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Imagine what life would be like without memory. Everything would be constantly new. There would be no past experiences. We would have no top-down processing. Even the present would be a state of massive confusion because we couldn’t use what we know, our memory, to interpret the world. Everything would be new and unfamiliar. So, instead of being critical of memory when we forget things, we should be thankful that we have it. Our memories may fail us sometimes, but they are essential for life as we currently experience it. Without memory, we would be lost in the present.

The study of memory is not only an extension of the study of sensation and perception discussed in Chapter 3 (top-down processing using stored memories enables current perceptions, and new memories are formed from these perceptions), but it is also an extension of the discussion of the learning processes in Chapter 4 (the learning involved in human memory is more complex than the associational learning involved in conditioning). In this chapter, we will focus on the memory processes essential to learning as we normally think about it—learning from books and other media. The material in this chapter will have a practical use—by finding out how memory works, you will be able to improve yours.

To help understand how your memory works, we begin with a discussion of the most influential model of our memory system—the three-stage model. Then, the focus will turn to how we get information into our memory system—a process called encoding. In this section, we will examine ways to improve memory through better encoding. Next, we will consider encoding’s companion process—retrieval, the process of getting information out of memory. In this section on retrieval, we will learn that memory is a constructive process and can be manipulated. We will also consider the question of whether information stored in memory is ever lost. Is the information truly no longer available or is it just not accessible at a particular point in time? Here we will also discuss false memories and the controversial topic of repressed memories of childhood abuse. But before considering these more complex issues in memory, let’s get a basic overview of how our memory system works by considering the classic three-stage model of memory.

### Three-Stage Model of Memory

The three-stage model of our memory system has guided much of the research on memory since the late 1960s (Atkinson & Shiffrin, 1968, 1971). Diagrams depicting this memory model typically use a series of boxes to indicate the stages of information processing, and arrows connecting the boxes to show the flow of information within the system. Figure 5.1 is an informational flow chart for the three-stage memory model. In general, information enters from the physical environment through our senses into sensory memory and flows from sensory memory to short-term memory to long-term memory and then back to short-term memory when we need to use it. In this section, we will discuss each of these three stages of information processing and how the stages interact to provide us with memory. The initial stage of processing, sensory memory, is roughly comparable to what we called sensation in Chapter 3. Information in this stage is bottom-up...
Sensory Memory

Sensory memory (SM) consists of a set of registers, where we temporarily store incoming sensory information from the physical environment until we can attend to it, interpret it, and move it to the next stage of memory processing (short-term memory). We have a register for each of our senses—vision, hearing, taste, smell, and touch. The sensory information stored temporarily in these registers has not yet been recognized. Once it is recognized and we are consciously aware of it, it has moved into the next memory stage, short-term memory. Vision is our dominant sense, so we'll focus on the visual sensory register, commonly referred to as iconic memory, to help you understand how these registers work.

A good way to think about iconic memory is that it is photographic memory but for less than 1 second. An exact sensory input that hasn’t been recognized yet. So let’s begin by discussing how memory researchers have demonstrated that a sensory-memory stage exists and how information is processed in this stage.
copy of the visual information exists in iconic memory, but only for a very brief period of time. We cannot attend to everything we see; therefore, the visual information in iconic memory that we attend to gets recognized and goes on to short-term memory, and the unattended information in the register fades away and is quickly forgotten. Information in long-term memory (top-down processing) is obviously necessary for recognition to occur. This is why there is an arrow in Figure 5.1 going from long-term memory back to the recognition process between sensory memory (in this case, iconic memory) and short-term memory. This recognition process (what we called perception in Chapter 3) is the mechanism for encoding information from iconic memory into short-term memory.

We said that iconic memory lasts less than a second. This means that its duration (how long information can remain in a memory stage if not attended to) is less than a second. How do we know this? We will examine how research psychologists have answered this duration question and a similar capacity question (how much information can be held in a memory stage at one time) for each of the three memory stages. We’ll start with a discussion of how the capacity and duration answers for iconic memory were found. Two different experimental procedures, one direct and one inferential, were used. We’ll consider the direct one, the temporal integration procedure, first, because it is easier to understand.

**The temporal integration procedure.** In the temporal integration procedure, two meaningless dot patterns are presented sequentially at the same visual location with a brief time delay between them. When these two meaningless patterns are integrated, a meaningful pattern is produced. So, if the meaningful pattern is recognized, this means that the two patterns must have been integrated in our memory system (since the two patterns were not presented simultaneously).

To see how this works, let’s consider an example. Look at the first two dot patterns (a and b) in Figure 5.2. Each is just a meaningless dot pattern. However, if you integrate the two patterns (as shown in c), you see a meaningful pattern—the letters V O H. If the first two patterns were shown simultaneously in the same

**Figure 5.2 | An Example of the Temporal Integration Procedure** | In this experimental procedure, two meaningless patterns (such as a and b) are shown sequentially at the same visual location. If the time interval between the two patterns is less than a second, a meaningful pattern (in this example, the letters V O H) is seen. The meaningful pattern can only be perceived when the two other patterns are integrated, so this integration must be taking place within our memory system, in what we call the visual sensory register or iconic memory.
visual location on a screen so that they were integrated, you would see V O H; but if they were presented sequentially, the only way you could see the three letters is if the two meaningless dot patterns were integrated somewhere within your memory system. This is exactly what happens. The two patterns were integrated in iconic memory (the visual sensory register). However, this is only the case if the interval between the two patterns is very brief, less than a second (Eriksen & Collins, 1967). Participants in experiments such as this do not see the meaningful pattern when the two dot patterns are separated by more than a second. The first pattern has already faded from iconic memory, and thus, the two patterns cannot be integrated in iconic memory.

This pattern of results using the temporal integration procedure is also observed for larger, more complex dot patterns (Hogben & Di Lollo, 1974). People see the meaningful integrated pattern if the interval between these larger patterns is less than a second. The capacity of iconic memory must be fairly large or these more complex patterns couldn’t be integrated. Thus, the capacity of iconic memory is large, but its duration is very brief, less than a second.

**Sperling’s full- and partial-report procedures.** We find the same results for the capacity and duration of iconic memory when we use a very different experimental procedure devised by George Sperling (1960). On each trial in Sperling’s research, participants were presented with a different display of unrelated consonants for 50 milliseconds (1/20th of a second), a very brief interval but long enough to process visual information. Unrelated consonants were used so that the letter displays did not contain any acronyms, syllables, or words. Different size displays were also used, but for our explanation we will consider 3 × 3, nine-letter displays (as illustrated in Figure 5.3). The task was to report the letters in the display briefly flashed on each trial, but Sperling used two different report procedures. In **Sperling’s full-report procedure**, the participant had to try to recall all of the letters in the display. A different 3 × 3 letter display was used on each trial.
so that the subject could not learn the letters in the display. Over trials, participants recalled 4.5 letters on average, usually those letters in the top row and the left section of the second row. However, participants also reported (subjectively) that they sensed the entire display, but that it had faded from memory by the time they reported the 4 or 5 letters. This sounds like iconic memory, doesn’t it? Let’s see how Sperling indirectly demonstrated through inference that the remaining unreported letters had been in iconic memory by using his partial-report procedure.

In Sperling’s partial-report procedure, the participant only had to report a small part of the presented letter display, a row indicated by an auditory cue on each trial. A high-pitched tone indicated that the top row was to be recalled, a medium-pitched tone the middle row, and a low-pitched tone the bottom row. These tones were easy to discriminate, so the participant had no difficulty in determining which row was indicated for recall. As in the full-report procedure, the letter display was different on every trial. In addition, the row that was cued was varied randomly across trials; therefore, the participant had no way of knowing which row would be cued on any particular trial. Regardless, when the auditory cue was given immediately after the brief presentation of the letter display, participants recalled the indicated row 100% of the time. From this result, we can infer that all of the rows must have been present in iconic memory; that is, an exact copy of the letter display must have been in iconic memory.

Based on the experimental results for the temporal integration procedure, what do you think would happen when Sperling inserted a time delay between the letter display and the auditory cue? Remember, the duration of iconic memory was estimated to be less than a second. Sperling found that as this time delay increased (up to 1 second), participants’ recall of the cued row worsened. This meant that the letter display was fading quickly from memory. We can conclude, then, based on two very different experimental procedures, that iconic memory exists and that it seems to hold an exact copy of the visual stimulus (indicating a large capacity), but only for a very brief time, less than a second (a very brief duration).

Sheingold (1973) replicated Sperling’s findings with children ages 5, 8, and 11 years old and with adults. He argued that the initial capacity of iconic memory was invariant across age. More recently, Blaser and Kaldy (2010), using a modified partial-report technique, found that by 6 months of age, infants’ iconic memory capacity nearly matches that of adults.
Given this finding of its early development, it appears that iconic memory is an essential component of our flexible, multifaceted visual system. We will learn about infants' visual memory in Chapter 7, on developmental psychology.

To get a feel for how iconic memory works in nonlaboratory situations, let's think about seeing a bolt of lightning. It's not really a singular, continuous bolt. It is actually three or more bolts that overlap in our iconic memory and lead to the perception of the single flash of lightning. If you turn off the lights and have a friend quickly move a flashlight in a circular motion, you see a circle of light. Why? Again, iconic memory is at work; it isn't a continuous stream of light, but that's what you perceive. This has larger implications. It is iconic memory that allows us to see the world as continuous and not as a series of unconnected snapshots.

The other sensory registers that have been studied also have large capacities but brief durations. How brief varies with the register. For example, the auditory sensory register (called echoic memory) that processes auditory information has a duration of around four seconds, slightly longer than the duration of iconic memory (Darwin, Turvey, & Crowder, 1972; Glucksberg & Cowen, 1970). The longer duration of echoic memory is due to the nature of auditory information (Radvansky, 2017). Auditory information is not present all at once like visual information. It is stretched out over time. Hence, it must stay in echoic memory longer so that it can be properly analyzed. The only other sensory register that has been adequately studied is the haptic sensory register that processes tactile (touch) information. Its duration is estimated to be less than 2 seconds (Shih, Dabrowski, & Carnahan, 2009). Collectively, the sensory registers make up sensory memory, the first step of information processing in the three-stage memory model. However, when we think about memory, we aren’t usually thinking about sensory memory. We’re thinking about memory with a much longer duration. So let’s take a look at the next major stage of processing in the memory system—short-term memory, which has a longer duration.

**Short-Term Memory**

Short-term memory (STM) is the memory stage in which the recognized information from sensory memory enters consciousness. We rehearse the information in short-term memory so we can transfer it into more permanent storage (long-term memory) and remember it at some later time. We also bring information from long-term memory back into short-term memory to use it to facilitate rehearsal, solve problems, reason, and make decisions; thus, short-term memory is often thought of as working memory (Baddeley, 2012; Engle, 2002). It is the workbench of the memory system. It is where you are doing your present conscious cognitive processing. What you’re thinking about right now as you read this sentence is in your short-term memory. As you work to understand and remember what you are reading, you are using your short-term working memory. The capacity of this...
type of memory is rather small. Humans just can’t process that many pieces of information simultaneously in consciousness. In addition, new information in this stage is in a rather fragile state and will be quickly lost from memory (in less than 30 seconds) if we do not concentrate on it. This is why it is called short-term memory. Now that we have a general understanding of the nature of this stage of memory, let’s see how and what researchers have learned about its capacity and duration.

