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Accounts of people with extraordinary memories raise many questions about the nature of memory itself (Wilding & Valentine, 1997): Why are some people so much better at remembering things than others? Are they simply born with this ability, or could any of us learn to remember as much as they do? And why is it that remembering may sometimes be so simple (think how effortlessly baseball fans remember the batting averages of their favorite players) and other times so difficult (as when we grope for answers on an exam)? Why do we find it so hard to remember something that happened only a few months back, yet we can recall in vivid detail some other event that happened 10, 20, even 30 years ago? Just how does memory work, and what makes it fail?

Among the first to seek scientific answers to these questions was the nineteenth-century German psychologist Hermann Ebbinghaus. Using himself as a subject, Ebbinghaus composed lists of “nonsense syllables,” meaningless combinations of letters, such as PIB, WOL, or TEB. He memorized lists of 13 nonsense syllables each. Then, after varying amounts of time, he relearned each list of syllables. He found that the longer he waited after first learning a list, the longer it took to learn the list again. Most of the information was lost in the first few hours. Ebbinghaus’s contributions dominated memory research for many years.

Today many psychologists find it useful to think about memory as a series of steps in which we process information, much like a computer stores and retrieves data (Massaro & Cowan, 1993). Together, these steps form what is known as the information-processing model of memory. In this chapter, you will find terms like encoding, storage, and retrieval convenient ways of comparing human memory to computers. But we will also consider the social, emotional, and biological factors that make us human and that also distinguish our memories from those of computers.

Far more information bombards our senses than we can possibly process, so the first stage of information processing involves selecting some of this material to think about and remember. Therefore, we turn first to the sensory registers and to attention, the process that allows us to select incoming information for further processing.

**THINK ABOUT IT**

You will find the answers to these questions in the chapter:

1. What is a sensory register, and how many do we have?
2. How many items can most people hold in short-term memory at one time?
3. How do implicit memories differ from explicit ones?
4. Where are short-term memories stored?
5. How does learning contribute to forgetting?
6. How accurate is eyewitness testimony?
If you were to walk into this room, your eyes and your other sense organs would pick up many impressions of what is to be found here. How much of this information would you remember later?

The Sensory Registers

What is a sensory register, and how many do we have?

Look slowly around the room. Each glance—which may last for only a fraction of a second—takes in an enormous amount of visual information, including colors, shapes, textures, relative brightness, and shadows. At the same time, you pick up sounds, smells, and other kinds of sensory data. All this raw information flows from your senses into what are known as sensory registers. These registers are like waiting rooms in which information enters and stays for only a short time. Whether we remember any of this information depends on which operations we perform on it, as you will see throughout this chapter. Although all our senses have registers, the visual and auditory registers have been studied most extensively, and therefore we focus on them.

Visual and Auditory Registers

Although the sensory registers have virtually unlimited capacity (Cowan, 1988), information disappears from them quite rapidly (Rainer & Miller, 2002). To understand how much visual information we take in, and how quickly it is lost, bring a digital camera into a darkened room and take a picture using a flash. During the split second that the room is lit up by the flash, your visual register will absorb a surprising amount of information about the room and its contents. Try to hold on to that visual image, or icon, as long as you can. You will find that it fades rapidly; in a few seconds it is gone. Then compare your remembered image of the room with what you actually saw at the time, as captured in the picture. You will notice that your visual register took in far more information than you were able to retain for even a few seconds.

A clever set of experiments by George Sperling (1960) clearly demonstrates the speed with which information disappears from the visual register. Sperling flashed groups of letters, arranged in rows, on a screen for just a fraction of a second. When the letters were gone, he sounded a tone to tell his participants which row of letters to recall: A high-pitched tone indicated that they should try to remember the top row of letters, a medium tone signaled them to recall the middle row, and a low tone meant they should recall the bottom row. Sperling found that if he sounded the tone immediately after the letters were flashed, his participants could usually recall three...
or four of the letters in any of the three rows; that is, they seemed to retain at least nine of the original twelve letters in their visual registers. But if he waited for even one second before sounding the tone, his participants were able to recall only one or two letters from any single row. In just one second, then, all but four or five of the original set of twelve letters had vanished from their visual registers.

Visual information may disappear from the visual register even more rapidly than Sperling thought (Cowan, 1988). In everyday life, new visual information keeps coming into the register, and this new information replaces the old information almost immediately, a process often called masking. This is just as well, because otherwise the visual information would simply pile up in the sensory register and get hopelessly scrambled. Under normal viewing conditions, visual information is erased from the sensory register in about a quarter of a second as it is replaced by new information.

Auditory information fades more slowly than visual information. The auditory equivalent of the icon, the echo, tends to last for several seconds, which, given the nature of speech, is certainly fortunate for us. Otherwise, “You did it!” would be indistinguishable from “You did it!” because we would be unable to remember the emphasis on the first word by the time we registered the last word.

### Attention

If information disappears from the sensory registers so rapidly, how do we remember anything for more than a second or two? One way is that we select some of the incoming information for further processing by means of attention (see Figure 6–1). Attention is the process of selectively looking, listening, smelling, tasting, and feeling (Egeth & Lamy, 2003). At the same time, we give meaning to the information that is coming in. Look at the page in front of you. You will see a series of black lines on a white page. Until you recognize these lines as letters and words, they are just meaningless marks. For you to make sense of this jumble of data, you process the information in the sensory registers for meaning.

How do we select what we are going to pay attention to at any given moment, and how do we give that information meaning? Donald Broadbent (1958) suggested that a filtering process at the entrance to the nervous system allows only those

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**Figure 6–1**

The sequence of information processing.
These children are working attentively in spite of the activity going on around them. If their teacher calls them to line up for recess, however, their attention will be quickly diverted from their work.

stimuli that meet certain requirements to pass through. Those stimuli that get through the filter are compared with what we already know, so that we can recognize them and figure out what they mean. If you and a friend are sitting in a restaurant talking, you filter out all other conversations taking place around you. As we discussed in Chapter 3, this practice is known as the *cocktail-party phenomenon* (Cherry, 1966; Conway, Cowan, & Bunting, 2001; Wood & Cowan, 1995). According to Broadbent, although you might be able to describe certain characteristics of those other conversations, such as whether the people speaking were men or women and whether their voices were loud or soft, you normally would not be able to recount what was being discussed, even at neighboring tables. Because you filtered out those other conversations, processing of that information did not proceed far enough for you to understand the meaning of what you heard.

Now suppose that during your restaurant conversation, someone at a neighboring table mentions your name. In all likelihood your attention would shift to that conversation. The filter that had screened out neighboring conversations has suddenly “let through” your name. Why? Anne Treisman (1960, 1964) modified Broadbent’s filter theory to account for such phenomena. She contended that the filter is not a simple on-off switch but rather a variable control, like the volume control on a radio, that can “turn down” unwanted signals without rejecting them entirely. According to this view, we may be paying attention to only some incoming information, but we monitor the other signals at a low volume. In this way, we can shift our attention if we pick up something particularly meaningful. This automatic processing works even when we are asleep: Parents often wake up immediately when they hear the baby crying, but sleep through other, louder noises.

To summarize, we consciously attend to very little of the information in our sensory registers; instead, we select some information and process those signals further as we work to recognize and understand them. However, even unattended information receives at least some initial processing, so that we can shift our attention to focus on any element of our surroundings that strikes us as potentially meaningful.

What happens to the information that we do attend to? It enters our short-term memory.

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**CHECK YOUR UNDERSTANDING**

1. Raw information from the senses stops here first before it is further processed or disappears.
   - a. amygdala
   - b. sensory registers
   - c. cortex
2. Auditory information fades from the sensory registers more slowly than information from which other sense?
   ___ a. taste
   ___ b. touch
   ___ c. sight

3. _______ is the process of selectively looking, listening, tasting, and feeling while giving meaning to that information.
   ___ a. partial report
   ___ b. attention
   ___ c. filtering

Answers: 1.b, 2.c, 3.b

Short-Term Memory

How many items can most people hold in short-term memory at one time?

Short-term memory (STM) holds the information we are thinking about or are aware of at any given moment (Stern, 1985). It was originally called primary memory by William James (1890; Waugh & Norman, 1960). When you listen to a conversation or a piece of music, when you watch a ballet or a tennis tournament, when you become aware of a leg cramp or a headache—in all these cases, you are using STM both to hold on to and to think about new information coming in from the sensory registers. STM therefore has two primary tasks: to store new information briefly and to work on that information. STM is sometimes called working memory to emphasize the active or working component of this memory system (Baddeley & Hitch, 1994; Nairne, 2003).

Capacity of STM

The arcade fanatic absorbed in a video game is oblivious to the outside world. Chess masters at tournaments demand complete silence while they ponder their next move. You shut yourself in a quiet room to study for final exams. As these examples illustrate, STM can handle only so much information at any given moment. Research suggests that STM can hold about as much information as can be repeated or rehearsed in 1.5 to 2 seconds (Baddeley, 1986, 2002).

To get a better idea of the limits of STM, read the first row of letters in the following list just once. Then close your eyes and try to remember the letters in the correct sequence. Repeat this procedure for each subsequent row:

1. C X W
2. M N K T Y
3. R P J H B Z S
4. G B M P V Q F J D
5. E G Q W J P B R H K A

Like most people, you probably found rows 1 and 2 fairly easy, row 3 a bit harder, row 4 extremely difficult, and row 5 impossible to remember after just one reading. This gives you an idea of the limited capacity of STM.
But the limits of STM depend, in part, on the material involved. Try reading through the following set of 12 letters just once and see whether you can repeat them: TJYFAVMCFKIB. How many letters were you able to recall? In all likelihood, not all 12. But what if you had been asked to remember the following 12 letters instead: TV FBI JFK YMCA. Could you do it? Almost certainly the answer is yes. These are the same 12 letters as before, but here they are grouped into four separate meaningful “words.” Organizing information so that it fits into meaningful units is called chunking (Gobet et al., 2001). The 12 letters have been chunked into four meaningful elements that STM can readily handle—they can be repeated in less than two seconds.

