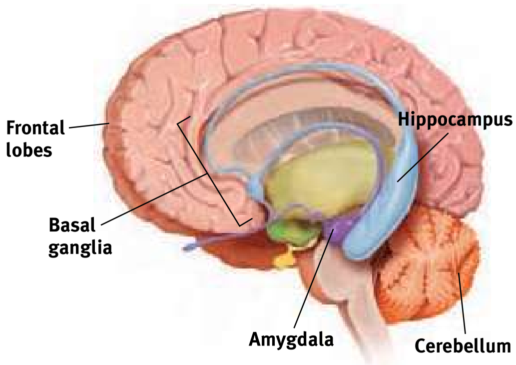


Figure 32.3
Review key memory structures in the brain
Frontal lobes and *hippocampus:* explicit memory formation
Cerebellum and *basal ganglia:* implicit memory formation
Amygdala: emotion-related memory formation

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).

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

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!"

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).

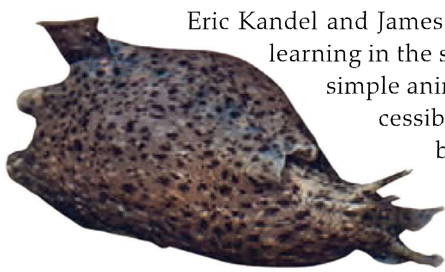
Our flashbulb memories are noteworthy for their vividness and the confidence with which we recall them. But as we relive, rehearse, and discuss them, these memories may come to err, as misinformation seeps in (Conway et al., 2009; Talarico & Rubin, 2003, 2007).

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,



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.

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.

"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

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:

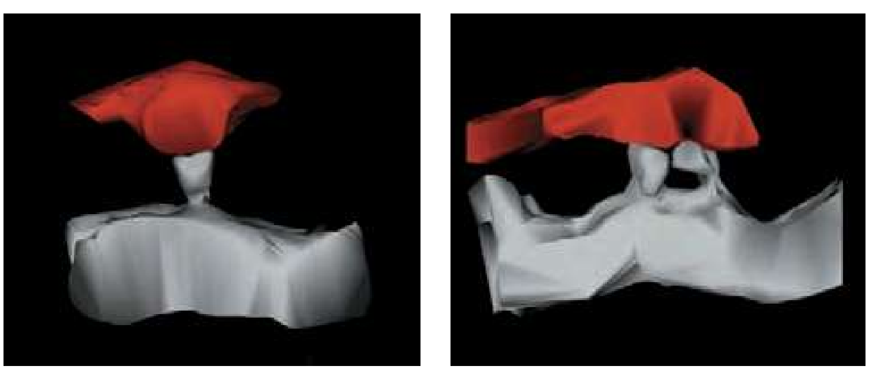
long-term potentiation (LTP) an increase in a cell's firing potential after brief, rapid stimulation. Believed to be a neural basis for learning and memory.

- 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).

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.)



(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.