The capacity of short-term memory. To assess the capacity of short-term memory, researchers have used the memory span task. In this task, the participant is presented a series of items one at a time and has to remember the items in the order that they were presented. The list items could be any of several types of stimuli such as unrelated letters or words. On each trial, the specific list items change. For example, if words are used, then it is a different list of words on each trial. What have researchers found? George Miller provided the answer in his classic 1956 paper, “The Magical Number Seven, Plus or Minus Two: Some Limits on Our Ability to Process Information.” Your memory span is defined as the average number of items you can remember across a series of memory span trials. Humans remember $7 \pm 2$ (5 to 9) chunks of information on memory span tasks. To see what Miller meant by the term chunk, let’s consider the memory span task.

In the memory span task, different types of items can be used. If the items were unrelated letters, most participants would remember 5 to 9 unrelated letters. But if the items were three-letter acronyms (meaningful abbreviations like ABC or USA) or words (like dog or boy), participants would remember 5 to 9 three-letter acronyms or words (15 to 27 letters). In this latter case, participants remember more letters than in the first case, but they remember the same number of meaningful units. This is what is meant by the term chunk. A chunk is a meaningful unit in memory. The capacity limit in short-term memory is in terms of chunks, $7 \pm 2$ chunks. So if the chunks are larger for a particular type of material (words vs. letters), we remember more information but not more chunks. Experts in a particular area, such as chess masters, have larger chunks for information in their area of expertise (Chase & Simon, 1973). In the case of a chess master, for example, several chess pieces on the board form a chunk, whereas for chess novices, each piece is a separate chunk.

The duration of short-term memory. Now let’s consider the duration of short-term memory, less than 30 seconds. Why is the duration of short-term memory said to be less than 30 seconds if this type of memory is equivalent to our conscious workspace? If we choose to do so, we could keep information in our consciousness for as long as we want, clearly longer than 30 seconds. The duration estimate refers to how long information can stay in short-term memory if we cannot attend to it. To measure this duration, researchers

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**memory span task** A memory task in which the participant is given a series of items one at a time and then has to recall the items in the order in which they were presented.

**memory span** The average number of items an individual can remember across a series of memory span trials.

**chunk** A meaningful unit in a person’s memory.
developed the distractor task (Brown, 1958; Peterson & Peterson, 1959). In the **distractor task**, a small amount of information (three unrelated consonants such as CWZ) is presented, the participant is immediately distracted from concentrating on the information for a brief interval of time, and then the information must be recalled. How is the participant distracted? A number is immediately presented, and the participant has to count rapidly aloud backward by 3s (or by some other interval). Counting backward rapidly occupies the short-term work space and prevents the participant from attending to the three letters. The experimenter varies the length of the distraction period. When the distraction period is over, the participant must try to recall the letters. What happens? Some typical data are presented in Figure 5.4.

As you can see in Figure 5.4, the estimated duration for information in short-term memory is rather brief, less than 30 seconds. To relate this to everyday life, think about what happens when a friend gives you her new cell phone number. She tells you the number. It goes into your echoic memory, and you attend to it and recognize it. It enters your conscious short-term memory. You start to concentrate on it so you can enter the number into your contacts list on your phone. Now what would happen to that number if you heard someone screaming outside and you ran to see what had happened? Chances are that you would forget the phone number (just like participants forget the three consonants in studies using the distractor task), and then have to ask your friend to give you the number again. Information in short-term memory is in a temporary storage state, and we need to concentrate on it to prevent it from being lost. Generally we use

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**distractor task** A memory task in which a small amount of information is briefly presented and then the participant is distracted from rehearsing the information for a variable period of time, after which the participant has to recall the information.

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![Figure 5.4](image-url) | Results for the Short-Term Memory Distractor Task
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This figure shows how forgetting in short-term memory occurs over time. As the length of the distractor interval increases, forgetting increases very rapidly. In less than 30 seconds, recall is essentially zero.

maintenance rehearsal to accomplish this. **Maintenance rehearsal** is repeating the information in short-term memory over and over again in order to maintain it. For example, in the case of the phone number, we rehearse it over and over again to ourselves until we complete the process of entering it into our contacts list.

Maintenance rehearsal is just one type of work (processing and manipulating information) performed in short-term memory. As we pointed out earlier, because of all of the various types of work done in short-term memory, it is now commonly referred to as working memory. For our purposes here, you can think of **working memory** as a more detailed description of short-term memory that includes the mechanisms that allow short-term memory to accomplish its tasks. To explain how working memory does this, researchers have proposed differing models of the mechanisms in working memory (Miyake & Shah, 1999). The most influential explanatory model is that of Alan Baddeley (2007, 2012; Baddeley & Hitch, 1974). In brief, Baddeley proposed that there are four components of working memory: (1) a phonological loop, (2) a visuospatial sketchpad, (3) an episodic buffer, and (4) a central executive. The phonological loop allows you to work with verbal information for a short period of time. It is what allows us to repeat the phone number in the maintenance rehearsal example over and over in order to maintain it. Similarly, the visuospatial sketchpad works with visual and spatial information, such as the figures and illustrations on a page in this book, as well as their spatial positions on the page. The episodic buffer integrates information from the phonological loop, the visuospatial sketchpad, and long-term memory, such as the integration of the visual information of your teacher writing on the blackboard, the verbal input from his lecture, and the meaning of all of this input from long-term memory. It is called the episodic buffer because it represents a temporary storage place (a buffer) for the integrated representation of what is happening at any moment in time (an episode). Lastly, the central executive component is responsible for coordinating the activities of and distributing resources to the other three components so that the work (the processing and manipulation of information) can be optimally accomplished. It is also the mechanism for controlling our attention and communicating with long-term memory. In brief, it is the CEO of working memory.

Now that we have a better understanding of short-term memory, we need to think about what our goal is when we are trying to learn. It is not merely to maintain information in short-term memory. Our goal is to put that information into long-term storage so that we can retrieve and use it in the future, and our short-term memory plays a large role in this task. In the last two major sections of this chapter, we will look at the process of encoding information from short-term memory into long-term memory and of retrieving that information from long-term memory back into short-term memory at some later time. But first we need to get an overview of long-term memory, the last memory stage in the three-stage model.
When we use the word memory, we normally mean what psychologists call long-term memory. **Long-term memory (LTM)** allows storage of information for a long period of time (perhaps permanently), and its capacity is essentially unlimited. Remember the trillions of possible synaptic connections in the brain that we discussed in Chapter 2? They represent the capacity of long-term memory. This capacity has been estimated to be around 2.5 petabytes (a million gigabytes). Although human memory does not work like a video recorder, imagining that it does will give you a better understanding of the enormous size of the capacity of long-term memory. If human memory worked like a video recorder, it could hold 3 million hours of television shows (Reber, 2010). You would have to leave the television running continuously for more than 300 years to use up all that storage. Whereas long-term memory has this incredibly large capacity, it definitely does not work like a video recorder (Lilienfeld, Lynn, Ruscio, & Beyerstein, 2010). However, many Americans believe that it does, about 50% according to recent surveys (Simons & Chabris, 2011, 2012). Why this misbelief exists is not clear. What is clear is that our long-term memories are far from exact replicas of what we experience; they are reconstructive and not reproductive. We will discuss both the reconstructive nature of long-term memories and theories of why we forget later in this chapter.

The durations and capacities for all three stages of memory are summarized in Table 5.1. Review these so that you have a better understanding of how these three stages differ. Next, let’s consider different types of long-term memories.

**Types of long-term memories.** Memory researchers make many distinctions between various types of long-term memories (Squire, 2004). The first distinction is between memories that we have to recall consciously and make declarative statements about and those that don’t require conscious recall or declarative statements (see Figure 5.5). What if someone asked you, “Who was the first president of the United States?” You would retrieve the answer from your long-term memory and consciously declare, “George Washington.” This is an example of

<table>
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<tr>
<th>Table 5.1</th>
<th>Durations and Capacities of the Three Memory Stages</th>
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<tbody>
<tr>
<td><strong>Memory Stage</strong></td>
<td><strong>Duration</strong></td>
</tr>
<tr>
<td>Sensory memory</td>
<td>&lt; 1 sec for iconic memory; 4–5 secs for echoic memory; &lt; 2 secs for haptic memory</td>
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<tr>
<td>Short-term memory</td>
<td>Up to 30 secs without rehearsal</td>
</tr>
<tr>
<td>Long-term memory</td>
<td>A long time (perhaps permanently)</td>
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what is called explicit (declarative) memory—long-term memory for factual knowledge and personal experiences. Explicit memory requires a conscious explicit effort to remember.

Tulving (1972) made a further distinction in explicit memory between semantic memory, memory for factual knowledge, and episodic memory, memory of your personal life experiences (the episodes in your life). Remembering that George Washington was the first president of the United States (semantic memory) is very different than remembering your first kiss (episodic memory). Semantic and episodic memories blend together in autobiographical memory (Williams, Conway, & Cohen, 2008). Autobiographical memories obviously include episodic memories of your past personal experiences, but they can also be about factual, semantic aspects of your personal history, such as remembering your birth date or what high school you attended.

Explicit memory is contrasted with implicit (nondeclarative) memory. Implicit memory is long-term memory that influences our behavior but does not require conscious awareness or declarative statements. Implicit memory happens automatically, without deliberate conscious effort. For
example, you remember how to drive a car and you do so without consciously recalling and describing what you are doing as you drive. Some implicit memories (like driving a car, typing, or hitting a tennis ball) are referred to as **procedural memories** because they have a physical procedural aspect (the execution of an ordered set of movements) to them. In contrast with declarative explicit memories, procedural implicit memories are like knowing “how” versus knowing “what.” Not all implicit memories, however, are procedural memories (see Figure 5.5). We learned about another type of implicit memory, classical conditioning, in Chapter 4. Classically conditioned responses elicited automatically by conditioned stimuli are also implicit memories.

Another type of nonprocedural implicit memory is priming. In **priming**, an earlier stimulus influences the response to a later stimulus. Priming is classified as implicit memory because it occurs independent of a person’s conscious memory for the priming stimulus. There are several experimental priming procedures, but let’s consider one called repetition priming so that you can gain a better understanding of how priming works. In repetition priming, a person first studies a list of words and then at some later time is asked to complete a list of word fragments with the first word that comes to mind for each fragment. For example, the fragment _c_ _ _ _ _ might be presented. The likelihood that the person answers “s o c i a l” (the primed word because the word social was on the earlier word list) is much higher than for unprimed words, such as _s o c c e r_ or _s o c k e t_, that fit the fragment but were not on the list. Such priming occurs even when people had not recognized the list word on an earlier recognition test (Tulving, Schacter, & Stark, 1982). Thus, priming occurs when explicit memory for the word does not, which means that priming is an involuntary, nonconscious implicit process. Graf, Squire, and Mandler (1984) provided further evidence that priming is an implicit, nonconscious type of memory. They found that **amnesics**, people with severe memory deficits following brain surgery or injury, who had no explicit memory for new information could perform as well as normal adults on a repetition priming-word fragment task even though the amnesics had no conscious memory of having seen the words before.