Here’s another example of chunking. Try to remember this list of numbers:

106619451812

Remembering 12 separate digits is usually very difficult, but try chunking the list into three groups of four:

1066 1945 1812

For those who take an interest in military history, these three chunks will be much easier to remember than 12 unrelated digits.

By chunking words into sentences or sentence fragments, we can process an even greater amount of information in STM (Baddeley, 1994; Carter, Hardy & Hardy, 2001). For example, suppose you want to remember the following list of words: tree, song, hat, sparrow, box, lilac, cat. One strategy would be to cluster as many of them as possible into phrases or sentences: “The sparrow in the tree sings a song”; “a lilac hat in the box”; “the cat in the hat.” But isn’t there a limit to this strategy? Would five sentences be as easy to remember for a short time as five single words? Simon (1974) found that as the size of any individual chunk increases, the number of chunks that can be held in STM declines. Thus, STM can easily handle five unrelated letters or words simultaneously, but five unrelated sentences are much harder to remember.

Keep in mind that short-term memory usually has more than one task to perform at once (Baddeley & Hitch, 1994). During the brief time you spent memorizing the rows of letters on page 229, you probably gave them your full attention. But normally, you have to attend to new information while you work on whatever is already present in your short-term memory. Competition between these two tasks for the limited workspace in STM often means that neither task will be done as well as it could be. Try counting backward from 100 while trying to learn the rows of letters in our earlier example. What happens?

Now turn on some music and try to learn the rows of letters. You’ll find that the music doesn’t interfere much, if at all, with learning the letters. Interestingly, when two memory tasks are presented in different sensory modalities (for instance visual and auditory), they are less likely to interfere with each other than if they are in the same modality (Cocchini, Logie, Sala, MacPherson, & Baddeley, 2002). This suggests the existence of domain specific working memory systems that can operate at the same time with very little interference.

**Chunking** The grouping of information into meaningful units for easier handling by short-term memory.
Encoding in STM

We encode verbal information for storage in STM phonologically—that is, according to how it sounds. This is so even if we see the word, letter, or number on a page rather than hear it spoken (Baddeley, 1986; Pollatsek, Rayner, & Lee, 2000). We know this because numerous experiments have shown that when people try to retrieve material from STM, they generally mix up items that sound alike (Sperling, 1960). A list of words such as mad, man, mat, cap is harder for most people to recall accurately than is a list such as pit, day, cow, bar (Baddeley, 1986).

But not all material in short-term memory is stored phonologically. At least some material is stored in visual form, and other information is retained based on its meaning (Cowan, 1988; Matlin, 1989). For example, we don’t have to convert visual data such as maps, diagrams, and paintings into sound before we can think about them. Moreover, research has shown that memory for images is generally better than memory for words because we often store images both phonologically and as images, while words are usually only stored phonologically (Pavio, 1986). The dual coding of images accounts for why it is sometimes helpful to form a mental picture of something you are trying to learn (Sadoski & Pavio, 2001).

Maintaining STM

As we have said, short-term memories are fleeting, generally lasting a matter of seconds. However, we can hold information in STM for longer periods through rote rehearsal, also called maintenance rehearsal (Greene, 1987). Rote rehearsal consists of repeating information over and over, silently or out loud. Although this may not be the most efficient way to remember something permanently, it can be quite effective for a short time.

CHECK YOUR UNDERSTANDING

1. What a person is thinking about at any given moment is called
   ___ a. episodic memory
   ___ b. elaborative rehearsal
   ___ c. emotional memory
   ___ d. short-term memory

2. Grouping items into meaningful and manageable units is known as
   ___ a. chunking
   ___ b. encoding
   ___ c. rote rehearsal

3. How are strings of letters and numbers encoded in short-term memory?
   ___ a. visually
   ___ b. phonologically
   ___ c. by elaborative rehearsal

4. Short term memory is sometimes called:
   ___ a. 1 minute memory
   ___ b. 2 minute memory
   ___ c. secondary memory
   ___ d. working memory

Answers: 1. d, 2. a, 3. b, 4. d
Long-term memory (LTM) is the portion of memory that is more or less permanent, corresponding to everything we “know.”

**Serial position effect**: The finding that when asked to recall a list of unrelated items, performance is better for the items at the beginning and end of the list.

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**Long-Term Memory**

*How do implicit memories differ from explicit ones?*

Everything that we learn is stored in long-term memory (LTM): the words to a popular song; the results of the last election; the meaning of justice; how to roller skate or draw a face; and what you are supposed to be doing tomorrow at 4 P.M.

**Capacity of LTM**

We have seen that short-term memory can hold only a few items, normally only for a matter of seconds unless it is maintained through rote rehearsal, but long-term memory can store a vast amount of information for many years. In one study, for example, adults who had graduated from high school more than 40 years earlier were still able to recognize the names of 75 percent of their classmates (Bahrick, Bahrick, & Wittlinger, 1974). And some people are able to remember their high school Spanish after 50 years, even if they have had little opportunity to practice it (Bahrick, 1984).

**Encoding in LTM**

Can you picture the shape of Florida? Do you know what a trumpet sounds like? Can you imagine the smell of a rose or the taste of coffee? When you answer the telephone, can you sometimes identify the caller immediately, just from the sound of the voice? Your ability to do most of these things means that at least some long-term memories are coded in terms of nonverbal images: shapes, sounds, smells, tastes, and so on (Cowan, 1988).

Yet most of the information in LTM seems to be encoded in terms of meaning. If material is especially familiar (the words of the national anthem, say, or the opening of the Gettysburg Address), you may have stored it verbatim in LTM, and you can often retrieve it word for word when you need it. Generally speaking, however, we do not use verbatim storage in LTM. If someone tells you a long, rambling story, complete with flashbacks, you may listen to every word, but you certainly will not try to remember the story verbatim. Instead, you will extract the main points of the story and try to remember those. Even simple sentences are usually encoded in terms of their meaning. Thus, when people are asked to remember that “Tom called John,” they often find it impossible to remember later whether they were told “Tom called John” or “John was called by Tom.” They usually remember the meaning of the message but not the exact words (Bourne, Dominowski, Loftus, & Healy, 1986).

**Serial Position Effect**

When given a list of items to remember (such as a list of grocery items), people tend to do better at recalling the first items (primacy effect) and the last items (recency effect) in the list. They also tend to do poorest of all on the items in the middle of the list (see Figure 6–2).

The explanation for this serial position effect resides in understanding how short- and long-term memory work together. The recency effect occurs because the last items that were presented are still contained in STM, and thus are available for recall. The primacy effect, on the other hand, reflects the opportunity to rehearse the first few items in the list—increasing their likelihood of being transferred to LTM.

Poor performance on the items in the middle of the list occurs because they were presented too long ago to still be in STM, and because so many items were presented before and after them that required attention that there was little opportunity for rehearsal. The serial position effect has been shown to occur under a wide
Beginning
Primacy effect
1. We can easily recall the first few items in a list because the opportunity to rehearse them increases the likelihood that they are transferred into long-term memory.

Middle
3. Items in the middle of the list are the hardest to recall because (a) they were presented too long ago to still be in short-term memory and (b) so many items came before and after them that there was little opportunity for rehearsal, limiting transfer into LTM.

End
Recency effect
2. We can easily recall items near the end of a list because they are still contained in short-term memory.

Figure 6–2
The serial position effect.
The serial position effect demonstrates how short- and long-term memory work together.

variety of conditions and situations (Neath, 1993; Suhr, 2002). A version of the serial position effect has even been demonstrated in monkeys (Wright, 1998).

Maintaining LTM

Rote Rehearsal Rote rehearsal, the principal tool for holding information in STM, is also useful for holding information in LTM. The old saying, practice makes perfect, has some merit. Millions of students have learned the alphabet and multiplication tables by doggedly repeating letters and numbers. Rote rehearsal is probably the standard method of storing away largely meaningless material, such as phone numbers, Social Security numbers, security codes, computer passwords, birth dates, and people’s names. Repetition is also important in mastering a wide variety of skills, from playing a piece of Mozart on the piano to doing a back flip on the balance beam. Mastering a skill means achieving automaticity, and automaticity is achieved only through long, hard, repetitive practice.

But while rote rehearsal is useful, laboratory experiments have shown that simply repeating something over and over does not always improve recall. It turns out that it is not so much the amount of rehearsal that increases memory, but rather the type of rehearsal (Craik & Watkins, 1973). Specifically, repetition without any intention to learn generally has little effect on subsequent recall (Greene, 1987; van-Hoff & Golden, 2002). You can probably prove this to yourself: Stop here and draw from memory the front side of a U.S. penny. Now look at Figure 6–3 and pick the illustration that most closely matches your memory of a penny. For most people, these tasks are surprisingly difficult: Despite seeing thousands of pennies, most people cannot accurately draw one, or even pick one out from among other, similar objects (Nickerson & Adams, 1979).

Elaborative Rehearsal As we have seen, repetition with the intent to learn is sometimes useful in storing meaningless information in LTM. But with meaningful material, an even more effective procedure is elaborative rehearsal (Craik & Lockhart, 1972; Craik, 2002; Postman, 1975): the act of relating new information to something that we already know. Through elaborative rehearsal, you extract the meaning of the new information and then link it to as much of the material already in LTM as possible. For instance, suppose that you had to remember that the French word poire means “pear.” You are already familiar with pear, both as a word and as a fruit. Poire, however, means nothing to you. To remember what it means,
you connect it to *pear*, either by telling yourself that “*pear* and *poire* both begin with *p*,” or by associating *poire* with the familiar taste and image of a *pear*. The more links or associations you can make, the more likely you are to remember the new information later, just as it is easier to find a book in the library if it is cataloged under many headings rather than just one or two.