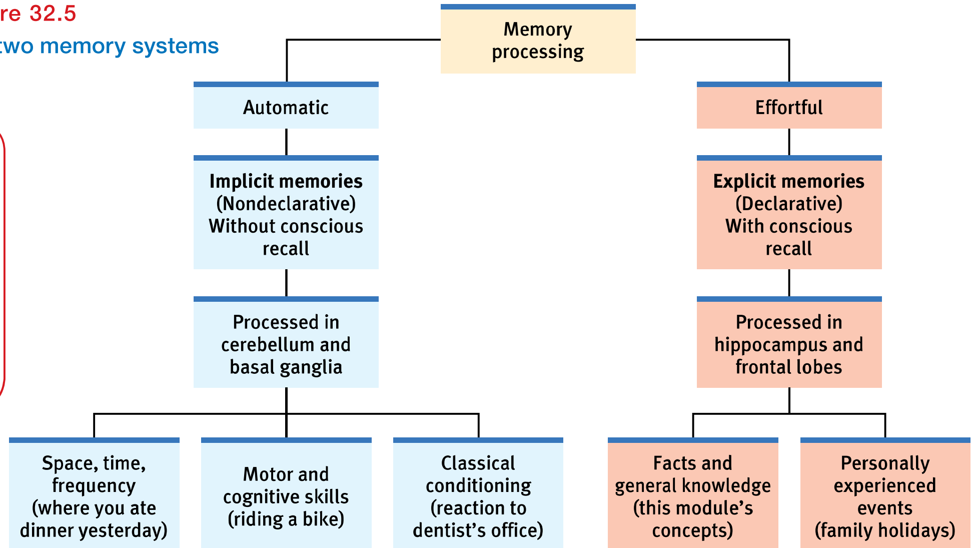


Figure 32.5
Our two memory systems

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?

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.

Measuring Retention

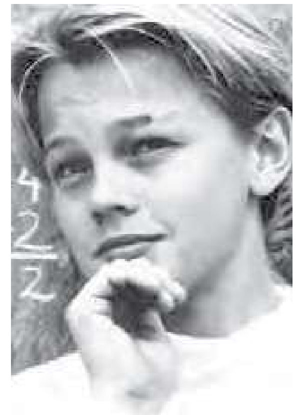
32-6 How is memory measured?

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.

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).

National News/ZUMAPRESS/ Newscom



National News/ZUMAPRESS/ Newscom

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 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.

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*.

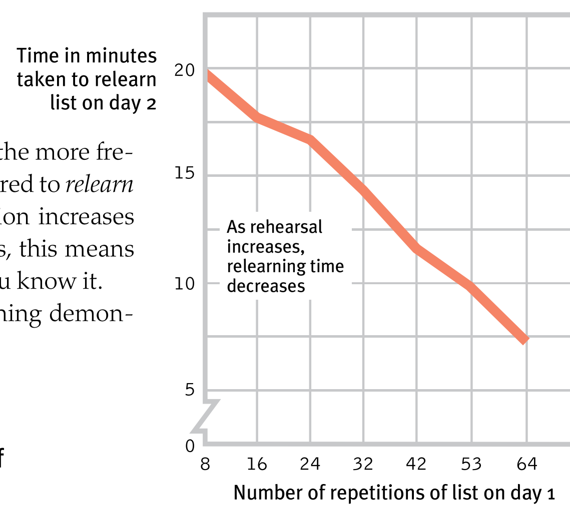


Figure 32.6

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.

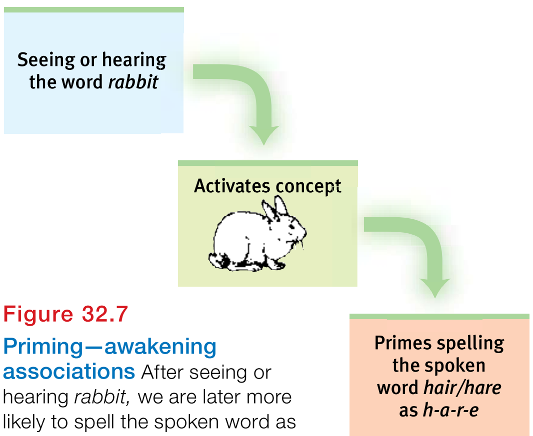


Figure 32.7
Priming—awakening associations After seeing or hearing *rabbit*, we are later more likely to spell the spoken word as *h-a-r-e*. The spreading of associations unconsciously activates related associations. This phenomenon is called priming. (Adapted from Bower, 1986.)

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?