Next we’ll see how other memory research with amnesics has allowed us to further differentiate explicit and implicit memory and even discover what parts of the brain seem to be involved in each type of memory.

**Amnesia, the loss of long-term memories.** There is some evidence from the studies of amnesics that explicit and implicit memories are processed in different parts of the brain. We will focus our discussion of amnesics on the most studied amnesic in psychological research, H. M., whom we discussed briefly in Chapter 1. When H. M. was 7 years old, he was hit by a bicyclist and suffered a brain injury that later led to severe epileptic seizures in his teens (Hilts, 1995). In
1953 at the age of 27, H. M. had his hippocampus and surrounding temporal lobe areas removed with the hope of reducing his epileptic seizures (Corkin, Amaral, Gonzalez, Johnson, & Hyman, 1997). The seizures were reduced, but the operation drastically affected his long-term memory. Before the operation, he had normal short-term memory and long-term memory. After the operation, he had normal short-term memory, above-average intelligence, and no perceptual or language deficits, but he didn't seem able to store any new information in long-term memory (Scoville & Milner, 1957). For example, H. M. could read the same magazine over and over again and think it was a new magazine each time. He could no longer follow the plot of a television show because the commercials would interfere with his memory of the story line. If he did not know someone before his operation and that person introduced herself to him and then left the room for a few minutes, he would not know the person when she returned. Even Brenda Milner and Suzanne Corkin, the two neuroscientists who studied H. M. for decades, had to introduce themselves anew each time they met with him.

H. M. had anterograde amnesia—the inability to form new explicit long-term memories following surgery or trauma to the brain. Anterograde amnesia is contrasted with retrograde amnesia—the disruption of memory for the past, especially episodic information for events before, especially just before, brain surgery or trauma. Such amnesia is typical in cases of brain concussions. H. M. had some retrograde amnesia, especially for the several days preceding the surgery, but this was mild compared with his severe, pervasive anterograde amnesia.

Remember, as we just learned, amnesics have shown implicit repetition priming effects. So what about H. M.? Although he didn’t form any new explicit long-term memories (but see O’Kane, Kensinger, & Corkin, 2004; Skotko et al., 2004), did he form new implicit memories? The answer is a resounding “yes” (Corkin, 2013). Let’s briefly consider some of the experiments demonstrating this. H. M. demonstrated implicit procedural memory on a mirror-tracing task. In this task, you have to trace a pattern that can be seen only in its mirror image, which also shows your tracing hand moving in the direction opposite to its actual movement. This is anterograde amnesia The inability to form new explicit long-term memories for events following surgery or trauma to the brain. Explicit memories formed before the surgery or trauma are left intact.

retrograde amnesia The disruption of memory for the past, especially episodic information for events before, especially just before, surgery or trauma to the brain.
a difficult motor task, but there is a practice effect in that the number of errors decreases across practice sessions. H. M.’s performance on this task showed a normal practice effect even when months elapsed between the sessions (Gabrieli, Corkin, Mickel, & Growdon, 1993). However, he did not remember ever having done this task and had to have the instructions repeated for each session. Corkin (1968) also found that H. M. improved with practice on another manual skill learning task, one in which he had to keep a stylus on a small dot that was spinning around on a turntable. H. M. got better at this task with practice, but he had no conscious memory of his earlier experiences that led to his improved performance.

H. M. also demonstrated implicit repetition priming effects on a word fragment completion task without conscious awareness of the earlier presented priming words (Corkin, 2002) and implicit memory for a classically conditioned eyeblink response (Woodruff-Pak, 1993). In the latter case, after he was classically conditioned to give an eyeblink response to a tone, he could not consciously remember the conditioning episodes; however, he stored an implicit memory of the conditioned association between the tone and eyeblink response. Thus, he blinked when he was exposed to the tone but had no idea why he did so. LeDoux (1996) tells the story of a similar finding with a female amnesic with memory deficits like those of H. M. She was unable to recognize her doctor (Edouard Claparède), so each day Dr. Claparède shook her hand and introduced himself. One day, however, the doctor concealed a tack in his hand so that when shaking hands, the tack pricked her. The next time the doctor tried to introduce himself and shake hands, she refused to do so but didn’t know why. She had been conditioned without any explicit awareness of it.

The Mirror-Tracing Task | The task is to trace the outline of a star (or some other shape) with a metal stylus when the star and your hand can be seen only in the mirror. Thus, the tracing movements have to be made in the direction opposite from the way in which they appear in the mirror. When the stylus moves off of the star outline (each red section in the illustrated tracing), it makes electrical contact with the underlying aluminum plate and a tracing error is recorded. There is nonconducting tape on the star outline, so as long as the stylus stays on the outline, no electrical contact is made. Just like we would, H. M. improved from session to session (the number of errors he made decreased) as he gained more experience in this task. However, unlike us, he could not remember ever having performed the task before and had to have the task explained to him each session. As explained in the text, this means that he formed new implicit procedural memories for how to do the task, but he did not form new explicit episodic memories of having performed the task.
How is it possible that H. M. and other amnesics like him can form new implicit but not explicit memories? Research indicates that other parts of the brain, such as the cerebellum and basal ganglia, and not the hippocampus, are important for implicit memory formation and storage (Green & Woodruff-Pak, 2000; Knowlton et al., 1996; Krebs, Hogan, Hening, Adamovich, & Poizner, 2001; Krupa, Thompson, & Thompson, 1993; Squire, 2004). Implicit memory formation is functional in these amnesics because the cerebellum, basal ganglia, and the other parts of the brain necessary for such memories are intact, but explicit memory formation isn’t functional because the hippocampus has been removed. Findings congruent with the major processing differences between the left and right hemispheres that we discussed in Chapter 2 are observed for people with only left- or right-hemisphere damage. Schacter (1996) reported that people with left hippocampal damage have difficulty recalling verbal information, but they do not have difficulty remembering visual information, and the opposite is true for those with right hippocampal damage.

A hippocampal explanation has also been proposed for infantile/child amnesia, our inability as adults to remember events that occurred in our lives before about three years of age. According to this explanation, we cannot remember our experiences during this period because the hippocampus, which is crucial to the formation of episodic explicit long-term memories, is not yet fully developed. Remember, as we discussed in Chapter 2, neurogenesis, the generation of new neurons, occurs in the hippocampus. During infancy, neurogenesis levels are high because the hippocampus is developing. Akers et al. (2014) found evidence that such high levels of neurogenesis disrupt hippocampus-dependent memories, causing them to degrade. It is also important to realize that although the hippocampus is critical to the formation of explicit memories, it is not the final repository for these memories, but is more like a holding zone for them. As explicit memories age, the hippocampus’s participation wanes (Smith & Squire, 2009). These memories are distributed throughout many areas in the cortex, a process called memory consolidation (the storage of long-term memories). How this happens and how these memories are represented remain questions to be answered (Miller, 2005).

Evidence for short-term versus long-term memory distinction. The memory findings for amnesics like H. M. also indicate that short-term memory and long-term memory are different stages of memory. H. M.’s short-term memory did not suffer any substantial deficits after the operation. For example, his memory span was within the normal range. He could repeat a telephone number with no difficulty. Researchers examining the free recall task have found additional evidence that long-term memory and short-term memory are different stages. In the free recall task, participants are given a list of words one at a time and then asked to recall them in any order they wish. Kirkpatrick

infantile/child amnesia Our inability as adults to remember events that occurred in our lives before about three years of age.

free recall task A memory task in which a list of items is presented one at a time and then the participant is free to recall them in any order.
(1894) introduced the free recall task, noting that some word positions are recalled much better than others. If recall performance for the words is plotted in terms of the order the words were presented (their position in the list—first, second, . . . , last), the figure has a very distinctive shape (Figure 5.6). The ends of the list are recalled much more often than the middle of the list. The superior recall of the early portion of the list is called the **primacy effect**. The superior recall of the latter portion of the list is called the **recency effect**.

How do the primacy effect and recency effect relate to the distinction between short-term and long-term memory? The recency effect is caused by recall from short-term memory. Items at the end of the list, the most recent items, have a high probability of still being in short-term memory, so they can be recalled immediately and very well. The primacy effect, however, is the result of superior recall from long-term memory of the first few words in the list versus those in the middle (Rundus & Atkinson, 1970). Let’s think about the task. The words are presented one at a time. The first word comes into your empty short-term memory to be rehearsed. It gets 100% of your attention. Then the second word appears and is rehearsed with the first word (each gets 50% of your attention). This goes on until short-term memory capacity (5 to 9 chunks) is reached and each new word causes a word already in short-term memory to be bumped out. This results in the first few items on the list being rehearsed more than the later words in the middle and thus having a higher probability of being stored in long-term memory and recalled better. The items in the middle of the list come into a filled short-term memory, get little rehearsal, and thus have a low probability of being stored in long-term memory and recalled later.

How do we know that this is so? Researchers have demonstrated that the primacy effect and the recency effect can be

**Figure 5.6** | **Serial Position Effects for a One-Trial Free Recall Task** | The superior recall of the first few items presented relative to those in the middle of the list is called the primacy effect. This effect is due to the fact that the primary items in the list are studied more and so have a higher probability of being in long-term memory for later recall. The recency effect refers to the superior recall of the last few items presented versus those in the middle of the list. This effect is due to the easy immediate recall of the items currently in short-term memory (those recently presented).
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manipulated independently, indicating that different memory stages are involved. For example, if recall is delayed by having the participants count rapidly backward by 3s for 30 seconds, the recency effect is eliminated, but the primacy effect remains (Glanzer & Cunitz, 1966). Thus, the distractor period only disturbed recall from short-term memory. Similarly, we can eliminate the primacy effect but still observe a recency effect if we force participants to rehearse each of the list items equally by having them only rehearse each word aloud after it is presented. With equal rehearsal, the primary and middle items are recalled equally well, so there is no primacy effect, and because amount of rehearsal is not critical to recall from short-term memory, a recency effect (although smaller) remains. In addition, fMRI neuroimaging data indicate that both short-term memory and long-term memory are involved in these serial position effects (Talmi, Grady, Goshen-Gottstein, & Moscovitch, 2005). Recognition of early items in the word list uniquely activated brain areas traditionally associated with long-term memory, but none of these areas were activated for retrieval of late items in the list.

Given the primacy and recency effects observed in the free recall task, what would you predict that the results would look like for a free recall task administered to people with anterograde amnesia, like H. M.? Remember, H. M. had his hippocampus and surrounding temporal lobe areas removed, impairing his ability to form new explicit long-term memories. If you predicted that amnesics like H. M. would show a normal recency effect but not a normal primacy effect, you are correct. Anterograde amnesics have little recall for the primacy portion of the free recall list because of their explicit long-term memory impairment, but they show a recency effect because it depends upon recall from short-term memory, which is still intact and functioning (Baddeley & Warrington, 1970; Carlesimo, Marfia, Loasses, & Caltagirone, 1996).

We learned that more rehearsal leads to better long-term memory, but is better memory just a matter of more rehearsal (more study)? This question is addressed in the next section, where we discuss moving information from short-term to long-term memory (what you try to do when you study). You will learn that the type of rehearsal (study method) you use is important. Thus, the information in the next section can help you to develop better study strategies and better memory.