**Schemata**

A variation on the idea of elaborative rehearsal is the concept of *schema* (plural: *schemata*). A schema is a mental representation of an event, object, situation, person, process, or relationship that is stored in memory and that leads you to expect your experience to be organized in certain ways. For example, a class lecture schema might include a large room, seating arranged in rows, a space in the front of the room where the professor or lecturer will stand, a podium or lectern, a chalkboard, a screen, and other characteristics common to your experience of attending lectures. You enter, sit down, open your notebook, and expect the professor or lecturer to come in and address the class from the front of the room.

Schemata such as this one provide a framework into which incoming information is fitted. For example, if you enter a restaurant and see that there are no servers, that people are placing their orders at a long counter and then seating themselves, you might reasonably conclude that this is a “fast-food restaurant.” Later in the day when a friend asks you where you had lunch, you might recall that it was “at a fast-food place.” Schemata can also influence the amount of attention you pay to a given event, and thus your memory for that event. If you attend a lecture on environmental pollution, you will probably pay more attention than if you simply overhear a conversation on the same topic in the cafeteria. Going to a lecture on a topic primes us to approach the situation as a learning experience—to attend carefully to what is said, and to attempt to remember the information (possibly for a test) after leaving. Overhearing a conversation on the same topic would cause us to approach the situation in a much more casual way. Indeed, we would probably be astonished if someone said, “Now summarize the main points of that conversation!”

In conclusion, long-term memory offers a vast storage space for information that we can retrieve in a variety of ways. Its capacity is immense, and material stored there may endure, more or less intact, for decades. By comparison, short-term memory has a sharply limited capacity; information may...
disappear from STM as a result of decay or simply because the storage space is full. The sensory registers can take in an enormous volume of less permanent information, but they have no ability to process memories. Together, these three stages of memory—the sensory registers, STM, and LTM—comprise the information-processing view of memory (see Table 6–1).

(The accurate illustration of a penny in Figure 6–3 is the third from the left.)

Types of LTM

The information stored in LTM can take many forms. However, most long-term memories can be classified into one of several types. Although the classification system remains somewhat controversial, as we shall later see, there is reason to believe that each of these kinds of memories has its own distinct structures in the brain.

Episodic memories (Tulving, 1985) are memories for events experienced in a specific time and place. These are personal memories, not historical facts. If you can recall what you ate for dinner last night, what presents you got at your sixth birthday party, or reading the Sunday comics with your parents when you were little, then you are calling up episodic memories. We can think of episodic memory as a diary or daily journal that lets you “go back in time” (Wheeler, Stuss, & Tulving, 1997).

Semantic memories are facts and concepts not linked to a particular time. Semantic memory is like a dictionary or encyclopedia, filled with facts and concepts, such as the meaning of the word semantic, the name of the inventor of the light bulb, where the Empire State Building can be found, the value of 2 times 7, and who George Washington was.

Procedural memories are motor skills and habits (Johnson, 2003). They are not memories about skills and habits; they are the skills and habits. Procedural memories have to do with knowing how: how to ride a bicycle, swim, play a violin, type a letter, make coffee, write your name, comb your hair, walk across a room, or slam on a car’s brakes.

### Table 6-1

<table>
<thead>
<tr>
<th>System</th>
<th>Means by Which Information Is Encoded</th>
<th>Storage Organization</th>
<th>Storage Duration</th>
<th>Means by Which Information Is Retrieved</th>
<th>Factors in Forgetting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory Register</td>
<td>Visual and auditory registers</td>
<td>None</td>
<td>From less than one second to only a few seconds</td>
<td>Reconsideration of registered information</td>
<td>Decay or masking</td>
</tr>
<tr>
<td>Short-Term Memory</td>
<td>Visual and phonological representation</td>
<td>None</td>
<td>Usually 15 to 20 seconds</td>
<td>Rote or maintenance rehearsal</td>
<td>Interference or decay</td>
</tr>
<tr>
<td>Long-Term Memory</td>
<td>Comprehension of meaning, elaborative rehearsal</td>
<td>Logical frameworks, such as hierarchies or categories</td>
<td>Perhaps for an entire lifetime</td>
<td>Retrieval cues linked to organized information</td>
<td>Retrieval failure or interference</td>
</tr>
</tbody>
</table>
Emotional memories are learned emotional responses to various stimuli: all of our loves and hates, our rational and irrational fears, our feelings of disgust and anxiety. If you are afraid of flying insects, become enraged at the sight of a Nazi flag, or are ashamed of something you did, you have emotional memories.

When we think of memory, we most often think of things we can deliberately call to mind. This typically includes episodic or semantic memories. These two kinds of memories are sometimes called declarative memory because we can declare (put into words) what we know (Squire, Knowlton, & Musen, 1993). For example, perhaps you know not only that Albany is the capitol of New York but also that you visited Albany once as a child, and you can state (declare) this knowledge precisely. But not all memories are like this. Many of the things we know cannot be described easily in words, and we cannot readily “bring them to mind.” Procedural and emotional memories are like that. You may be a highly skilled golfer, for example, but be unable to describe precisely what you know about swinging a golf club. If someone asks you how you know the right amount of force to apply for a six-foot putt on a level and “fast” green, you will probably end up saying “I just know” or “You just have to practice.” You may know that you are terrified of snakes, but that declarative knowledge is distinct from the fearful reaction you have when you see a snake.

Explicit and Implicit Memory Because of these differences among long-term memories, psychologists distinguish between things we are aware that we know and can readily describe such as episodic and semantic memories (explicit memory) and things we are not aware that we know and cannot easily describe such as procedural and emotional memories (implicit memory).

Serious interest in the distinction between explicit and implicit memory began as a result of experiments with people who had suffered brain damage that, it was thought, prevented them from forming new long-term memories. Brenda Milner (Milner, Corkin, & Teuber, 1968) studied the now famous case of patient H. M., a young man who had a portion of his brain removed in order to control severe epileptic seizures. The surgery greatly reduced the frequency and severity of seizures, but it left behind a new problem: H. M. apparently could not form new memories. He could meet someone again and again, and each time it was as if he were meeting the person for the first time. He could read the same magazine day after day and not recall ever having seen it before. Old memories were intact: He could remember things that he had learned long before the operation, but he could not learn anything new. Or so it seemed!

One day Milner asked H. M. to trace the outline of a star while looking in a mirror. This simple task is surprisingly difficult, but with practice most people show steady progress. Surprisingly, so did H. M. Each day he got better and better at tracing the star, just as a person with an undamaged brain would do—yet each day he had no recollection of ever having attempted the task. H. M.’s performance demonstrated that he could still learn a skill but have no memory of having done so (see Table 6–2 for a summary of implicit and explicit memory; see also On the Cutting Edge: Storing Emotional Experiences).
Research on a phenomenon called priming also demonstrates the distinction between explicit and implicit memory. For example, you might be shown a list of words including the word *tour* without being asked to remember any of the words. Later on you might be shown a list of word fragments, including _ou_, and asked to fill in the blanks to make a word. In these circumstances, you are far more likely to write *tour* than you are *four*, *pour*, or *sour*, all of which are just as acceptable as *tour*. Even though you weren’t asked to remember the word *tour*, simply being exposed to it primes you to write it.

Interestingly, people with amnesia do as well on priming tasks as do people with normal memory. For example, one study (Warrington & Weiskrantz, 1970) gave several people with amnesia a list of words to remember. When these patients were asked to recall the words or pick them out of longer lists, they performed poorly, as one might expect. But when the experimenters showed the patients fragments of the
words and asked them to guess what the word might be or to say the first thing that popped into their heads, they produced just as many of the words on the list as did people not suffering from amnesia. In other words, the amnesia victims had perfectly good implicit memories for words that they did not explicitly know they had heard!

The Tip-of-the-Tongue Phenomenon  Everyone has had the experience of knowing a word but not quite being able to recall it. This is called the **tip-of-the-tongue phenomenon** or TOT (Brown & McNeil, 1966; Hamberger & Seidel, 2003; Schwartz, 2002). Although everyone experiences TOTs, these experiences become more frequent during stressful situations and as people get older (White & Abrams, 2002). Moreover, other words—usually with a sound or meaning similar to the word you are seeking—occur to you while you are in the TOT state and these words interfere with and sabotage your attempt to recall the desired word. The harder you try, the worse the TOT state gets. The best way to recall a blocked word, then, is to stop trying to recall it! Most of the time, the word you were searching for will pop into your head, minutes or even hours after you stopped consciously searching for it (Schwartz, 2002). (If you want to experience TOT yourself, try naming Snow White’s seven dwarfs.)

The distinction between explicit and implicit memories means that some knowledge is literally unconscious. Moreover, as we shall soon see, explicit and implicit memories also seem to involve different neural structures and pathways. However, memories typically work together. When we remember going to a Chinese restaurant, we recall not only when and where we ate and who we were with (episodic memory), but also the nature of the food we ate (semantic memory), the skills we learned such as eating with chopsticks (procedural memory), and the embarrassment we felt when we spilled the tea (emotional memory). When we recall events, we typically do not experience these kinds of memories as distinct and separate; rather they are integrally connected, just as the original experiences were. Whether we will continue to remember the experiences accurately in the future depends to a large extent on what happens in our brain.

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**CHECK YOUR UNDERSTANDING**

1. Match the following terms with the appropriate definitions.

___ primacy effect  a. tendency to remember well items at the end of a long list

___ recency effect  b. tendency to remember well items at the beginning of a long list

___ serial position effect  c. describes our relatively weaker memory for items in the middle of a long list

2. Learning information through repetition is a process called

___ a. rote rehearsal

___ b. elaborative rehearsal

___ c. schema

3. Match the following terms with the appropriate definitions.

___ procedural memories  a. memories specific to one’s own experiences

___ episodic memories  b. memories of general facts and concepts

___ emotional memories  c. memories of motor skills and habits

___ semantic memories  d. fear, love, and hate, for example, associated with specific events
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Long-Term Potentiation (LTP)

A long-lasting change in the structure or function of a synapse that increases the efficiency of neural transmission, and is thought to be related to how information is stored by neurons.

