### **Storing and Retrieving memory**

### **Memory Storage**

**LOQ 8-9**What is the capacity of long-term memory? Are our long-term memories processed and stored in specific locations?

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

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

Contrary to Holmes’ “memory model,” our brain is *not* like an attic, which once filled can store more items only if we discard old ones. Our capacity for storing long-term memories is essentially limitless. One research team, after studying the brain’s neural connections, estimated its storage capacity as “in the same ballpark as the World Wide Web” (Sejnowski, 2016).

#### **Retaining Information in the Brain**

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

For a time, some surgeons and memory researchers marveled at patients’ apparently vivid memories triggered by brain stimulation during surgery. Did this prove that our whole past, not just well-practiced music, is “in there,” in complete detail, just waiting to be relived? On closer analysis, the seeming flashbacks appeared to have been invented, not a vivid reliving of long-forgotten experiences (Loftus & Loftus, 1980). In a further demonstration that memories do not reside in single, specific spots, psychologist Karl Lashley (1950) trained rats to find their way out of a maze, then surgically removed pieces of their brain’s cortex and retested their memory. No matter which small brain section he removed, the rats retained at least a partial memory of how to navigate the maze. Memories *are* brain-based, but the brain distributes the components of a memory across a network of locations. These specific locations include some of the circuitry involved in the original experience: Some brain cells that fire when we experience something fire again when we recall it (Miller, 2012a; Miller et al., 2013).

*The point to remember:* Despite the brain’s vast storage capacity, we do not store information as libraries store their books, in single, precise locations. Instead, brain networks encode, store, and retrieve the information that forms our complex memories.

“Our memories are flexible and superimposable, a panoramic blackboard with an endless supply of chalk and erasers.”

**Elizabeth Loftus and Katherine Ketcham, *The Myth of Repressed Memory*, 1994**

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

**LOQ 8-10**What roles do the frontal lobes and hippocampus play in memory processing?

Explicit, conscious memories are either [**semantic**](https://jigsaw.macmillanhighered.com/books/9781319067991/epub/OEBPS/xhtml/mye_9781319050627_glossary.xhtml#gloss516) (facts and general knowledge) or [**episodic**](https://jigsaw.macmillanhighered.com/books/9781319067991/epub/OEBPS/xhtml/mye_9781319050627_glossary.xhtml#gloss183) (experienced events). The network that processes and stores new explicit memories for these facts and episodes includes your frontal lobes and hippocampus. When you summon up a mental encore of a past experience, many brain regions send input to your frontal lobes for working memory processing (de Chastelaine et al., 2016; Michalka et al., 2015). The left and right frontal lobes process different types of memories. Recalling a password and holding it in working memory, for example, would activate the left frontal lobe. Calling up a visual party scene would more likely activate the right frontal lobe.

Cognitive neuroscientists have found that the [**hippocampus**](https://jigsaw.macmillanhighered.com/books/9781319067991/epub/OEBPS/xhtml/mye_9781319050627_glossary.xhtml#gloss255), a temporal-lobe neural center located in the limbic system, can be likened to a “save” button for explicit memories ([**FIGURE 8.8**](https://jigsaw.macmillanhighered.com/books/9781319067991/epub/OEBPS/xhtml/mye_9781319050627_ch08_02.xhtml?create=true#fig8_8)). Brain scans reveal activity in the hippocampus and nearby brain networks as people form explicit memories of names, images, and events (Squire & Wixted, 2011; Wang et al., 2014).

Explicit memories for facts and episodes are processed in the hippocampus (orange structures) and fed to other brain regions for storage.

Damage to this structure therefore disrupts the formation and recall of explicit memories. If their hippocampus is severed, chickadees and other birds will continue to cache food in hundreds of places, but later be unable to find them (Kamil & Cheng, 2001; Sherry & Vaccarino, 1989). With left-hippocampus damage, people have trouble remembering verbal information, but they have no trouble recalling visual designs and locations. With right-hippocampus damage, the problem is reversed (Schacter, 1996).

Subregions of the hippocampus also serve different functions. One part is active as people and mice learn social information (Okuyama et al., 2016; Zeineh et al., 2003). Another part is active as memory champions engage in spatial mnemonics (Maguire et al., 2003a). The rear area, which processes spatial memory, grows bigger as London cabbies navigate the city’s complicated maze of streets (Woolett & Maguire, 2011).

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

Memories are not permanently stored in the hippocampus. Instead, this structure seems to act as a loading dock where the brain registers and temporarily holds the elements of a to-be-remembered episode—its smell, feel, sound, and location. Then, like older files shifted to a basement storeroom, memories migrate for storage elsewhere. This storage process is called [**memory consolidation.**](https://jigsaw.macmillanhighered.com/books/9781319067991/epub/OEBPS/xhtml/mye_9781319050627_glossary.xhtml#gloss330) Removing a rat’s hippocampus 3 hours after it learns the location of some tasty new food disrupts this process and prevents long-term memory formation; removal 48 hours later does not (Tse et al., 2007).