**Section Summary**

In this section, we discussed the three-stage model that describes the processing of information entering from the physical environment through our senses into our memory system. In general, sensory information enters the sensory registers that comprise the first stage of processing—sensory memory. These temporary storage registers have large capacities and hold essentially exact copies of the information until we can attend to it and process it further. The duration of these registers is very brief, however. For example, the duration of the visual sensory register (iconic memory) is less than a second. We can only attend to part of the information in each register to process it farther into the memory system. The rest of the information fades quickly from the register and is forgotten.
The information that we attend to gets recognized and moves into our short-term memory, the second stage in the three-stage memory model. Short-term memory is like our conscious workspace. It has a small capacity (7 ± 2 chunks of information) and a brief duration (less than 30 seconds). Short-term memory is often referred to as working memory, because it is here that we do the work necessary to encode new information into long-term memory and to accomplish all of our other conscious activities, such as problem solving and decision making. Working memory can be thought of as the collection of mechanisms in short-term memory that allows it to accomplish these tasks. According to Baddeley’s model of working memory, the mechanisms are a phonological loop, a visuospatial sketchpad, an episodic buffer, and a central executive. The central executive coordinates the activities of the other three components and the storing and retrieval of information from long-term memory.

The third stage of processing, long-term memory, is what we normally mean when we use the word memory. It is our long-term (perhaps permanent) repository for information. In addition, the capacity of long-term memory is essentially limitless. There are different types of long-term memories. The major distinction is between explicit memories (those that require conscious recall and declaration) and implicit memories (those that do not require conscious recall and declaration). There are two types of explicit memories—semantic memories (our factual knowledge base) and episodic memories (our personal life experiences). There are three types of implicit memories—procedural memories that involve some type of physical or cognitive procedure, classical conditioning memories, and memories leading to priming effects.

Research findings with amnesics who have suffered hippocampal damage indicate that the hippocampus is important for explicit memory formation but not implicit memory formation. These findings also support the distinctiveness of short-term and long-term memories because these amnesics have relatively normal short-term memory. Further evidence for these two stages is provided by the primacy effect and the recency effect for free recall. The independent manipulation of these effects indicates that they are the products of recall from different memory stages.

**Concept Check 1**

Explain why you can think of the information in sensory memory as bottom-up input and the information in long-term memory as top-down input.

Explain why the very brief duration of iconic memory is necessary for normal visual perception.

Explain what is meant by the term *chunk* with respect to the capacity of short-term memory, 7 ± 2 chunks.

Explain how the studies of H. M. indicate that he could not form any new explicit long-term memories but could form new implicit long-term memories.
Encoding Information into Memory

There are three essential processes in our memory system—encoding, storage, and retrieval. **Encoding** is the process of transferring information from one memory stage to the next (from sensory into short-term memory and from short-term into long-term memory). **Storage** refers to the process of maintaining information in a particular stage. Storage is temporary except for in long-term memory. **Retrieval** is the process of bringing information stored in long-term memory to the conscious level in short-term memory. Let’s go back to the flow chart of the three-stage model of memory in Figure 5.1. Encoding and retrieval determine the flow of information within the three-stage system. Information is first encoded from sensory to short-term memory, where it can be stored temporarily. Information is then encoded from short-term to long-term memory, where it is stored more permanently but can be retrieved and brought back into short-term memory when we need to use it.

In this section, we will cover encoding and its role in moving information from short-term into long-term memory. Our focus will be on the best ways to achieve this transfer. We begin with a consideration of general encoding strategies.

How We Encode Information

The first distinction to consider is automatic versus effortful processing (Hasher & Zacks, 1979). **Automatic processing** is processing that occurs subconsciously and does not require attention. In contrast, **effortful processing** is processing that occurs consciously and requires attention. For a particular type of processing to become automatic, much practice is needed. A good example is reading. At first, learning to read is very effortful, but after years of practice it becomes easier and more automatic. Wouldn’t it be nice if encoding to learn (studying) were an automatic process? It is unlikely that studying can become as automatic as reading, but we can get better at it by using better encoding strategies and practicing these strategies. In this section, we’ll discuss some of these better ways to encode. If you practice them, your encoding (and your memory) will improve.

**Levels-of-processing theory.** Remember that encoding is the process of transferring information from one memory stage into another. Here we are interested in encoding from short-term to long-term memory. Encoding information into long-term memory is related to retrieving information from long-term memory. Some types of encoding lead to better retrieval. The **levels-of-processing theory** describes what types of encoding lead to better retrieval (Craik & Lockhart, 1972). This theory assumes that incoming information can be processed at different levels, from...
the simplistic physical level to the semantic level, and that semantic processing, especially elaborative semantic processing, leads to better memory. According to this theory, there are three general levels of processing—physical, acoustic, and semantic. To understand the differences among these three levels, consider processing the word *brain*. We can process it as a string of lowercase letters. This would be the physical level. Next we could process *brain* by how it sounds, the acoustic level, which is a little deeper than the physical level. Third, we can process what *brain* means and then elaborate upon that meaning by relating it to what we know about parts of the brain and brain chemistry. This theory assumes that the strength of the memory trace is a function of the depth of processing involved. Shallow processing that only involves surface details (e.g., whether a word is italicized or not) leads to fragile memory traces and poor memory, whereas deeper processing that involves semantic details and elaboration upon these details leads to strong, durable memory traces and good memory. Next we’ll consider an experiment that clearly supports this assumption, even though the learning was incidental and not intentional.

Craik and Tulving (1975, Experiment 2) presented participants with a long list of words one at a time, but manipulated the level of processing of the words by manipulating the task to be performed on each word (Craik & Tulving, 1975, Experiment 2). For each word, one of three types of questions had to be answered. One type of question required processing the word at a physical level (for example, “Is this word in capital letters?”). A second type of question required acoustic processing (for example, “Does the word rhyme with bear?”). The third type of question required semantic processing (for example, “Will the word fit in the sentence, The man placed the ____________ on the table?”). An incidental learning paradigm was used. Participants did not know that they would be tested for their memory of the words. They only thought that they had to answer a question about each word. However, the experimenter later surprised the participants with a memory test for the words. Levels-of-processing theory predicts that memory for the words that had to be processed semantically should be best, those processed acoustically next best, and those only processed physically worst. This is exactly what was found (see Figure 5.7). Long-term recognition memory was the best for the words encoded semantically, next best for those encoded acoustically, and worst for those only encoded physically. In sum, deeper processing leads to better memory.

Now that you understand that successful retrieval from long-term memory involves both effortful and elaborative semantic processing, next we will discuss elaborative rehearsal, the real key to successful encoding.
Elaborative rehearsal. Maintenance rehearsal, the repetitive cycling of information in short-term memory, was discussed earlier in the chapter. This type of rehearsal serves to maintain information in short-term memory. Levels-of-processing theory, however, views this type of rehearsal as shallow, acoustic rehearsal. It is not very effective in producing good long-term memory for information. Semantic processing is much better. Once at the semantic level of processing, though, we should engage in elaborative rehearsal—rehearsing by relating the new material to information already in long-term memory. The memory organization created by the integration of the new information with existing information leads to more successful retrieval of the information than shallower processing. This organization provides more retrieval cues (links with other information in long-term memory) for the new information, thereby facilitating its retrieval. For example, to elaborately encode the concept of elaborative rehearsal, you could relate it to other concepts that you learned recently by thinking about such things as how elaborative rehearsal is different from maintenance rehearsal, how it relates to levels-of-processing theory, and how it is an example of effortful processing. Such elaboration enables much better long-term memory.

In elaborative rehearsal, the key then is to relate new information to information in long-term memory that you know well. Because you know yourself so well, you should also elaborate by tying the new information to yourself. To learn new concepts, you should personalize them by thinking of examples of these concepts in your own experiences. It is easier to remember information that you have related to yourself. This is called the self-reference effect, and it is a well-established research finding (Symons & Johnson, 1997). For example, researchers have found that people can remember more words from a list if they related the words to themselves (Rogers, Kuiper, & Kirker, 1977). Participants were asked whether list words such as generous applied to them. Later recall of such words was very good, even better than for words processed at the semantic level (as in the Craik and Tulving study). Think about how this might work. What if the word were honest? You would start thinking about incidents in your life in which you were honest and in which you were not. The word would then be linked to all of these incidents, facilitating its later recall. So when you are studying a new concept, you should not only link it to related concepts that you know well but also try to find examples of it in your own life. For some concepts this is easy to do; for others it isn’t. However, it’s worth the effort because such connections will help you to remember the concept through the self-reference effect.

Environmental effects on encoding. The fact that elaborative rehearsal improves memory stems from a larger principle—the encoding specificity principle (Tulving, 1983). In simple terms, the encoding specificity principle elaborative rehearsal A type of rehearsal in short-term memory in which incoming information is related to information from long-term memory to encode it into long-term memory.

self-reference effect The superior long-term memory for information related to oneself at time of encoding into long-term memory.

encoding specificity principle The principle that the environmental cues (both internal and external) present at the time information is encoded into long-term memory serve as the best retrieval cues for the information.
proposes that the cues present during encoding serve as the best cues for retrieval. This is why the various concepts and examples that you relate to a new concept during elaborative rehearsal help you remember the concept. They were present during encoding so they serve as good retrieval cues. Such cues are internal environmental cues; they refer to internal cognitive processing, what you were thinking about during rehearsal. Encoding specificity also applies to the external environmental cues present during encoding. Many research studies have shown that long-term memory is better when the physical study and test environments are as similar as possible. For example, in one rather dramatic demonstration of this, participants learned and were tested either underwater or on land (Godden & Baddeley, 1975). The two groups that had the same study and test environments (both were underwater or both were on land) remembered significantly better than the two groups that had their study and test environments reversed (one underwater and the other on land, or vice versa). However, you need not rush to classrooms to study. Classroom environmental effects on college exam performance are not very strong (Saufley, Otaka, & Bavaresco, 1985). Why? External environmental effects on learning diminish when the learning has taken place in several environments (Smith, Glenberg, & Bjork, 1978). In the case of exams, students have successfully learned the relevant information in a variety of environments ranging from the classroom to nonclassroom environments such as the library and dormitory rooms, thereby overriding the classroom environmental effect.

We have limited our discussion so far to a rather narrow definition of internal environment—a person’s mental activities at the time of encoding. Broader internal environmental factors, such as a person’s physiological state or mood, also impact encoding and retrieval. These effects lead to a phenomenon known as state-dependent memory, memory that depends upon the relationship of one’s physiological state at time of encoding and retrieval. The best memory occurs when people are in the same state at retrieval as they were at encoding, and memory is hindered by state differences. For example, people under the influence of alcohol at the time of encoding would recall best if under the influence at the time of retrieval. Please note, however, that memory under the influence of alcohol, regardless of the state at the time of retrieval, is very poor. It is best to encode and retrieve in a nonalcoholically influenced state.