ENDURING ISSUES

4. We know and can readily describe which type of memories?
___ a. explicit
___ b. implicit
___ c. emotional

The Biology of Memory

Where are short-term memories stored?

Research on the biology of memory focuses mainly on the question, How and where are memories stored? Simple as the question is, it has proved enormously difficult to answer, although considerable progress has been made in the last two decades.

How Are Memories Formed?

Everything you learn is ultimately recorded in the brain in the form of changes in the size, shape, chemical functioning, and connectedness of neurons (Squire & Kandel, 1999). When we learn new things, new connections are formed in the brain; when we review or practice previously learned things, old connections are strengthened. These chemical and structural changes can continue over a period of months or years (Squire, Slater & Chace, 1975), during which the number of connections among neurons increases as does the likelihood that cells will excite one another through electrical discharges, a process known as Long-Term Potentiation (LTP).

While learning takes place in the brain, it is also influenced by events occurring elsewhere in the body. In particular, two hormones, epinephrine and cortisol, affect long-term retention. A number of studies with rats, monkeys, and humans have shown, for example, that epinephrine can enhance the recall of exposure to stimuli associated with unpleasant experiences, such as exposure to shock (McGaugh, 1990).

Effects of Stress on Body and Brain

Epinephrine secretion is part of the “fight or flight” syndrome (see Chapter 12, Stress and Health Psychology) and has the effect of arousing the organism to action. However, the effect of epinephrine and other stress related hormones on memory is not merely the result of general arousal. Apparently these hormones indirectly act on specific brain centers, such as the hippocampus and the amygdala, that are critical for memory formation (Vermetten & Bremner, 2002). In one experiment, McGaugh (1983) gave rats epinephrine following Pavlovian fear conditioning and discovered that this enhanced recall. Increased blood levels of epinephrine probably also explain improved performance in humans under conditions of Long-Term Potentiation (LTP) A long-lasting change in the structure or function of a synapse that increases the efficiency of neural transmission, and is thought to be related to how information is stored by neurons.
mild stress (see Ledoux, 1994). Extreme stress, however, undermines both learning and later recall (Luine, Villegas, Martinez, & McEwen, 1994). If you are studying for an exam, then, a little anxiety will probably improve your performance, but a high level of anxiety will work against you.

Where Are Memories Stored?

Where in the brain does learning occur? Is there one place where all memories can be found, or is each kind of memory stored in its own special location? It has been known for a long time that the brain has specialized areas for vision and hearing (see Chapter 3, Sensation and Perception), so it seems logical that one part of the brain might be set aside for memory.

Hoping to locate the specific site of memory, Lashley (1950) systematically removed various parts of rats’ brains after they had learned a task. Although losing part of the brain weakened memories, it didn’t remove them completely. In fact, performance had less to do with the area of the brain removed than with the amount of tissue involved: The more of the brain Lashley removed, the less the rats remembered. Lashley was forced to conclude that memories are stored throughout the brain.

Although all memories are not stored in one place (Brewer, Zhao, Desmond, Glover, & Gabriel, 1998), this does not mean that memories are randomly distributed throughout the brain. In fact, research has provided ample evidence that different parts of the brain are specialized for the storage of certain memories (Rolls, 2000). Short-term memories, for example, seem to be located primarily in the prefrontal cortex and temporal lobe (Fuster, 1997; Rainer & Miller, 2002; Rao, Rainer, & Miller, 1997; Rolls, Tovee, & Panzeri, 1999; Szatowska, Grabowska, & Szymanska, 2001; see Figure 6–4). Long-term semantic memories seem to be located primarily in the frontal and temporal lobes of the cortex which, interestingly, also seem to play a prominent role in consciousness and awareness (see Figure 6–4). Research shows increased activity in a particular area of the left temporal lobe, for example, when people are asked to recall the names of people. A nearby area shows increased activity when they are asked to recall the names of animals, and another neighboring area becomes active when they are asked to recall the names of tools (Damasio, Grabowski, Tranel, Hichawa, & Damasio, 1996) (see Figure 6–5). Destruction of these areas of the cortex (through head injury, surgery, stroke, or disease) results in selective memory loss (e.g., Damasio et al., 1996; Semenza & Zettin, 1989). Some patients may be unable to recall the name of a tool although they can describe how to use it, while others may be unable to recall the name of an old friend or their spouse.

Episodic memories also find their home in the frontal and temporal lobes (Nyberg et al., 2003; Wheeler, Stuss, & Tulving, 1997). But some evidence shows that episodic and semantic memories involve different portions of these brain structures. Wood and colleagues (1980) compared blood flow in the brain as people worked on two different kinds of tasks (blood flow to an area is associated with activity in that area). Some people performed a task involving episodic memory; others performed a task involving semantic memory. The researchers found that the two kinds of tasks resulted in increased blood flow to somewhat different areas of the brain.

Procedural memories appear to be located primarily in the cerebellum (an area required for balance and motor coordination) and in the motor cortex (see Figure 6–4; Gabrieli, 1998). When people perform a task that requires them to follow a rotating object with a hand-held stylus, activity in their motor cortex increases (Grafton et al., 1992).
The frontal lobes store semantic and episodic memories.

Motor cortex
The motor cortex is involved in storing procedural memories.

Prefrontal cortex
The prefrontal cortex is involved in the storage of short-term memories.

Temporal lobe
The temporal lobe is involved in the formation and storage of long-term semantic and episodic memories and contributes to the processing of new material in short-term memory.

Amygdala
The amygdala is vital to the formation of new emotional memories.

Hippocampus
The hippocampus plays a pivotal role in the formation of new long-term semantic and episodic memories.

Cerebellum
The cerebellum plays an important role in the storage of procedural memories.

Figure 6–4
The biological basis of memory.
Many different parts of the brain are specialized for the storage of memories.

Subcortical structures also play a role in long-term memory. For example, the hippocampus has been implicated in the functioning of episodic memory (Rolls, 2000), as well as being involved in the ability to remember spatial relationships (Cassaday & Rawlins, 1997; Eichenbaum, 1997; Jackson, Kesner, & Amann, 1998; Robertson, Rolls, & Georges-Francois, 1998; Rolls, 1996). Emotional memories are dependent on the amygdala (Cahill & McGaugh, 1998; Vazdarjanova & McGaugh, 1999), a structure that lies near the hippocampus. The amygdala seems to play a role in emotional memory that is similar to the role the hippocampus plays.
in episodic, semantic, and procedural memory (Pare, Collins, & Guillaume, 2002). For example, damage to the amygdala reduces the ability to recall new emotional experiences, but it does not prevent the recall of emotional events that occurred prior to the damage though they are often remembered as neutral facts, devoid of emotional content. This may explain why people with amygdala damage are sometimes unable to “read” facial expressions, even though they recognize the person’s face (Young, Hellawell, Wan de Wal, & Johnson, 1996).

Clearly, psychologists have a long way to go before they will fully understand the biology of memory, but progress is being made in this fascinating area. As we will see in the next section, another problem that is beginning to succumb to scientific analysis is, Why do we forget?

CHECK YOUR UNDERSTANDING

1. Match the following types of memories to the location in the brain where they appear to be formed and/or stored.

   - short-term memories
   - long-term semantic and episodic memories
   - procedural memories
   - emotional memories

   a. frontal and temporal lobes
   b. cerebellum and motor cortex
   c. amygdala
   d. prefrontal cortex and temporal lobe

2. Two hormones, epinephrine and cortisol, affect which kind of memory retention?

   - a. short-term
   - b. long-term

3. Which of the following acts as memory’s storage facility in the human body?

   - a. sensory registers
   - b. spinal cord
   - c. cerebral cortex

Answers:

1. short-term memories—d; long-term semantic and episodic memories—a; procedural memories—b; emotional memories—c

Forgetting

How does learning contribute to forgetting?

Forgetting is a very commonplace phenomenon, familiar to one and all. But why should we forget? Why do memories, once formed, not remain forever in the brain? Part of the answer has to do with the biology of memory, and another part has to do with the experiences we have before and after learning.

The Biology of Forgetting

According to the decay theory, memories deteriorate because of the passage of time. Most of the evidence supporting decay theory comes from experiments known as distractor studies. For example, in one experiment, participants learned a sequence of letters, such as PSQ. Then they were given a three-digit number, such
Retrograde amnesia  The inability to recall events preceding an accident or injury, but without loss of earlier memory.

Brain damage caused by accidents, surgery, poor diet, or disease is the most likely cause of severe memory loss. Damage to the hippocampus profoundly affects long-term memory formation. Studies of elderly people who are having trouble remembering new material, for instance, show that the hippocampus is smaller than normal (Golomb et al., 1994). Brain scans also reveal a diminished hippocampus in people suffering from Alzheimer’s disease, a neurological disorder that causes severe memory loss (Bennett & Knopman, 1994; see Chapter 10, Life Span Development, for more information about Alzheimer’s disease). Chronic alcoholism can lead to a form of amnesia called Korsakoff’s syndrome caused by a vitamin deficiency in the poor diet typically eaten by people who abuse alcohol (Baddeley, 1987). Head injuries often result in retrograde amnesia, a condition in which people cannot remember what happened to them shortly before their injury. It is thought that in such instances, forgetting occurs because memories are not fully “anchored” in the brain. The problem is analogous to something every computer user has experienced: A momentary power outage results in the loss of information that has not been saved to the hard drive.