Sleep supports memory consolidation. During deep sleep, the hippocampus processes memories for later retrieval. After a training experience, the greater one’s heart rate efficiency and hippocampus activity during sleep, the better the next day’s memory will be (Peigneux et al., 2004; Whitehurst et al., 2016). Researchers have watched the hippocampus and brain cortex displaying simultaneous activity rhythms during sleep, as if they were having a dialogue (Euston et al., 2007; Mehta, 2007). They suspect that the brain is replaying the day’s experiences as it transfers them to the cortex for long-term storage (Squire & Zola-Morgan, 1991). When our learning is distributed over days rather than crammed into a single day, we experience more sleep-induced memory consolidation. And that helps explain the spacing effect.

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

**LOQ 8-11**What roles do the cerebellum and basal ganglia play in memory processing?

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

The *cerebellum* plays a key role in forming and storing the implicit memories created by classical conditioning. With a damaged cerebellum, people cannot develop certain conditioned reflexes, such as associating a tone with an impending puff of air—and thus do not blink in anticipation of the puff (Daum & Schugens, 1996; Green & Woodruff-Pak, 2000). Implicit memory formation needs the cerebellum.

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

Our implicit memory system, enabled by these more ancient brain areas, helps explain why the reactions and skills we learned during infancy reach far into our future. Yet as adults, our *conscious* memory of our first four years is largely blank, an experience called *infantile amnesia.* In one study, events children experienced and discussed with their mothers at age 3 were 60 percent remembered at age 7 but only 34 percent remembered at age 9 (Bauer et al., 2007). Two influences contribute to infantile amnesia: First, we index much of our explicit memory with a command of language that young children do not possess. Second, the hippocampus is one of the last brain structures to mature, and as it does, more gets retained (Akers et al., 2014).

##### **THE AMYGDALA, EMOTIONS, AND MEMORY**

**LOQ 8-12** How do emotions affect our memory processing?

Our emotions trigger stress hormones that influence memory formation. When we are excited or stressed, these hormones make more glucose energy available to fuel brain activity, signaling the brain that something important is happening. Moreover, stress hormones focus memory. Stress provokes the *amygdala* (two limbic system, emotion-processing clusters) to initiate a memory trace that boosts activity in the brain’s memory-forming areas (Buchanan, 2007; Kensinger, 2007) ([**FIGURE 8.9**](https://jigsaw.macmillanhighered.com/books/9781319067991/epub/OEBPS/xhtml/mye_9781319050627_ch08_02.xhtml?create=true#fig8_9)). It’s as if the amygdala says, “Brain, encode this moment for future reference!” The result? Emotional arousal can sear certain events into the brain, while disrupting memory for irrelevant events (Brewin et al., 2007; McGaugh, 2015).

*Frontal lobes* and *hippocampus:* explicit memory formation

*Cerebellum* and *basal ganglia:* implicit memory formation

*Amygdala:* emotion-related memory formation

Significantly stressful events can form almost unforgettable memories. After a traumatic experience—a school shooting, a house fire, a rape—vivid recollections of the horrific event may intrude again and again. It is as if they were burned in: “Stronger emotional experiences make for stronger, more reliable memories,” noted James McGaugh (1994, 2003). Such experiences even strengthen recall for relevant, immediately preceding events (Dunsmoor et al., 2015: Jobson & Cheraghi, 2016). This makes adaptive sense: Memory serves to predict the future and to alert us to potential dangers. Emotional events produce tunnel vision memory. They focus our attention and recall on high priority information, and reduce our recall of irrelevant details (Mather & Sutherland, 2012). Whatever rivets our attention gets well recalled, at the expense of the surrounding context.

Emotion-triggered hormonal changes help explain why we long remember exciting or shocking events, such as our first kiss or our whereabouts when learning of a loved one’s death. In a 2006 Pew survey, 95 percent of American adults said they could recall exactly where they were or what they were doing when they first heard the news of the 9/11 terrorist attacks. This perceived clarity of memories of surprising, significant events leads some psychologists to call them [**flashbulb memories**](https://jigsaw.macmillanhighered.com/books/9781319067991/epub/OEBPS/xhtml/mye_9781319050627_glossary.xhtml#gloss208).

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

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

Our flashbulb memories are noteworthy for their vividness and our confidence in them. But as we relive, rehearse, and discuss them, even these memories may come to err. With time, some errors crept into people’s 9/11 recollections (compared with their earlier reports taken right after 9/11). Mostly, however, people’s memories of 9/11 remained consistent over the next two to three years (Conway et al., 2009; Hirst et al., 2009).

Dramatic experiences remain clear in our memory in part because we rehearse them (Hirst & Phelps, 2016). We think about them and describe them to others. Memories of personally important experiences also endure (Storm & Jobe, 2012; Talarico & Moore, 2012). Compared with non-Catholics, devout Catholics recalled better the resignation of Pope Benedict XVI (Curci et al., 2015). Ditto for baseball fans’ memories of their team’s championship games (Breslin & Safer, 2011). When their team won, fans enjoyed recalling and recounting the victory, leading to longer-lasting memories.