There are similar effects on memory that depend on the relationship between a person’s emotional states, such as
being happy or sad, at the time of encoding and retrieval. Because one’s mood is involved, these effects are referred to as mood-dependent memory. The retrieval of a particular memory is better when a person’s mood at retrieval is the same as it was during encoding. Like state-dependency effects, mood-dependency effects furnish support for the encoding specificity principle—context is important for successful memory retrieval. There is also a related phenomenon called the mood-congruence effect—the tendency to recall memories that are congruent with a person’s current mood. A particular mood cues memories that are consistent with that mood (Eich, 1995). We tend to remember more positive events when we are feeling good and more negative events when we are feeling down. These events have been associated with the accompanying emotions. Thus, the emotions serve as retrieval cues for the events. This congruence effect may hinder recovery in depressed people because they will tend to remember negative events and not positive ones. In fact, this is the case. Depressed patients report more memories related to illness, injury, and death than nondepressed people (Schacter, 2000). Think positively, and the mood-congruence effect will help maintain that positive attitude.

The foregoing discussion of environmental effects on encoding may bring to mind the concept of learning styles. This concept refers to the claim that different students have different (preferred) modes of learning, such as verbal, visual, auditory, or kinesthetic learners. Proponents of learning styles believe that students’ learning can be improved by matching teaching styles with students’ preferred learning styles (Riener & Willingham, 2010). However, extensive research on this claim has clearly demonstrated that matching teaching styles to students’ preferred learning styles does not lead to better performance (Massa & Mayer, 2006; Rogowsky, Calhoun, & Tallal, 2015; Pashler, McDaniel, Rohrer, & Bjork, 2008). After a thorough review of the learning styles research literature, Pashler et al. (2008) concluded that “there is no adequate evidence base to justify incorporating learning-styles assessments into general educational practice” (p. 105). In fact, this claim about learning styles has been identified as an educational myth (Holmes, 2016; Lilienfeld et al., 2010). Good teaching involves varied methods, typically based on the nature of the material, not based on students’ preferred learning styles.

Interestingly, Husmann and O’Loughlin (2019) found that most students don’t even choose study strategies that mesh with their self-reported learning styles, and those that do show no academic benefit. Although students may believe that learning styles influence performance, it is clear that they do not. Husmann and O’Loughlin also found that many students are using study strategies that are simply not appropriate for effective encoding and retention of information. They observed negative correlations between study strategies reported by students (e.g., making flashcards or recopying their notes) and course performance. There are, however, a number of strategies that have been identified by mood-dependent memory Long-term memory retrieval is best when a person’s mood state at the time of encoding and retrieval of the information is the same. mood-congruence effect Tendency to retrieve experiences and information that are congruent with a person’s current mood.
memory researchers for enhancing knowledge acquisition and retention. We have discussed one of these, elaborative rehearsal. We will discuss others in the next section on how to improve encoding.

In summary, elaborative rehearsal is the most effective strategy for encoding. Research has even found that actors working to learn their lines use extensive elaborative rehearsal, including self-referencing and mood congruency (Noice & Noice, 1997, 2006). They do not use shallow processing and just memorize their lines. Neither should you use shallow processing in studying for your courses. Reading and shortly thereafter rereading text content that you are trying to learn is not a very effective study strategy (Callander & McDaniel, 2009; Phillips, Mills, D’Mello, & Risko, 2016). Rereading is too passive and leads your mind to wander and thus results in incomplete shallow rehearsal. Minimally, you should space your readings over time and not mass them together, but elaborative rehearsal is the real key to more effective learning. It is important to practice this type of rehearsal. You should integrate information that you are trying to learn with as much other information in your knowledge base as you can, especially relating it to yourself. You will get better at this elaboration strategy as you practice it, and learning will become easier. The superiority of elaborative rehearsal for learning also holds for studying lecture videos. Immediately rewatching a lecture video doesn’t improve learning (Martin, Mills, D’Mello, & Risko, 2018). As in rereading, your mind tends to wander more the second time around. You need to use elaborative rehearsal in learning the content in the lecture video. Also, as we will discuss in the next section, repeatedly testing yourself on the content leads to better learning. Thus, continually test yourself on the content in the lecture video (and your textbook and class notes). It not only will help you to learn the content but also will make you aware of what you do not know and need to learn. Next, let’s see what else you can do to be a more effective learner.

How to Improve Encoding

In this section, we will discuss a few more specific ways to improve memory, including some that are optimal for preparing for exams in your courses. First, though, we’ll discuss some techniques that improve memory for lists and more organized sets of concepts. These techniques involve the use of a mnemonic, a memory aid. Mnemonics are useful for remembering lists of items, especially ordered lists, speeches, and long passages of text. We’ll start with a mnemonic that was used by ancient Greek orators to remember speeches.

The Greek orators used a mnemonic called the method of loci (Yates, 1966). Loci is the plural of locus, which means place or location. In the method of loci, the sequential pieces of information to be remembered are first associated with sequential locations in a very familiar room or place. Then, when retrieving the information, one would merely mentally
go around the room (or place) and retrieve the item stored at each sequential location. The Greek orators would mentally store the major points of a speech at sequential locations in the room where they were speaking. Then, during the speech an orator would go from location to location within the room to retrieve the key points of his speech. If you were trying to remember an ordered list of items for an exam, you could pair the items sequentially with locations within the classroom and then during the exam go mentally from location to location within the classroom to retrieve them. The method of loci is a type of elaborative rehearsal using mental imagery. You elaborate upon items that you want to remember by visually associating them with a series of locations that you already know well or that will be available at the time of recall.

All mnemonics work by using some type of elaboration. In another mnemonic, the peg-word system, you visually associate the items in a list with a jingle that you first memorize. The jingle is “One is a bun, two is a shoe, three is a tree, four is a door, five is a hive, six is sticks, seven is heaven, eight is a gate, nine is swine, and ten is a hen.” You then associate each successive item in the list with the object for each successive number. For example, the first item on the list would be associated visually in a mental image with bun. If the word to be remembered were dog, then you might construct an image of a big bun with a dog in it. Then, as you go through the peg words, you retrieve the associated image, so you can retrieve the list.

One might think that these mnemonic techniques require much more effort than just memorizing the information that we want to remember. But researchers have found that people using mnemonics demonstrate much better memory than those who have just attempted to memorize a list. Why? As we discussed earlier, elaborative rehearsal is better for encoding into long-term memory. Professional memory experts do not have exceptional intelligence or structural brain differences but rather have their own unique mnemonic techniques and are superior at using them (Maguire, Valentine, Wilding, & Kapur, 2003). Their techniques, like the ones that we have described, are all essentially based on elaborative encoding, the key to superior memory. For a fascinating journey into the world of these memory experts, you should read Joshua Foer’s engaging book, Moonwalking with Einstein:
The Art and Science of Remembering Everything (2011). Under the tutelage of some of these experts, Foer went from being a journalist with an average memory to winning the U.S. Memory Championship in 2006, testifying to the effectiveness of mnemonic techniques.

Mnemonics that involve little elaboration have not been found to be very effective. A good example is the first-letter technique (Grunenberg & Herrmann, 1997). In the first-letter technique, you compose a word, acronym, or sentence from the first letters of the words you want to remember. This is the mnemonic that we suggested in Chapter 3 to use to remember the colors of the spectrum (the name ROY G. BIV—Red, Orange, Yellow, Green, Blue, Indigo, Violet). This mnemonic helps, but it is not as effective as the other, more elaborative mnemonics, especially for more complex information.

Let’s relate this discussion of improving encoding to something important to you as a student—encoding information from a class setting. An essential component for encoding information from classes is taking notes. Many students have stopped taking notes by writing them out by hand, and instead type their notes on their laptops. This seems like a good strategy—one that might allow you to take more detailed and accurate notes. However, researchers have found that taking notes by typing them on your laptop versus taking them by hand often leads to worse performance on tests (Dynarski, 2017; Mueller & Oppenheimer, 2014; Pettit-O’Malley, Liesz, & Sisodiya, 2017). Why might this be the case? Typing notes on a laptop tends to lead to a mindless type of transcription of information. In other words, students tend not to think about the information and synthesize it as they type. Instead, they simply transcribe the information verbatim into their laptops. This means that the notes are typically more detailed, but because students are not paying attention to the information, they are not encoding it as well as they would when taking notes by hand. Mueller and Oppenheimer (2014) found that the more words the students copied verbatim, the worse they performed on recall tests. Thus, having a larger quantity of more detailed notes due to typing them into a laptop led to worse performance in comparison to those who had fewer notes but wrote them out by hand. In sum, you take more thoughtful notes by hand. We also strongly recommend that you study (not just read) the material assigned for a class before class. Prior study of the assigned material not only makes encoding the information presented in class easier but also leads to taking better, more thoughtful notes. Why is this so? Remember, elaborative rehearsal, which is very effective for encoding, involves integrating information that you are trying to learn with as much other information in your knowledge base as you can. Hence, if you have studied the assigned material before class, you have a more relevant knowledge base to use for encoding the related information presented in class, which in turn leads to better, more thoughtful notetaking.

One additional aspect of your behavior during class lecture that impacts encoding of the lecture content should be self-evident, but it seems that it is not. Research has shown that the use of any electronic device (laptop, tablet, or cell phone) for nonacademic purposes (e.g., texting or playing a game) during class
has a negative impact on subsequent exam performance (Glass & Kang, 2019). Dividing your attention between the electronic device and the lecture leads to poorer encoding of the lecture content and, hence, reduced long-term memory of it. Simply put, multitasking during class inhibits learning and academic performance (e.g., Holmes, 2016). Get the most out of the time you spend in class and studying outside of class. Read and study the assigned material before class so you can better encode the related lecture content. Take notes by hand. Pay singular attention to the class lecture by putting your electronic devices away during class. Ditto goes for studying. Avoid multitasking during study sessions. Attention is a limited resource so the more of it you devote to the material that you are studying, the better your encoding and later retrieval of the material will be.

So what else improves encoding and retrieval? There are three concepts that extensive research has shown will help: (1) distributed study is better than cramming, (2) practice makes perfect, and (3) continual testing enhances memory. The superior memory for spaced study versus cramming is called the **spacing (distributed study) effect**. Your memory will improve if you distribute your studying for an exam over the entire preparation interval and not just the few days before the exam (Payne & Wenger, 1996). Hundreds of experiments have shown the benefits of distributed study (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). In fact, for best results, distribute your studying and cram. The more you study, the more you learn. Overlearning, continuing to study material past the point of initial learning, improves memory (Rohrer & Taylor, 2006). Remember what we said about practice and automatic processing. Continued practice will make retrieval more automatic. Such practice may not make you “perfect,” but you’ll definitely do better. Lastly, don’t just study. Incorporate repeated self-testing during your distributed study periods. Such testing will enhance your memory by allowing you to practice retrieval, which is what exams require (Roediger & Karpicke, 2006). Don’t wait for an exam to test your retrieval; test it regularly during study. It will not only help you to practice retrieval but also help you to guide your study by pointing out what you have learned and what you have not learned.