Neurotransmitters also play a role in forgetting. One in particular, acetylcholine, seems to be significant (Hasselmo & Bower, 1993; Hasselmo, Schnell, & Barkai, 1995; McIntyre, Marriott, & Gold, 2003). In one group of studies, rats developed memory problems after researchers destroyed acetylcholine-producing cells in their brains (Fibiger, Murray, & Phillips, 1983). Alzheimer’s sufferers commonly have below-normal levels of acetylcholine in their brains, and autopsies show that many of the acetylcholine-producing neurons in their brain have been extensively damaged (Coyle, 1987). Indeed, some research with animals and humans suggests that drugs and surgical procedures that increase acetylcholine levels may alleviate some age-related memory deficits (Li & Low, 1997; Parnetti, Senin, & Mecocci, 1997; D. E. Smith, Roberts, Gage, & Tuszynski, 1999). The precise role of neurotransmitters in the memory process is complex, however, and evidence suggests that other neurotransmitters are involved as well (DeZazzo & Tully, 1995). The problem of forgetting is further complicated by the effects of experience, as we will now see.

Experience and Forgetting

Often, forgetting is simply due to inadequate learning. When you forget where you put your car keys, it is usually because you did not attend to the act of placing the car keys. If you can’t find your car, most of the time you didn’t take notice of where you parked the car in the first place.

Other times forgetting occurs because, although we attended to the matter to be recalled, we did not rehearse the material adequately. Merely “going through the motions” of rehearsal may do little good. Prolonged, intense practice with the intention of learning results in less forgetting than a few, desultory repetitions. Elaborative rehearsal can also help make new memories more durable. When you park your car in space G–47, you will be more likely to remember its location if you think, “G–47. My uncle George is about 47 years old.” The bottom line is that we cannot expect to remember information for long if we have not learned it well in the first place.
Retroactive interference The process by which new information interferes with information already in memory.

Proactive interference The process by which information already in memory interferes with new information.

Interference Learning itself can cause forgetting because learning one thing can interfere with remembering another. Information gets mixed up with, or pushed aside by, other information and thus becomes harder to remember. Such forgetting is said to be due to interference. There are two kinds of interference (see Figure 6–6).

In one kind of interference, new material interferes with remembering information already in long-term memory; this is known as retroactive interference. Retroactive interference is often studied by means of paired associate learning. First a person learns a list of word pairs, such as happy–apple; when presented with happy, the person is expected to say apple. After this list is learned, the person learns a different list, including happy–pencil; when presented with happy, the person is to say pencil. After learning the second list, the person is tested for memory of the first list; as before, the task is to say apple in response to happy. The typical finding is that learning the second list interferes with the ability to recall the first (Thune & Underwood, 1943). Retroactive interference is an everyday occurrence. Once you learn a new telephone number, for example, you may find it difficult to recall your old number, even though you used that old number for years.

In the second kind of interference, old material in memory interferes with new material being learned; this is called proactive interference. These experiments proceed as above but this time the participants are tested for their memory of the second list they learned. Typically, they do less well than people who learned only the second list. Thus, learning the first list interferes with later learning. Like retroactive interference, proactive interference is an everyday phenomenon. Suppose you always park your car in the lot behind the building where you work. Then one day your parking space is moved to a lot across the street. It will take you longer to remember the new parking space than it would have if you had not been previously parking behind the building. Learning to look for your car behind the building interferes with your new memory that you are now parking across the street.

The most important factor in determining the degree of interference is the similarity of the competing items. In paired associate learning, for example, items such as happy–apple and happy–pear are more likely to interfere with one another.

Figure 6–6
Diagram of experiments measuring retroactive and proactive interference.

In retroactive interference, the experimental group usually does not perform as well on tests of recall as those in the control group, who experience no retroactive interference from a list of words in Step 2. In proactive interference, people in the experimental group suffer the effects of proactive interference from the list in Step 1; when asked to recall the list from Step 2, they perform less well than those in the control group.
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(retroactively or proactively) than happy–oak and happy–train, as shown in the following experiment (Bower & Mann, 1992). Participants learned two lists of 21 letters each. The first list was SOJFNUGAHWMSELICBQTA, and the second was YADIOHSREKNABYHTLAEW. Then the participants were asked to recall the first list. Retroactive interference occurred because the second list consisted of a sequence of letters very similar to first list and thus interfered with it. But when some of the participants were told that the second list spells WEALTHY BANKERS HOLIDAY backwards, interference dropped significantly. This information made the second list very different from the first, so there was less interference. The more dissimilar something is from other things you have already learned, the less likely it will be to mingle and interfere with other material in memory.

Situational Factors Situational factors can also contribute to forgetting. In one experiment, a group of people was given a list of 40 adjectives and asked to write down the opposite of each word (Schab, 1990). The experimenter informed them that the next day he would ask them to recall the words they had written. The smell of chocolate permeated the air surrounding one group of students while they were writing their list of words. The next day, adding a chocolate smell to the air significantly increased the number of words these students recalled from the previous day. The smell of chocolate became an effective “contextual cue” or “hint” that helped them recall the correct words. Although this may seem odd, it happens all the time: Whenever we try to commit something to memory, we are also unintentionally picking up facts about the context in which the learning is taking place. Those facts become useful retrieval cues when we later try to retrieve the corresponding information from LTM.

When environmental cues that were present during learning are absent during recall, the effort to remember is often less successful. This phenomenon, called cue-dependent forgetting, has been demonstrated in a wide variety of situations. For instance, scuba divers recalled a list of words better if learned underwater and recalled underwater, than if learned underwater and recalled on the beach (Godden & Baddeley, 1975). Similar context effects have been demonstrated with background music (Balch & Lewis, 1996; de-l’Etoile, 2002), odors (Herz, 1997), and even classrooms (Smith, Glenberg, & Bjork, 1978). The police make use of contextual cues when they take witnesses back to the scene of a crime in the hope of improving their recall of crucial details.

State-Dependent Memory In addition to being influenced by environmental cues, our ability to accurately recall information is affected by internal cues. This phenomenon is known as state-dependent memory. State-dependent memory refers to the intriguing finding that people who learn material in a particular physiological state tend to recall that material better if they return to the same state they were in during learning. For example, one study showed that people who learned material while under the influence of marijuana later recalled more of the material under the influence of marijuana than not (J. E. Eich, Weingartner, Stillman, & Gillin, 1975). State-dependent memory has also been demonstrated in research using other drugs such as caffeine (Keleman & Creeley, 2003). However, these studies do not show that being in a drug-induced state improves memory; on the contrary, being in an intoxicated state greatly reduces the overall effectiveness of memory. State-dependent memory research simply shows that the physiological state during learning can act as a cue during recall. The best results, however, occur when the person is sober and alert during both learning and recall.

The Reconstructive Process Forgetting also occurs because of what is called the “reconstructive” nature of remembering. Earlier we talked about how schemata are used in storing information in long-term memory. Bartlett proposed that people
also use schemata to “reconstruct” memories (Bartlett, 1932; Schacter, Norman, & Koutstaal, 1998). When an experience doesn’t fit our view of the world or ourselves, we tend, unconsciously, to adjust it or to blot it out of memory altogether (Bremner & Marmar, 1998). In other words, people unknowingly “rewrite” past events to fit their expectations, their current image or their desired image of themselves, and their past decisions (Lyubomirsky & Ross, 1999; Mather, Shafir, & Johnson, 2000).

How to Reduce Forgetting

At a party, you’re embarrassed when a familiar-looking person comes over and hugs you, but you can’t remember her name. You’re describing a movie you’ve just seen, but you can’t recall its title. After returning from the grocery store, you realize that you’ve forgotten to buy two of the things on your list.

Has your memory always been bad, or is it deteriorating? Many people worry that their memory is not what it used to be. Studies of memory show that most people, even those who are older, have better memories than they realize. The following steps can be taken to improve recall:

1. Develop motivation. Without a strong desire to learn or remember something, you probably won’t. But if you find a way to keep yourself alert and stimulated, you will have an easier time learning and remembering things.

2. Practice memory skills. To stay sharp, memory skills, like all skills, must be practiced and used. Memory experts recommend exercises such as crossword puzzles, acrostics, anagrams, Scrabble, Monopoly, Trivial Pursuit, and bridge. Or you might learn Japanese, join a chess club, or make a point of discussing current events regularly with friends.

3. Be confident in your ability to remember. Self-doubt often leads to anxiety, which, in turn, interferes with the ability to retrieve information from memory. Relaxation exercises, experts agree, may substantially boost your ability to retrieve information from memory. Also, if you’re convinced that you won’t remember something, you probably won’t. For example, people who are sure they won’t remember the parts of the nervous system for a psychology test will undoubtedly have more difficulty mastering this material than people who adopt a more positive attitude toward the task.

4. Minimize distractions. Although some people can study for an exam and listen to the radio simultaneously, most people find that outside distractions interfere with both learning and remembering. If you are being distracted, look for a quiet, even secluded, setting before attempting to commit something to memory.

5. Stay focused. Paying close attention to details, focusing on your surroundings, emotions, and other elements associated with an event, will help you remember it clearly.

6. Make connections between new material and other information already stored in your long-term memory. One key to improving memory lies in organizing and encoding material more effectively when it first enters LTM. Discuss things you want to remember with other people. Think about or write down ways in which the new information is related to things you already know. The more links you forge between new information and old information already in LTM, the more likely you are to remember the new material.

In some situations, special techniques called mnemonics may help you to tie new material to information already in LTM. Some of the simplest mnemonic techniques are the rhymes and jingles that we often use to remember dates and other facts. “Thirty days hath September, April, June, and November . . .” enables us to recall how many days are in a month. We are also familiar with other simple
mnemonic devices in which we make up words or sentences out of the material to be recalled. We can remember the colors of the visible spectrum—red, orange, yellow, green, blue, indigo, and violet—by using their first letters to form the name ROY G. BIV. In remembering the musical notes, the spaces in the treble clef form the word FACE, and the lines in the treble clef may be remembered by the phrase “Every Good Boy Does Fine.” In addition, several studies have shown that when you can relate a mnemonic to personal information, such as your hobbies or interests, you are even more likely to be able to recall it later (Symons & Johnson, 1997). Whenever you can devise a mnemonic to help you remember something, do so.