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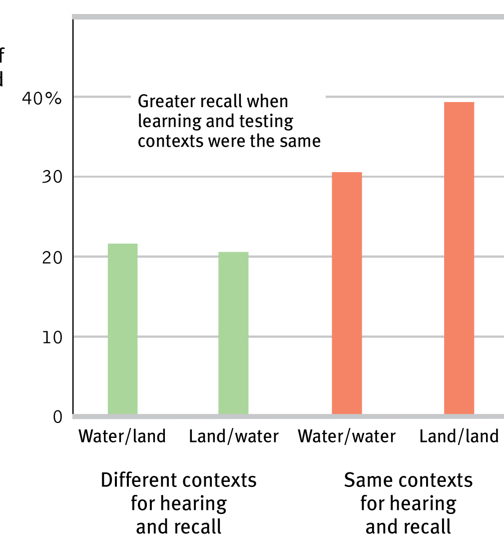


Figure 32.8
The effects of context on memory In this experiment, words heard underwater were best recalled underwater. Words heard on land were best recalled on land. (Adapted from Godden & Baddeley, 1975.)

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

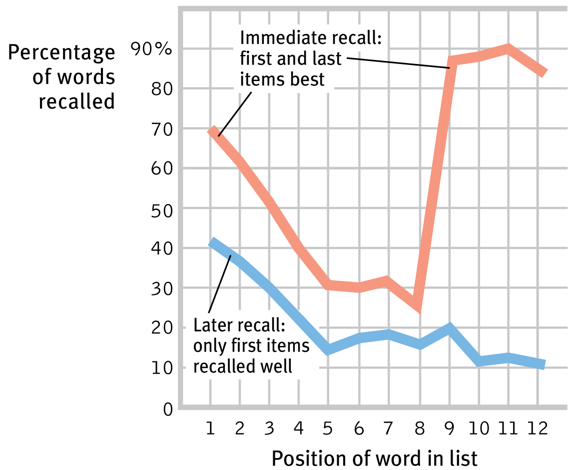
Another memory-retrieval quirk, the **serial position effect,** can leave us wondering why we have large holes in our memory of a list of recent events. Imagine it's your first day in a new job, and your manager is introducing co-workers. As you meet each person, you silently repeat everyone's name, 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.



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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.

3. Which of the following is an example of flashbulb memory?

a. Barry remembers an especially bright sunrise because he was by the ocean and the sunlight reflected off the water.
b. Robert remembers that correlation does not prove a cause–effect relationship because his teacher emphasized this fact over and over again.
c. Anna remembers when her father returned from an overseas military deployment because the day was very emotional for her.
d. Kris has stronger memories of her second grade teacher than she does of her third grade teacher because her second grade teacher has the same name as her neighbor.
e. Anton remembers a moment from his last homecoming dance because a strobe light seemed to freeze the scene in his imagination.

4. Juan returns to his grandparent's house after a 10-year absence. The flood of memories about his childhood visits is best explained by which of the following?

a. Recall
b. Priming
c. Explicit memory
d. The serial position effect
e. Flashbulb memory

5. Which of the following is an example of the primacy effect?

a. Remembering the most important assignment you have to complete for school tomorrow
b. Remembering the skills you learned early in life, such as walking
c. Remembering the last thing your English teacher talked about in class yesterday, but nothing from earlier in the class period
d. Remembering the names of the first two co-workers you met on the first day of your new job
e. Remembering that your clocks must be moved ahead one hour when daylight savings time begins in the spring

Practice FRQs

1. Consider an explicit memory, such as a memory of what happened in your science class yesterday.

Explain the process that allows memory to occur at the synaptic level.
Explain the role of two parts of the brain in your memory of the class.

Answer

1 point: Long-term potentiation (LTP) increases the cells' firing potential at the synapse.

1 point: The hippocampus gives the command to "save" a memory.

1 point: The frontal lobes allow you to process the memory information.

2. You have a friend, Rachel, who cannot remember where she left a check she had received from a relative for her birthday. She remembers having drunk several cups of tea the morning she received the check, and she remembers taking it to her bedroom. Explain how Rachel can take advantage of context-dependent memory and state-dependent memory to remember where in her bedroom she left the check.

(2 points)