**Section Summary**

In this section, we discussed the most effective encoding strategy, elaborative rehearsal, which is relating new information to well-known information in long-term memory. Elaboration is most effective when we relate the new information to ourselves, the self-reference effect. Elaborative rehearsal leads to better memory because we create good retrieval cues when we integrate the new information with older, well-known information. This relates to the encoding specificity principle, which states that the best retrieval cues are those present during encoding. State-dependent memory, mood-dependent memory, and mood-congruent memory are special cases of this principle. In these cases, the physiological state and
the emotional mood provide strong cues that enhance retrieval. We pointed out that there is no evidence that teaching styles should be altered based on students’ preferred learning styles and that good teaching involves varied methods, typically based on the nature of the material and not on students’ preferred learning styles. In fact, the belief that matching teaching styles to students’ preferred learning styles will enhance learning has been shown to be a myth. With respect to classroom behavior, we discussed how notetaking by hand leads to better exam performance than taking notes on a laptop and how using an electronic device for a nonacademic purpose during class lecture leads to worse exam performance. This is also true for multitasking during study sessions.

We discussed how mnemonic devices, memory aid techniques, are especially effective for remembering ordered information in a list, speech, or text. The method of loci, which originated in ancient Greece, and the peg-word system are both very effective because of their use of elaboration and visual imagery. Moreover, when taking notes in class, recent research indicates that writing them out by hand leads to better encoding of the information in comparison to typing them on a laptop. In addition, to improve memory we should engage in spaced study—distributing our elaborative study over time rather than cramming. Doing both is best. Overlearning and repeated self-testing are also beneficial.

**Concept Check 2**

Explain why elaborative encoding is more effective than just memorizing.

Explain how state-dependent memory and mood-dependent memory stem from the encoding specificity principle.

Explain what the method-of-loci mnemonic and the peg-word system mnemonic have in common.

**Retrieving Information from Memory**

In the last section, we focused on how to encode information into long-term memory. In this section, we will examine how we retrieve encoded information. First, we will consider the various ways that retrieval is measured. This will be followed by a discussion of forgetting, the failure to retrieve. We will discuss the major theories of why our memories fail us. Then, we will examine the reconstructive nature of the retrieval process by considering the role of schemas, source misattribution, and the misinformation effect. Finally, we will discuss the problem of “false” memories.

**How to Measure Retrieval**

The three main methods for measuring our ability to retrieve information from long-term memory are recall, recognition, and relearning. Recall is a measure of retrieval that requires
the reproduction of the information with essentially no retrieval cues. Common recall measures would be short-answer and essay test questions. **Recognition** is a measure of retrieval that only requires the identification of the information in the presence of retrieval cues. In a recognition test, you do not have to reproduce the information—you only have to identify it. Multiple-choice and matching test questions are examples of recognition test questions. Usually such questions are easier because retrieval cues (the answers themselves) are present to help you remember the information. The third method, **relearning**, is sometimes called the savings method because it is a measure of the amount of time saved when learning information for the second time. The most relevant example of relearning for students is studying for a comprehensive final examination in a course. You must relearn the material. It will take you less time to relearn it, but how much less depends upon how well you learned it the first time.

Hermann Ebbinghaus conducted the first experimental studies on human memory more than 100 years ago in Germany using the relearning method (Ebbinghaus, 1885/1964). His stimulus materials were lists of nonsense syllables, groupings of three letters (consonant-vowel-consonant such as BAV) that were not words or acronyms. He used meaningless nonsense syllables because he wanted to study pure memory for the list items. His familiarity with and knowledge of words and acronyms would have affected his ability to learn and remember the lists. His experimental procedure was very straightforward. He would study a list of nonsense syllables until he could correctly recite the complete list without any hesitations. He then put the list aside and waited some period of time (from 20 minutes up to 31 days) and then relearned the list to the same criterion (one complete recitation without any hesitations).

To get a measure of relearning, Ebbinghaus computed what he called a savings score—the reduction in the number of trials it took him to reach criterion. For example, if it took him 10 trials to learn a list initially and only 5 to relearn it, he saved 50%. He used many different lists of nonsense syllables and many different retention intervals (the different amounts of time between initial learning and relearning). The results were like those shown in Figure 5.8. The forgetting curve in this figure shows that the greatest amount of forgetting occurs rather quickly and then tapers off. In Ebbinghaus’s case, after about two days, little more forgetting occurred. This type of forgetting curve for long-term memory has been obtained over and over again in memory research (Bahrick, 1984). What causes this forgetting? Let’s consider some possible explanations.

**Why We Forget**

There is no question that we forget. Our memories clearly fail us. This is especially problematic for exams. Haven’t we all taken an exam and forgotten some information and then retrieved it after the exam was over? To understand forgetting, we must confront two questions. First, why do we

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**recognition** A measure of long-term memory retrieval that only requires the identification of the information in the presence of retrieval cues.

**relearning** The savings method of measuring long-term memory retrieval in which the measure is the amount of time saved when learning information for the second time.
forget? Second, do we really ever truly forget or do we just fail to retrieve information at a particular point in time? To answer these questions, we’ll take a look at four theories of forgetting—encoding failure theory, storage decay theory, interference theory, and cue-dependent theory.

**Encoding failure theory** states that occasionally forgetting is not really forgetting but rather encoding failure (sometimes called pseudoforgetting). The information in question never entered long-term memory. We can’t forget information that we never encoded into long-term memory. The information was never there. This would be like trying to locate a particular book in a library when the library never purchased it. There are many studies that have found encoding failure, even for the details of everyday objects, such as coins and numerical keypads (Rinck, 1999; Rubin & Kontis, 1983). Let’s consider a classic study by Nickerson and Adams (1979). They found that our memory, both recall and recognition, for the common penny is not very good. The participants in the study found it incredibly difficult to draw the front and back of a penny. There are eight critical features on a penny, and Nickerson and Adams found the median number recalled and located correctly to be just three. Next, they asked other participants to select a real penny from an array

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**Figure 5.8 | Forgetting Curve for Long-Term Memory** | The course of long-term forgetting usually takes on the shape of this figure—a rapid steep decrease that then levels off. In Ebbinghaus’s memory research with nonsense syllables, the amount of time he saved relearning the material decreased dramatically for the first 2 days following initial learning and then leveled off after that. Information from Ebbinghaus, H. (1964). Memory: A contribution to experimental psychology (H. A. Ruger & C. E. Bussenius, Trans.). New York, NY: Dover. (Original work published in 1885.)
of pennies that included the real one and several fake ones. Nickerson and Adams found that most of the participants could not pick out the real one from the fake ones. Why? They probably never bothered to encode the details of the penny. If we do not encode information into long-term memory, we obviously will not be able to remember it.

Now let’s test your memory for an everyday object that has a less detailed design than a penny, the Apple logo, which has often been referred to as one of the most recognizable logos in the world. Without sneaking a glance at any Apple products that may be near you, try to draw the Apple logo from memory. Once you have done so, look up the logo online to determine if your drawing is correct. If it isn’t, don’t feel bad. Blake, Nazarian, and Castel (2015) asked some UCLA students, the vast majority being Apple users or primarily Apple users, first to recall (draw) the Apple logo from memory and then later to recognize the correct Apple logo in an array including it and other similar but incorrect logos. Only 1 student out of 85 could draw the logo correctly, and less than 50% could identify it in an array of similar logos. Like Nickerson and Adams’s participants who had not encoded the details of the penny, the UCLA students had not encoded the details of the Apple logo. Given that we do not seem to remember details unless we consciously make an effort to encode them, make sure that you do encode them in studying for your exams. If the details are not encoded, then they cannot be remembered.

The other three theories of forgetting deal with information that was encoded into long-term memory but that we cannot retrieve. The storage decay theory suggests that forgetting occurs because of a problem in the storage of the information. The storage decay theory assumes that the biological representation of the memory gradually decays over time and that periodic use of the information will help to maintain it in storage. This latter assumption reflects the “use it or lose it” principle. This theory proposes that we forget because the information is no longer available in long-term memory. We forget because we cannot possibly remember it. The memory trace has decayed away. This would be like trying to get a particular book from a library, but finding that its pages had rotted away. Whereas there is experimental evidence that storage decay does contribute to forgetting from sensory and short-term memory, there is no reliable evidence that such decay is a cause of forgetting from long-term memory (Slamecka, 1992). However, to be fair to this theory, it is important to point out that it has proven extremely difficult to obtain such evidence given the theory’s assumptions.

There is much evidence, however, for the two theories of forgetting that suggest forgetting is caused by retrieval problems. Both assume that the forgotten information is still available in long-term memory but cannot be retrieved. Each of the theories proposes a different reason for why the information cannot be retrieved. Interference theory proposes that other information interferes and makes the forgotten information inaccessible. In our library book example, this
would be comparable to boxes of books blocking access to the location where the book is located. This theory proposes two types of such interference: (1) **proactive interference**—the disruptive effect of prior learning on the retrieval of new information, and (2) **retroactive interference**—the disruptive effect of new learning on the retrieval of old information. To help you understand the difference between these two types of interference, remember that proactive is forward-acting and retroactive is backward-acting interference. Let’s consider a couple of examples. Think about changing phone numbers after having a particular number for many years. When asked for your phone number, remembering the old one interferes with retrieving the new one. This would be proactive interference. The disruptive effect is from prior learning (your old phone number). For an example of retroactive interference, think about being at a party with many people you do not know. You meet someone who you want to talk to later, but after meeting her, you are introduced to several other people. Now you cannot remember her name. The names of the people that you met after her are interfering with your retrieval of her name. This is retroactive interference because it is a case of the disruptive effect of new learning on the retrieval of old information. An additional example of each type of interference is given in Figure 5.9.

**Proactive and Retroactive Interference** | In the proactive interference example, prior learning (French) disrupts memory for newly learned information (Spanish). In the retroactive interference example, new learning (Spanish) disrupts memory for information learned earlier (French).

**Cue-dependent theory** also assumes that forgetting stems from not gaining access to the desired information (Tulving, 1974). According to cue-dependent theory, we forget because the cues necessary for retrieval are not available. The information is available, but we cannot access it because we cannot find it. This is like trying to find a particular book in a library without its call number and a map of the library stacks. We wouldn’t have the cues necessary to locate it, so it

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**proactive interference** The disruptive effect of prior learning on the retrieval of new information.

**retroactive interference** The disruptive effect of new learning on the retrieval of old information.

**cue-dependent theory** A theory of forgetting that proposes that forgetting is due to the unavailability of the retrieval cues necessary to locate the information in long-term memory.
is likely we would not be able to do so. Successful retrieval is dependent upon the availability of the relevant retrieval cues. An example of forgetting involving inaccessibility due to insufficient cues that all of us have experienced is the tip-of-the-tongue (TOT) phenomenon in which we can almost recall something, but the memory eludes us (Brown & McNeill, 1966). The phenomenon’s name comes from the colloquial saying “It’s on the tip of my tongue.” You feel like you know the inaccessible information and are on the brink of retrieving it. Diary research indicates that college students experience roughly one or two TOT states per week, compared with two to four per week for elderly adults; middle-aged adults fall somewhere in between (Schacter, 2000). TOT experiences occur most often for names of people. You may remember what letter begins a person’s name, but you still cannot retrieve the name. You are confident that you know it, but you just don’t seem able to pull it out of your memory. Partial information about the name often helps to resolve the TOT state by providing cues that lead to successful recall.