7. **Use mental imagery.** Imagery works wonders as an aid to recalling information from memory. Whenever possible, form mental pictures of the items, people, words, or activities you want to remember. For example, to remember that someone’s last name is Glass, you might imagine her holding a glass or looking through a glass. If you want to remember that a friend lives on Manchester Street, you might imagine a Tarzan-like man (with your friend’s face) beating his chest. If you have a sequence of stops to make, picture yourself leaving each place and heading for the next. Greek and Roman orators used a similar mnemonic technique to memorize long speeches. They would visit a large house or temple and walk through the rooms in a specific order, noting where particular objects were placed in each room. When the orators had memorized the plan of the building and its contents, they would imagine going through the rooms, placing images of the material to be remembered at different spots in the rooms. To retrieve the material in the proper sequence during the speech, the orators would imagine themselves going through the rooms in order and, by association, would recall each point of their speech as they came to each object in each room.

8. **Use retrieval cues.** The more retrieval cues you have, the more likely it is that you will remember something. One way to establish automatic retrieval cues is to create routines and structure. For example, when you come in the door, put your house and car keys in the same place every time. Then when you ask yourself, “Where did I put my keys?” the fact that you have a special place for the keys serves as a retrieval cue. Sometimes something that is clearly not routine or structured can serve as a retrieval cue. For example, if you want to remember to do something before you go to bed, leave an unusual item on your bed (perhaps a shoe or a sock); when it’s time to go to bed, you’ll see the unusual object, and that should help remind you of what you wanted to do.

Similarly, if you are having difficulty remembering something, you might find it useful to return to the setting where you last used that information. That way the cues present when you used that information will be available and may help you remember. If you can’t do that, try to recreate the setting vividly in your mind in as much detail as possible, including the thoughts and feelings you were having at the time. This may provide enough contextual cues to pry the information from you.

9. **Rely on more than memory alone.** Human memory is less than perfect, so it’s wise to make use of other tools. Write down the things you need to remember, and then post a note or list of those things somewhere obvious, such as on your bulletin board or refrigerator door. Put all the dates you want to remember on a calendar, and then put the calendar in a conspicuous place. If you witness an accident, immediately write down everything you saw and heard in as much detail as you can; then use your written account to refresh your memory periodically.

10. **Be aware that your own personal schemata may distort your recall of events.** As noted earlier, people sometimes unknowingly “rewrite” past events to fit their current image or their desired image of themselves and their past decisions. Being on guard against such distortions may help you avoid them.
IMPROVING YOUR MEMORY FOR TEXTBOOK MATERIAL

You can use all the principles discussed in this chapter to help you remember material from textbooks in most of your courses. The key to storing new material in long-term memory is making associations between that material and information that is already in LTM. If you simply passively reread the chapter over and over, you are not likely to store, retain, or retrieve information effectively (McDaniel, Waddill, & Shakesby, 1996; Wilke, 1998). Highlighting or underlining passages makes for a slight improvement, if only because you are at least thinking about which material is most important.

A more effective technique is to prepare an outline of the chapter before reading it so that you have associations and links ready to be made when you actually read the material. Some textbooks (including this one) provide you with a ready-made outline at the beginning of the chapter, but creating one yourself forces you to start thinking about the content of the chapter and how one section relates to another. Then, as you read, write comments under the headings of your outline. Your personal summary will not only help you remember material as you are reading the chapter, but will be useful when you are reviewing the material for a test.

Another memory-enhancing technique is to rehearse the material as you read the chapter. You might write in the margin of the text as you go along, recording your reactions, questions, ideas about how the new material may relate to other material, thoughts about how you might apply what you are learning in your own life, and so on. Try to relate the new material to all sorts of things you already know, expressing this relationship in your own words. You can also work with a friend, taking turns challenging each other with questions that draw on material from different sections or paragraphs. However you go about it, integrating and elaborating on the textual material forces you to process it and to form new associations among the pieces of information that you are storing.

Elaborative rehearsal offers two distinct benefits: It ties the new material to information already in memory, and it generates a multitude of retrieval cues to help you recall the material when you need it. Even after you feel well prepared, continued rehearsal may improve your retention. In fact, studies have shown that if you overlearn a subject in school, such as a foreign language or a part in a school play, you may be able to remember much of it for the rest of your life (Bahrick, 1984; Bahrick & Hall, 1991; Noice & Noice, 2002).

A more ambitious, and even more effective, system for studying is known by the letters of its five stages: SQRRR (or SQ3R, for short):

1. Survey. Before you even start to read, look quickly at the chapter outline, the headings of the various sections in the chapter, and the chapter summary. This gives you an overview of what you will be reading, and helps you organize and integrate the material as you go along.

2. Question. Before you start to read, translate each heading in the chapter into questions about the text to follow. Before reading this chapter, for example, you might have recast the heading “Short-Term Memory” on page 233 into questions such as “Why is it called ‘short-term’?” “Is there another type of memory that lasts longer?” “What good is memory if it’s only short-term?” “Why do memories fade?”

3. Read. Now read the first section in the chapter, looking for answers to the questions you have posed. If you discover major points not directly related to your questions, either revise your old questions to encompass the new material or make up new questions.

4. Recite. Once you finish reading a section, close the book, and recite from memory the answers to your questions and any other major points that you can remember. You can also jot down your answers in outline form or recite them to someone else. Then open the book and check to make sure that you have covered all the key points raised in the section. Repeat steps 3 and 4 for each section of the chapter.

5. Review. After reading through the whole chapter, review your notes, and then recite or say mentally your questions and answers from memory. Relate the material to other ideas, to experiences in your own life, or to familiar things. Try to think of particularly good examples or illustrations of key points or concepts in the chapter. Get involved.

The SQ3R method forces you to react—to enter into a dialogue with the text. This interaction makes the material more interesting and meaningful and improves your chances of recalling it. It also organizes the material and relates it to what you already know. This method certainly takes longer than simply reading a chapter does, but you will save time later on when studying for exams.

To learn more about study skills, visit our web site at www.prenhall.com/morris.
Finally, while you’re working to improve your memory, keep in mind that forgetting is not always a bad thing. Most of us have many experiences we would like very much to forget, and forgetting them might be a blessing. A study of children whose home life had been so troubled that they had been placed for a time in a child guidance clinic found that changing or “rewriting” their memories of early childhood made a difficult, disadvantaged life less of a liability. For example, when these children were interviewed 30 years later, those who incorrectly recalled their childhood as fairly normal were also the ones who had been able to develop a basically stable, conventional life of their own (Robins et al., 1985). Forgetting is sometimes a blessing, rather than a curse. (For more on improving memory, see Applying Psychology: Improving Your Memory for Textbook Material.)

CHECK YOUR UNDERSTANDING

1. Memories deteriorate because of the passage of time according to which theory?
   ___ a. Korsakoff’s syndrome
   ___ b. decay
   ___ c. brain damage
   ___ d. interference

2. Mnemonics are memory
   ___ a. aids
   ___ b. blockers
   ___ c. disrupters

3. The smell of chocolate helped students remember information they had learned previously because it was in the air at the time of the original learning. The previous sentence describes a
   ___ a. situational factor
   ___ b. hint
   ___ c. contextual cue
   ___ d. all of the above

Answers: 1.b, 2.a, 3.d

Special Topics in Memory

How accurate is eyewitness testimony?

Autobiographical Memory

Autobiographical memory refers to our recollection of events that happened in our life and when those events took place (Koriat, Goldsmith, & Pansky, 2000); as such, it is a form of episodic memory. Autobiographical memories are of fundamental importance. Indeed, Conway (1996) contends that “autobiographical memory is central to self, to identity, to emotional experience, and to all those attributes that define an individual” (p. 295).

Research confirms that, in general, more recent life events are easier to recall than earlier ones (Crovitz & Schiffman, 1974). But one review of the research shows that people over 50 years of age are more likely than younger people to recall events
from relatively early in life (Holland & Rabbitt, 1990). Because we typically make the most pivotal life choices (such as those concerning marriage and career) in late adolescence and young adulthood, and the outcomes of these choices shape the rest of our lives, it makes sense for us to focus on this period when we look back to summarize and evaluate our lives (Mackavey, Malley, & Stewart, 1991).

You might like to explore your own earliest memories. You and a friend should each make up a list of 20 nouns, such as table, robin, and Brussels sprouts, that can be easily pictured, and then switch lists and write down the earliest personal memory that comes to mind for each of the other person’s words. Try to date each memory as accurately as possible. Did you have more memories for recent events than for events early in your life? Did you have any memories for events in the first three or four years of your life?

**Childhood Amnesia**

Research shows that our earliest personal memories tend to date back to between three and four years of age (Eacott, 1999; Kihlström & Harackiewicz, 1982; Newcombe et al., 2000). People rarely recall events that occurred before they were two years old. This phenomenon is sometimes called childhood amnesia or infantile amnesia.

Exactly why people have difficulty remembering events from their first years of life is not well understood, although several explanations have been advanced (Eacott, 1999; Newcombe, Drummey, Fox, Lie, & Ottinger-Alberts, 2000; Wang, 2003; Wheeler et al., 1997). One hypothesis holds that childhood amnesia is a result of the child’s brain not being fully developed at birth. Jacobs and Nadel (1997) point out that the hippocampus, which is so important in the formation of episodic and semantic memories, is not fully formed until about age two. Another theory suggests that childhood amnesia occurs because the very young do not possess a clear sense of self (Wheeler et al., 1997). Without a sense of one’s self, very young children find it difficult to organize and integrate their experiences into a coherent autobiographical memory scheme. Still other theorists contend that childhood memories are lost because young children do not possess the language skills necessary to strengthen and consolidate early experiences (Hudson & Sheffield, 1998).

**Extraordinary Memory**

As you saw at the beginning of this chapter, some people are able to perform truly amazing feats of memory. From time to time, the newspaper will carry a report of a person with a “photographic memory.” Such people can apparently create unusually sharp and detailed visual images of something they have seen—a picture, a scene, a page of text. This phenomenon, called eidetic imagery, enables people to see the features of an image in minute detail, sometimes even to recite an entire page of a book they read only once.

One study screened 500 elementary schoolchildren before finding 20 with eidetic imagery (Haber, 1969). The children were told to scan a picture for 30 seconds, moving their eyes to see all its various parts. The picture was then removed, and the children were told to look at a blank easel and report what they saw in an eidetic image. They needed at least three to five seconds of scanning to produce an image, even when the picture was familiar. In addition, the quality of eidetic imagery seemed to vary from child to child. One girl in this study could move and reverse images and...
recall them several weeks later. Three children could produce eidetic images of three-dimensional objects, and some could superimpose an eidetic image of one picture onto another and form a new picture. Interestingly, the children with eidetic imagery performed no better than their noneidetic classmates on other tests of memory.

One of the most famous documented cases of extraordinary memory comes from the work of the distinguished psychologist Alexander Luria (Luria & Solotaroff, 1987). For over 20 years, Luria studied a Russian newspaper reporter named Shereshevskii (“S”). In The Mind of a Mnemonist (1968), Luria described how “S” could recall masses of senseless trivia as well as detailed mathematical formulas and complex arrays of numbers. He could easily repeat lists of up to 70 words or numbers after having heard or seen them only once.

“S” and other people with exceptional memories were not born with a special gift for remembering things. Rather, they have carefully developed memory techniques using certain principles. For example, Luria discovered that when “S” studied long lists of words, he would form a graphic image for every item. When reading a long and random list of words, for example, “S” might visualize a well-known street, specifically associating each word with some object along the way. When asked to recite the lists of words, he would take an imaginary walk down that street, recalling each object and the word associated with it. By organizing his data in a way that was meaningful to him, he could more easily link it to existing material in his long-term memory. In turn, this connection provided him with many more retrieval cues than he would have had for isolated, meaningless facts.

Developing an exceptional memory takes time and effort (Ericsson & Charness, 1994, Wilding & Valentine, 1997). Mnemonists (pronounced nee-MON-ists), people who are highly skilled at using memory techniques, frequently have compelling reasons for developing their memories. “S” used his memory skills to his advantage as a newspaper reporter. As we will see in the next chapter, chess masters also sometimes display astonishing recall of meaningful chessboard configurations (Bédard & Chi, 1992; Haberlandt, 1997). For example, some master chess players are able to recall the position of every single piece on the board after only a 5-second exposure to a particular pattern. Yet when these same masters view a totally random and meaningless array of chess pieces, their recall is no better than yours or mine (Ericsson & Chase, 1982).

In view of research data such as these, one memory researcher concluded:

One of the most interesting things we’ve found is that just trying to remember things does not insure that your memory will improve. It’s the active decision to get better and the number of hours you push yourself to improve that makes the difference. Motivation is much more important than innate ability. (Singular, 1982, p. 59)

**Flashbulb Memories**

Where were you and what were you doing when you first learned of the terrorist attacks on the World Trade Center on September 11, 2001? Most people can describe exactly where they were and what they were doing at that moment. This is an example of a flashbulb memory, the experience of remembering vividly a certain event and the incidents surrounding it even after a long time has passed. We often remember events that are shocking or otherwise highly significant in this way (Davidson & Glisky, 2002). The death of a close relative, a birth, a graduation, or

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**Mnemonist** Someone with highly developed memory skills.

**Flashbulb memory** A vivid memory of a certain event and the incidents surrounding it even after a long time has passed.
Millions of people will forever have a vivid flashbulb memory of planes flying into the twin towers of the World Trade Center in New York City on September 11, 2001.

Researchers have developed several theories about how people form such memories (Finkenauer et al., 1998). According to the “now print” theory, a mechanism starts up in the brain when something especially significant, shocking, or noteworthy is at hand. The entire event is captured and then “printed,” much like a photograph. The “print” is then stored, like a photograph in an album, for long periods, perhaps for a lifetime. It is periodically strengthened, because such an important event is bound to be remembered and discussed many times throughout the years.

The “now print” theory implies, among other things, that flashbulb memories are accurate, that they form at the time of an event, and that we remember them better because of their highly emotional content. All these implications have come under criticism. First, flashbulb memories are certainly not always accurate. Although this is a difficult contention to test, let’s consider just one case. Psychologist Ulric Neisser vividly recalled what he was doing on the day in 1941 when the Japanese bombed Pearl Harbor. He clearly remembered that he was listening to a professional baseball game on the radio, which was interrupted by the shocking announcement. But professional baseball is not played in December, when the attack took place, so this sharp flashbulb memory was simply incorrect (Neisser, 1982).

Even if an event is registered accurately, it may undergo periodic revision, just like other long-term memories. We are bound to discuss and rethink a major event many times, and we probably also hear a great deal of additional information about that event in the weeks and months after it occurs. As a result, the flashbulb memory may undergo reconstruction and become less accurate over the years until it sometimes bears little or no resemblance to what actually occurred. For instance, one study asked college students how they first heard about the O.J. Simpson trial verdict. The researchers found that the recollections they initially reported just three days after the verdict had changed markedly after a year had passed. In addition, inaccuracies and distortions continued to increase when the students were questioned again three years after the event (Schmolck, Buffalo, & Squire, 2000).

**Eyewitness Testimony**

“I know what I saw!” When an eyewitness to a crime gives evidence in court, that testimony often overwhelms evidence to the contrary. Faced with conflicting or ambiguous testimony, jurors tend to put their faith in people who saw an event with their own eyes. However, there is now compelling evidence that this faith in eyewitnesses is often misplaced (Brodsky, 1999; Wells & Olsen, 2003).

In several classic studies, Loftus and Palmer (1974) showed people a film depicting a traffic accident. Some of the people were asked, “About how fast were the cars going when they hit each other?” Other people were asked the same question, but with the words smashed into, collided with, bumped into, and contacted in place of hit. The researchers discovered that people’s reports of the cars’ speed depended on which word was inserted in the question. Those asked about cars that “smashed into” each other reported that the cars were going faster than those who were asked about cars that “contacted” each other. In another experiment, people were shown a film of a collision and then asked either “How fast were the cars going when they hit each other?” or “How fast were the cars going when they smashed into each other?” One week later, they were asked some additional questions about the accident they had seen on film the week before. One of the questions was “Did you see any broken glass?” More of the participants who had been asked about cars that had “smashed into” each other reported that they had seen broken glass than did participants who had been asked the speed of cars that “hit” each other.

Why do eyewitnesses make such mistakes? Some research suggests that the problem may be source error: People are sometimes unable to tell the difference between
what they witnessed and what they merely heard about or imagined (Garry & Polaschek, 2000; Lindsay & Johnson, 1989; Reyna & Titcomb, 1997; Taylor, Pham, Rivkin, & Armor, 1998). This is especially true for young children (Shapiro, 2002). We all know what it is like to imagine an event in a particularly vivid way and then later have difficulty remembering whether the event really happened or we simply imagined it. Indeed, studies have shown that imagining an event sometimes makes people believe it actually happened (Garry & Polaschek, 2000; Henkel, Franklin, & Johnson, 2002).

Similarly, if you hear information about an event you witnessed, you might later confuse your memory of that information with your memory of the original event. The impact of subsequent information seems to be particularly strong when it is repeated several times (Zaragoza & Mitchell, 1996), as is often the case with extensive media coverage, or when it comes from an authority figure such as a police officer (Roper & Shewan, 2002). Based on this research, many psychologists (Lindsay, 1993; Zaragoza, Lane, Ackil, & Chambers, 1997) contend that if people paid more attention to the source of their memories, eyewitness accounts would be more reliable.

Whatever the reason for eyewitness errors, there is good evidence that such mistakes can send innocent people to jail (Kassin, Tubb, Hosch, & Memon, 2001). A study of over 1,000 cases in which innocent people were convicted of crimes concludes that errors made by eyewitnesses were the single most persuasive element leading to false conviction (Wells, 1993). Increasingly, courts are recognizing the limits of eyewitness testimony. For example, judges instruct juries to be skeptical about eyewitness testimony and to evaluate it critically.

### Recovered Memories

In recent years a controversy has raged, both within the academic community and in society at large, about the validity of recovered memories (McNally, 2003). The idea is that it is possible for people to experience an event, then lose all memory of it, and then later recall it, often in the course of psychotherapy or while under hypnosis. Often, the recovered memories concern physical or sexual abuse during childhood. No one denies the reality of childhood abuse, or the damage that such experiences cause. But are the recovered memories real? Did the remembered abuse really occur? The answer is by no means obvious. There is ample evidence that people can be induced to “remember” events that never happened (Smith et al., 2003). For example, Loftus and her colleagues (Loftus, Coan, & Pickrell, 1996; Loftus & Pickrell, 1995) conducted experiments in which adults were asked to recall events that a close relative had supposedly mentioned. Three events had actually occurred, the other had not. Twenty-five percent of the participants eventually “remembered” the fictitious event.

Other research confirms that it is relatively easy to implant memories of an experience merely by asking about it. The more times people are asked about the event, the more likely they are to “remember” it. Sometimes these memories become quite real to the participant. In one experiment (Hyman, Husband, & Billings, 1995), 25 percent of adults “remembered” fictitious events by the third time they were interviewed about them. One of the fictitious events involved knocking over a punch bowl onto the parents of the bride at a wedding reception. At the first interview, one participant said that she had no recollection whatsoever of the event; by the second interview she “remembered” that the reception was outdoors and that she knocked over the bowl while running around. Some people even “remembered” details about the event, such as what people looked like and what they wore. Yet the researchers documented that Father Bernard Pagano (right) was identified as an armed robber by seven eyewitnesses and was nearly convicted for crimes actually committed by the man on the left.
As the result of testimony from Eileen Franklin, based on repressed memory, her father was found guilty of murder. The validity of repressed memory, especially in investigating crimes, remains controversial. Can you think of a test to tell whether a recovered memory is accurate or not?

these events never occurred. Other research shows that people can even become convinced that they remember experiences from infancy that never happened (Spanos, 1996; Spanos, Burgess, Burgess, Samuels, & Blois, 1997).