The four major theories that we have described are summarized in Table 5.2, but how can you apply this knowledge to enhance your learning? First, sometimes

<table>
<thead>
<tr>
<th>Theory</th>
<th>Explanation of Forgetting</th>
</tr>
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<tbody>
<tr>
<td>Encoding failure theory</td>
<td>Forgetting is due to the failure to encode the information into long-term memory</td>
</tr>
<tr>
<td>Storage decay theory</td>
<td>Forgetting is due to the decay of the biological representation of the information in long-term memory</td>
</tr>
<tr>
<td>Interference theory</td>
<td>Forgetting is due to the interference of other information in long-term memory, making the forgotten information inaccessible</td>
</tr>
<tr>
<td>Cue-dependent theory</td>
<td>Forgetting is due to the unavailability of the retrieval cues necessary to locate the information in long-term memory</td>
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</tbody>
</table>
we forget because we do not encode the information into long-term memory. If you don’t encode the information, you cannot remember it. You should be especially wary of this reason when you are preparing for your class exams. You need to study thoroughly to avoid encoding failure on exams. Second, we may forget if information that is encoded and stored in long-term memory isn’t periodically recalled and refreshed. The information can fade away over time. Think about what you have learned in the various courses that you have taken so far in college. After a course is over, you may sometimes feel like you retained little of that information for very long. If you want to retain more of it for a longer period of time, you need to regularly recall and use it. Third, the information that we are trying to retrieve may still be there, but we forget because other information may interfere with our retrieval of it or we may not have the necessary retrieval cues available to find it. Both elaboration during encoding and overlearning will help to reduce these retrieval problems.

The next section concerns the information that we do retrieve. Is it accurate or is it distorted? The answer is that it is often distorted. How does this occur? It occurs because retrieval is reconstructive and not exact. Let’s take a look at the retrieval process to see how its reconstructive nature may distort our memories.

**The Reconstructive Nature of Retrieval**

The act of remembering is an act of reconstruction. Memory does not work like a tape recorder or a video recorder. Retrieval is not like playback. Our memories are far from exact replicas of past events. If you read a newspaper this morning, do you remember the stories that you read in the paper word for word? We usually encode the gist or main theme of the story along with some of the story’s highlights. Then, when we retrieve the information from our memory, we reconstruct a memory of the story using the theme and the highlights.

Our retrieval reconstruction is guided by what are called schemas—frameworks for our knowledge about people, objects, events, and actions. These schemas allow us to organize our world. For example, what happens when you enter a dentist’s office or what happens when you go to a restaurant to eat? You have schemas in your memory for these events. The schemas tell us what normally happens. For example, consider the schema for eating out in a restaurant (Schank & Abelson, 1977). First, a host or hostess seats you and gives you a menu. Then the waitperson gets your drink order, brings your drinks, and then takes your meal order. Your food arrives, you eat it, and the waitperson brings the bill. You pay the bill, leave a tip, and go. These schemas allow us to encode and retrieve information about the world in a more organized, efficient manner.

The first experimental work on schemas and their effects on memory was conducted by Sir Frederick Bartlett in the first half of the twentieth century (Bartlett, 1932). Bartlett had his participants study some stories that were rather unusual. He then tested their memory for these stories at
varying time intervals. When the participants recalled the stories, they made them more consistent with their own schemas about the world. For example, one story did not say anyone was wounded in the battle described, but participants recalled that many men were wounded, fitting their schemas for battles. Unusual details were normalized. For example, participants recalled incorrectly that the men in another story were fishing rather than hunting seals. In addition, the stories were greatly shortened in length when recalled. Strangely, the participants did not even realize that they were changing many of the details of the stories. In fact, the parts that they changed were those that they were most confident about remembering.

Bartlett’s participants had reconstructed the stories using their schemas and did not even realize it. The main point to remember is that they distorted the stories in line with their schemas. Why? Schemas allow us to encode and retrieve information more efficiently. It would be impossible to encode and retrieve the exact details of every event in our lives. That’s why we need organizing schemas to guide us in this task, even though they do not provide an exact copy of what happened. This seems a small cost given the benefits provided by organizing memory in terms of schemas.

Memory can be further distorted in reconstruction by source misattribution and the misinformation effect. **Source misattribution** occurs when we do not remember the true source of a memory and attribute the memory to the wrong source. Maybe you dream something and then later misremember that it actually happened. You misattribute the source to actual occurrence rather than occurrence in a dream. Source information for memories is not very good. You need to beware of this when writing papers. You may unintentionally use another person’s ideas and think they are yours. You have forgotten their source. Even if source misattribution is unintentional, it is still plagiarism. Source misattribution also helps to explain déjà vu, that eerie sense that you have been in the exact same situation before, but in actuality you have not (Cleary, 2008). You have a feeling of familiarity because you have previously experienced elements in the situation in other contexts, but you cannot make the correct source attributions for them. Thus, déjà vu may result from feelings of familiarity that occur in a new situation without proper identification of their sources.

Source misattribution can also lead to other problems. A famous case of source misattribution involved noted developmental psychologist Jean Piaget (Loftus & Ketcham, 1991). For much of his life, Piaget believed that when he was a child, his nursemaid had thwarted an attempt to kidnap him. He remembered the attempt, even remembered the details of the event. When the nursemaid finally admitted to making up this kidnapping story, she said that she did so with the hopes of being rewarded for saving Piaget. Actually, she was rewarded. Piaget’s parents gave her a gold Swiss watch, which she returned 13 years later with a letter explaining that she had made up the attempted kidnapping story. She had joined the Salvation Army and decided to come clean with Piaget’s parents. Piaget couldn’t believe that the kidnapping attempt had not happened. He had reconstructed the
event from the many times the nursemaid recounted the incident and had misattributed the source to actual occurrence. This is like thinking that something we dreamed really occurred. The source of the memory is misattributed. Source misattribution results in what is called a false memory, an inaccurate memory that feels as real as an accurate memory. False memories can also be the result of imagination and observation inflation and the misinformation effect.

Imagination inflation is increased confidence in a false memory of an event caused by repeatedly imagining the event. For example, imagining performing an action often induces a false memory of having actually performed it (Garry, Manning, Loftus, & Sherman, 1996; Goff & Roediger, 1998). Repeated imagining inflates the confidence the person has that she actually performed the action, the imagination inflation effect. What might cause this disconcerting memory failure? Several factors likely contribute to the formation of these false memories. First, actually perceiving something and imagining it activate the same brain areas, leading to similar neural events that when tested might cause confusion as to whether the event was imagined or real (Gonsalves et al., 2004). Second, repeatedly imagining an event makes it seem increasingly familiar. This sense of familiarity can then be misinterpreted as evidence that the event actually occurred (Sharman, Garry, & Beuke, 2004). Lastly, the more vividly we are able to imagine events, the more likely it is that the imagined events feel like real events (Loftus, 2001; Thomas, Bulevich, & Loftus, 2003).

There is now evidence for a similar false memory effect in which a false memory of self-performance of an action is induced by merely observing another person’s actions (Lindner, Echterhoff, Davidson, & Brand, 2010). It has been named the observation inflation effect because of its similarity to the imagination inflation effect. What could account for this effect? The controversial mirror neuron systems that we discussed in Chapter 4 may be involved. Some mirror neuron research suggests that observation of another person’s action may trigger a covert simulation of the action and thus activate motor representations similar to those produced during actual self-performance of the action (Iacoboni, 2009). Other
evidence suggests that the neural correlates for such mirrored motor representations are similar to those for self-performed actions (Senfor, Van Petten, & Kutas, 2002). Thus, when a person is tested about actually performing the observed action, the mirrored action representations could erroneously be reactivated, leading to the observation inflation effect (Lindner et al., 2010).

The misinformation effect occurs when a memory is distorted by subsequent exposure to misleading information (Loftus, 2005). Elizabeth Loftus and her colleagues have provided numerous demonstrations of the misinformation effect, involving thousands of subjects, over the past 4 decades (Frenda, Nichols, & Loftus, 2011). These studies usually involve witnessing an event and then being tested for memory of the event but being given misleading information at the time of the test. Let’s consider an example. Loftus and John Palmer (1974) showed participants a film of a traffic accident and then later tested their memory for the accident. The test included misleading information for some of the participants. For example, some participants were asked, “How fast were the cars going when they smashed into each other?” and others were asked, “How fast were the cars going when they hit each other?” Participants who were asked the question with the word smashed estimated the speed to be much higher than those who were asked the question with the word hit. In addition, when brought back a week later, those participants who had been questioned with the word smashed more often thought that they had seen broken glass in the accident when in fact there was none. The key theme of this line of research is that our memories for events are distorted by exposure to misinformation. The resulting false memories seem like real memories.

False memories have important implications for use of eyewitness testimony in criminal cases and for the controversy over memories of childhood sexual abuse that have supposedly been repressed but then are “recovered” in adulthood. The Loftus and Palmer research example shows us that eyewitness testimony is subject to error and manipulation by misleading information. Between 1989 and 2007, for example, 201 prisoners in the United States were freed because of DNA evidence; and 77% of these prisoners had been mistakenly identified by eyewitnesses (Hallinan, 2009). Many of these overturned cases rested on the testimony of two or more mistaken eyewitnesses. Eyewitnesses not only often misidentify innocent people as criminals but they also often do so with the utmost confidence, and jurors tend to heavily weigh an eyewitness’s confidence when judging their believability.

Clearly, certain types of interrogation, including the way questions are worded, could lead to false memories. With respect to the repressed memory controversy, many memory researchers are skeptical and think that these “recovered” memories may describe events that never occurred (like the kidnapping attempt on Piaget as a child). Instead, they may be false memories that have been constructed and may even have been inadvertently implanted by therapists during treatment sessions. In fact, researchers have demonstrated that such implanting is possible (Loftus,
Coan, & Pickrell, 1996; Loftus & Ketcham, 1994). We must remember, however, that demonstrating the possibility of an event does not demonstrate that it actually happened. So, are all memories of childhood sexual abuse false? Absolutely not. Sexual abuse of all kinds is unfortunately all too real. The important point for us is that the research on false memory has provided empirical evidence to support an alternative explanation to the claims for recovered memories, and this will help to sort out the true cases from the false.

**Section Summary**

In this section, we considered the three ways to measure retrieval—recall, recognition, and relearning. In recall, the information has to be reproduced, but in recognition it only has to be identified. In relearning, the time one saves in relearning information is the measure of memory. For all three retrieval measures, forgetting from long-term memory levels off after a rapid initial burst of forgetting.

There are four major theories that address the question of why we forget. Encoding failure theory assumes that the information is never encoded into long-term memory, so it is not there to be retrieved. The storage decay theory assumes that the information is encoded but that it decays during storage so that it is no longer available to be retrieved. The other two theories assume that the information is still available in long-term memory but cannot be accessed. Interference theory assumes that the retrieval failure is due to other information blocking our retrieval. This interfering information could be older information interfering with the retrieval of new information (proactive interference) or new information interfering with the retrieval of older information (retroactive interference). The other theory, cue-dependent theory, assumes that the cues necessary to retrieve the information are not available, meaning that the information cannot be located in long-term memory.