Yet there is reason to believe that not all recovered memories are merely the product of suggestion. There are numerous case studies of people who have lived through traumatic experiences, including natural disasters, accidents, combat, assault, and rape, who then apparently forgot these events for many years, and who later remembered them (Arrigo & Pezdek, 1997). For example, Wilbur J. Scott, a sociologist, claimed to remember nothing of his tour of duty in Vietnam during 1968–1969, but during a divorce in 1983 he discovered his medals and souvenirs from Vietnam and the memories came back to him (Arrigo & Pezdek, 1997).

What is needed is a reliable way of separating real memories from false ones, but so far no such test is available. The sincerity and conviction of the person who “remembers” long-forgotten childhood abuse is no indication of the reality of that abuse. We are left with the conclusion that recovered memories are not, in themselves, sufficiently trustworthy to justify criminal convictions. There must also be corroborative evidence. For, as Loftus (1997) has noted, without corroboration there is no way even the most experienced examiner can separate real memories from false ones.

Cultural Influences on Memory

Does culture have an effect on memory? Research evidence indicates that it does indeed (Confino & Fritzsche, 2002; Mistry & Rogoff, 1994). For example, in many Western cultures, being able to recite a long list of words or numbers, to repeat the details of a scene, and to provide many facts and statistics about historical events are all signs of a “good memory.” In fact, such tasks are often used to test people’s memory abilities. But these kinds of memory tasks reflect the type of learning, memorization, and categorization skills taught in Western schools and considered important in Western culture. Members of other cultures often perform poorly on such memory tests because the exercises seem odd or foreign to them.
In contrast, consider the memory skills of a person living in a society where a rich oral tradition passes cultural information on from one generation to the next. This individual may be able to recite the deeds of the culture’s heroes in verse or rattle off the lines of descent of families, larger lineage groups, and elders. Or perhaps the individual has a storehouse of knowledge about the migration of animals or the life cycles of plants—information that helps people to obtain food and know when to harvest crops. An oral tradition of epic poetry (D’Azevedo, 1982), detailed recollection of the workings of nature, and the ability to recite long genealogies (Bateson, 1982) all demonstrate impressive memory skills that are to a great extent dependent on a person’s culture.

Memory and Culture

Frederic Bartlett, whose work on memory was discussed earlier in this chapter, anticipated the intertwining of memory and culture long ago. Bartlett (1932) related a tale of a Swazi cowherd who had a prodigious memory for facts and figures about cattle. The cowherd could recite, with virtually no error, the selling price, type of cattle bought, and circumstances of the sale for purchases dating back several years. These skills are not surprising when you know that in Swazi culture the care and keeping of cattle are very important in daily life, and many cultural practices focus on the economic and social importance of cattle. In contrast, Bartlett reported, Swazi children did no better than his young European subjects in recalling a 25-word message. Stripped of its cultural significance, their memory performance was not exceptional.

CHECK YOUR UNDERSTANDING

1. Older adults are more likely than younger adults to remember events that occurred during which time period?
   ___ a. childhood
   ___ b. late adolescence
   ___ c. early adulthood

2. What phenomenon enables people to create detailed visual images of things they have seen?
   ___ a. mnemonics
   ___ b. flashbulb memory
   ___ c. eidetic imagery

3. It is relatively easy to implant memories for events that never happened.
   ___ a. True
   ___ b. False

Answers:
1. b 2. c 3. a
Scientific research on memory began with Ebbinghaus’s experiments in the 19th century. Today the information-processing model of memory describes how information is encoded, stored, and retrieved from memory.

**The Sensory Registers**

Sensory registers are the entry points for raw information from all the senses. If we do not process this information further, it disappears.

Visual and Auditory Registers As new visual information enters the registers, old information (the icon, or visual image) is “masked” almost immediately and disappears. Otherwise, the registers would overload as visual information piled up and became scrambled. Auditory information fades more slowly; the echo may last for several seconds.

**Attention** From the mass of incoming information, we select elements for further processing. In this process, called attention, we also give meaning to the information.

**Short-Term Memory**

Information that we attend to enters short-term memory (STM), also called primary memory and working memory. STM contains everything that we are thinking about or are aware of at any instant. STM not only briefly stores information but also processes that information further.

**Capacity of STM** STM has its limits. Researchers have found that STM can hold only as much information as can be repeated or rehearsed in 1.5 to 2 seconds, which is usually 5 to 10 separate bits of information. We can process more information by grouping it into larger meaningful units, a process called chunking.

**Encoding in STM** Information can be encoded for storage in STM phonologically (according to the way it sounds), in visual form, or in terms of its meaning. Researchers conclude that STM has a greater capacity for material encoded visually than for information encoded phonologically.

**Maintaining STM** Through rote rehearsal, or maintenance rehearsal, we retain information in STM for a minute or two by repeating it over and over again. However, rote memorization does not promote long-term memory.

**Long-Term Memory**

Long-term memory (LTM) is more or less permanent and stores everything we “know.”

**Capacity of LTM** Long-term memory can store a vast amount of information for many years.

**Encoding in LTM** Most of the information in LTM seems to be encoded in terms of meaning.

Serial Position Effect Short- and long-term memory work together to explain the serial position effect, the fact that when given a list of items to remember, people tend to recall the first and last items in the list.

**Maintaining LTM** Rote rehearsal is useful for holding information in LTM, particularly meaningless material such as phone numbers. Through elaborative rehearsal, we extract the meaning of information and link it to as much material that is already in LTM as possible. Elaborative rehearsal processes new data in a deeper and more meaningful way than simple rote repetition. The way in which we encode material for storage in LTM affects the ease with which we can retrieve it later on.

A schema is a mental representation of an object or event that is stored in memory. Schemata provide a framework into which incoming information is fitted. They may prompt the formation of stereotypes and the drawing of inferences.

Types of LTM Episodic memories are memories for events experienced in a specific time and place. Semantic memories are facts and concepts not linked to a particular time. Procedural memories are motor skills and habits. Emotional memories are learned emotional responses to various stimuli.

Explicit memory refers to memories we are aware of, including episodic and semantic memories. Implicit memory refers to memories for information that either was not intentionally committed to LTM or is retrieved unintentionally from LTM, including procedural and emotional memories. This distinction is illustrated by research on priming, which finds that people are more likely to complete fragments with items seen earlier than with other, equally plausible items.

**The Biology of Memory**

**How Are Memories Formed?** Memories consist of changes in the synaptic connections among neural cells. The process by which these changes occur is often very slow.

**Where Are Memories Stored?** There is no one place where all memories are stored, but research has shown that different parts of the brain are specialized for the storage of memories. Short-term memories seem to be located primarily in the prefrontal cortex and temporal lobe. Long-term memories seem to involve both subcortical and cortical structures. Semantic and episodic memories seem to be located primarily in the frontal and temporal lobes of the cortex, and procedural memories appear to be located primarily in the cerebellum. Emotional memories are dependent on the amygdala.

**Forgetting**

The Biology of Forgetting According to the decay theory, memories deteriorate because of the passage of time. Severe memory loss can be traced to brain damage caused by accidents, surgery, poor diet, or disease. Head injuries can cause retrograde amnesia, the inability of people to remember what happened shortly before
their accident. Some studies have focused on the role of the hippocampus in long-term memory formation. Other research has emphasized the role of neurotransmitters, especially acetylcholine, in the memory process.

Experience and Forgetting  To the extent that information is apparently lost from LTM, researchers attribute the cause to inadequate learning or to interference from competing information. Interference may come from two directions: In **retroactive interference**, new information interferes with old information already in LTM; **proactive interference** refers to the process by which old information already in LTM interferes with new information.

When environmental cues that were present during learning are absent during recall, cue-dependent forgetting may occur. The ability to recall information is also affected by one’s physiological state when the material was learned; this is known as state-dependent memory.

Sometimes we “reconstruct” memories for social or personal self-defense.

How to Reduce Forgetting  A number of steps can be taken to improve recall: Develop motivation. Practice memory skills. Be confident in your ability to remember. Minimize distractions. Stay focused. Make connections between new material and other information already stored in your long-term memory, using such techniques as **mnemonics**. Use mental imagery. Use retrieval cues. Rely on more than memory alone. Be aware that your own personal schemata may distort your recall of events.

Special Topics in Memory

Autobiographical Memory  Autobiographical memory refers to our recollection of events that happened in our life and when those events took place.

**Childhood Amnesia**  People generally cannot remember events that occurred prior to age two. This phenomenon, known as **childhood amnesia**, is not well understood.

**Extraordinary Memory**  People with exceptional memories have carefully developed memory techniques. Mnemonists are individuals who are highly skilled at using those techniques. A phenomenon called **eidetic imagery** enables some people to see features of an image in minute detail.

**Flashbulb Memories**  Years after a dramatic or significant event occurs, people often have vivid memories of that event as well as the incidents surrounding it. These memories are known as **flashbulb memories**. According to the “now print” theory, the event triggers a mechanism in the brain that captures the memory, prints it like a photograph, and stores it for a long time. Recent research has challenged the assumptions that flashbulb memories are accurate and stable.

**Eyewitness Testimony**  Jurors tend to put their faith in witnesses who saw an event with their own eyes. However, some evidence suggests that eyewitnesses sometimes are unable to tell the difference between what they witnessed and what they merely heard about or imagined.

**Recovered Memories**  There are many cases of people who experience a traumatic event, lose all memory of it, but then later recall it. Such **recovered memories** are highly controversial, since research shows that people can be induced to “remember” events that never happened. So far there is no way to distinguish real recovered memories from false ones.

**Cultural Influences on Memory**  Cultural values and practices influence what kinds of things we remember and how easily we recall them.

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**Key Terms**

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