Memory is a reconstructive process guided by our schemas—organized frameworks of our knowledge about the world. The use of schemas along with source misattribution problems, imagination and observation inflation, and the misinformation effect can lead to false memories, inaccurate memories that feel as real as accurate memories. Such false memories create questions about the accuracy of eyewitness testimony and the validity of supposed repressed memories of childhood abuse.

**Concept Check 3**

Explain the difference between recall and recognition as methods to measure retrieval.

Explain how the four major theories of forgetting differ with respect to the availability versus accessibility of the forgotten information.

Explain how schemas help to create false memories.

Explain how source misattribution and the misinformation effect lead to false memories.
Study Guide

Chapter Key Terms
You should know the definitions of the following key terms from the chapter. They are listed in the order in which they appear in the chapter. For those you do not know, return to the relevant section of the chapter to learn them. When you think that you know all of the terms, complete the matching exercise based on these key terms.

- sensory memory (SM)
- iconic memory
- temporal integration procedure
- Sperling’s full-report procedure
- Sperling’s partial-report procedure
- short-term memory (STM)
- memory span task
- memory span chunk
- distractor task
- maintenance rehearsal
- working memory
- long-term memory (LTM)
- explicit (declarative) memory
- semantic memory
- episodic memory
- implicit (nondeclarative) memory
- procedural memory
- priming
- amnesic
- anterograde amnesia
- retrograde amnesia
- infantile/child amnesia
- free recall task
- primacy effect
- recency effect
- encoding
- storage
- retrieval
- automatic processing
- effortful processing
- levels-of-processing theory
- elaborative rehearsal
- self-reference effect
- encoding specificity principle
- state-dependent memory
- mood-dependent memory
- mood-congruence effect
- mnemonic
- method of loci
- peg-word system
- spacing (distributed study) effect
- recall
- recognition
- relearning
- encoding failure theory
- storage decay theory
- interference theory
- proactive interference
- retroactive interference
- cue-dependent theory
- tip-of-the-tongue (TOT) phenomenon
- schemas
- source misattribution
- false memory
- misinformation effect

Key Terms Exercise
Identify the correct term for each of the following definitions. The answers to this exercise follow the answers to the ConceptChecks at the end of the chapter.

1. The principle that states that the cues (both internal and external) present at the time information is encoded into long-term memory serve as the best retrieval cues for the information.

2. A measure of long-term memory retrieval that requires the reproduction of the information with essentially no retrieval cues.

3. The disruptive effect of new learning on the retrieval of old information.

4. The visual sensory register that holds an exact copy of the incoming visual input but only for a very brief period of time—less than a second.
5. A meaningful unit in memory.

6. Long-term memory for factual knowledge and personal experiences that requires a conscious effort to remember and that entails making declarations about the information remembered.

7. The inability to form new explicit long-term memories for events following surgery or trauma to the brain.

8. A type of rehearsal in short-term memory in which incoming information is related to information from long-term memory to encode it into long-term memory.

9. Superior long-term memory for spaced study versus massed study (cramming).

10. Frameworks of knowledge about people, objects, events, and actions that allow us to organize and interpret information about our world.

11. Explicit memory for personal experiences.

12. A theory of forgetting that proposes that forgetting is due to the unavailability of the retrieval cues necessary to locate the information in long-term memory.

13. An experimental procedure in which, following the brief presentation of a matrix of unrelated consonants, the participant is given an auditory cue about which row of the matrix to recall.

14. Our inability as adults to remember events that occurred in our lives before about three years of age.

15. A memory task in which the participant is given a series of items one at a time and then has to recall the items in the order in which they were presented.

**Practice Test Questions**

The following are practice multiple-choice test questions on some of the chapter content. The answers are given after the Key Terms Exercise answers at the end of the chapter. If you guessed on a question or incorrectly answered a question, restudy the relevant section of the chapter.

1. Which of the following types of memory holds sensory input until we can attend to and recognize it?
   a. short-term memory
   b. sensory memory
   c. semantic memory
   d. episodic memory

2. Our short-term memory capacity is ________ ± 2 chunks.
   a. 3
   b. 5
   c. 7
   d. 9

3. Which of the following types of memory has the shortest duration?
   a. sensory memory
   b. short-term memory
   c. semantic memory
   d. episodic memory

4. Procedural memories are ________ memories and thus are probably processed in the ________.
   a. explicit; hippocampus
   b. explicit; cerebellum
   c. implicit; hippocampus
   d. implicit; cerebellum

5. Which of the following leads to the best long-term memory?
   a. maintenance rehearsal
   b. elaborative rehearsal
c. physical processing
d. acoustic processing

6. The primacy and recency effects in free recall demonstrate that we have the greatest difficulty recalling the words ____________ of a list.
   a. at the beginning
   b. at the end
   c. in the middle
   d. at the beginning and end

7. Which of the following is not a mnemonic aid?
   a. method of loci
   b. peg-word system
   c. temporal integration procedure
d. first-letter technique

8. An essay test measures ____________, and a multiple-choice test measures ____________.
   a. recall; recall
   b. recall; recognition
c. recognition; recall
d. recognition; recognition

9. Which of the following theories of forgetting argues that the forgotten information was in long-term memory but is no longer available?
   a. encoding failure theory
   b. storage decay theory
c. interference theory
d. cue-dependent theory

10. Piaget’s false memory of a kidnapping attempt when he was a child was the result of ____________.
    a. infantile amnesia
    b. source misattribution
   c. encoding failure
d. storage decay

11. After learning the phone number for Five Star Pizza, Bob cannot remember the phone number he learned last week for the Donut Connection. After living in Los Angeles for 3 years, Jim is unable to remember his way around his hometown in which he had lived the previous 10 years prior to moving to Los Angeles. Bob is experiencing the effects of ____________ interference, and Jim is experiencing the effects of ____________ interference.
    a. proactive; proactive
    b. proactive; retroactive
c. retroactive; proactive
d. retroactive; retroactive

12. Per the levels-of-processing theory, which of the following questions about the word **depressed** would best prepare you to correctly remember tomorrow that you had seen the word in this practice test question today?
   a. How well does the word describe you?
   b. Does the word consist of 10 letters?
c. Is the word typed in capital letters?
d. Does the word rhyme with obsessed?

13. The forgetting curve for long-term memory in Ebbinghaus’s relearning studies with nonsense syllables indicates that ____________.
    a. the greatest amount of forgetting occurs rather quickly and then it levels off
    b. little forgetting occurs very quickly and the greatest amount occurs later, after a lengthy period of memory storage
c. forgetting occurs at a uniform rate after learning
d. little forgetting ever occurs

14. In the Loftus and Palmer experiment, participants were shown a film of a traffic accident and then later tested for their memory of it. The finding that memory differed based upon the specific words used in the test questions illustrated ____________.
    a. state-dependent memory
    b. source misattribution
c. the self-reference effect
d. the misinformation effect

15. The results for the experiment in which word lists were studied either on land or underwater and then recalled either on land or underwater provide evidence for ____________.
    a. source misattribution
    b. encoding specificity
c. proactive interference
d. retroactive interference
Chapter ConceptCheck Answers

ConceptCheck | 1

- As pointed out in Chapter 3, bottom-up processing is the processing of incoming sensory information from the physical environment. This is what occupies sensory memory so it is bottom-up input. Also, as pointed out in Chapter 3, top-down processing uses the information in our long-term knowledge base to interpret the bottom-up input. Thus, long-term memory can be thought of as providing top-down input because it is the repository of our knowledge base and past experiences.

- The duration of iconic memory must be very brief because if it were not, our visual sensory register would get overloaded quickly, leading to successive visual images overlapping in the register. Thus, we wouldn’t perceive the world normally because it would be a constant mix of conflicting overlapping images.

- A chunk is a meaningful unit in our memory; for example, a single letter, an acronym, and a word each comprise one chunk. We have a memory span of 7 ± 2 unrelated letters, acronyms, or words.

- H. M. demonstrated a practice effect on the mirror-tracing task and the manual skill learning task in which he had to keep a stylus on a small dot that was spinning around on a turntable, but he did not consciously remember ever having done either task. This shows that he formed new implicit long-term memories for how to do these tasks because his performance on the tasks improved as he gained experience on them, but that he did not form new explicit long-term memories for actually having done the tasks because he could not remember ever doing these tasks. H. M. also demonstrated repetition priming effects on a word fragment completion task without conscious awareness of the earlier presented priming words. Thus, he demonstrated implicit long-term memory for the words on the word fragment completion task but he had no explicit long-term memory for having seen them before. In another study, he was classically conditioned to give an eyeblink response to a tone. After the conditioning, whenever he was exposed to the tone, he gave the eyeblink response, but he did not consciously remember ever having been conditioned. This finding shows that he formed new implicit long-term memories of the association between the tone and eyeblink but did not form any new explicit long-term memories for the conditioning episodes.

ConceptCheck | 2

- Elaborative encoding is more effective than memorizing because the process of elaboration ties the new information to older, well-known information. This older information provides many good retrieval cues for the new information. Thus, elaborative encoding provides both more retrieval cues and better ones than memorizing.

- State-dependent memory and mood-dependent memory are both instances of the encoding specificity principle operating because in each case, maximal similarity in study-test physiological states or moods leads to the best long-term memory.

- Both mnemonics relate the new information to a well-known sequence. In each mnemonic you step through the sequence and retrieve the list item tied to that step. In the case of the method of loci, sequential locations within a well-known room or place are used, whereas in the peg-word system, the steps are part of a well-learned jingle (one is a bun, two is a shoe, . . .). Thus, both mnemonics use elaborative rehearsal.

ConceptCheck | 3

- In recall, the information has to be reproduced. In recognition, the information only has to be identified.

- Encoding failure theory and storage decay theory assume the forgotten information is not available in long-term memory. Both the interference and cue-dependent theories of forgetting assume it is still available but not accessible.

- Schemas help to create false memories because in using them, we tend to replace the actual details of what happened with what typically happens in the event that the schema depicts. As Bartlett found in his schema research, this is especially true for unusual details. This means that schemas tend to normalize our memories and lead us to remember what usually happens and not exactly what did happen.

- Source misattribution leads to false memories because we don’t really know the source of a
memory. The event may never have occurred, but we think that it did because we misattributed the source of the memory. The misinformation effect leads to false memories through the effect of misleading information being given at the time of retrieval. We incorporate this misleading information for an event into our memory and thus create a false memory for it.

**Answers to Key Terms Exercise**
1. encoding specificity principle
2. recall
3. retroactive interference
4. iconic memory
5. chunk
6. explicit (declarative) memory
7. anterograde amnesia
8. elaborative rehearsal
9. spacing (distributed study) effect
10. schemas
11. episodic memory
12. cue-dependent theory
13. Sperling’s partial-report procedure
14. infantile/child amnesia
15. memory span task

**Answers to Practice Test Questions**
1. b; sensory memory
2. c; 7
3. a; sensory memory
4. d; implicit; cerebellum
5. b; elaborative rehearsal
6. c; in the middle
7. c; temporal integration procedure
8. b; recall; recognition
9. b; storage decay theory
10. b; source misattribution
11. d; retroactive; retroactive
12. a; How well does the word describe you?
13. a; the greatest amount of forgetting occurs rather quickly and then it levels off
14. d; the misinformation effect
15. b; encoding specificity