UNIT
VII
Cognition

MODULES

31 Studying and Encoding Memories
32 Storing and Retrieving Memories
33 Forgetting, Memory Construction, and Improving Memory
34 Thinking, Concepts, and Creativity
35 Solving Problems and Making Decisions
36 Thinking and Language

What is the capacity of long-term memory?

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)

Learning Targets

Module 32

Storing and Retrieving Memories

- **32-1** Discuss the capacity of and location of our long-term memories.
- **32-2** Describe the roles of the frontal lobes and hippocampus in memory processing.
- **32-3** Describe the roles of the cerebellum and basal ganglia in memory processing.
- **32-4** Discuss how emotions affect our memory processing.
- **32-5** Explain how changes at the synapse level affect our memory processing.
- **32-6** Analyze how external cues, internal emotions, and order of appearance influence memory retrieval.

Where is long-term memory stored?

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.

TRY IT

Talk with your partner:

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

What role do the frontal lobes play in processing explicit memories?

Remember from Module 31 that explicit memory is retention of facts and experiences in the long-term memory that one can consciously know and "declare".

Explicit memories are either
semantic (facts and general knowledge)
such as *George Washington was our first president*
or
episodic (experienced events)
such as *I had a clown at my 6th birthday party.*

What role do the frontal lobes play in semantic and episodic memory?

semantic memory	*episodic memory*
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.

What does the research show about the subregions of the hippocampus?

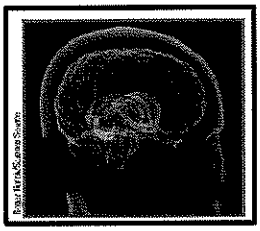
One subregion is active as people and mice learn social information.
(Okuyama et al., 2016; Zeineh et al., 2003)

Part of the hippocampus is active as memory champions engage in spatial mnemonics.
(Maguire et al., 2003a)

The rear hippocampal region, which processes spatial memory, grows bigger as London cabbies navigate the city's complicated maze of streets.
(Woolett & Maguire, 2011)

the *hippocampus*

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



Hippocampus: a subcortical limbic system structure in the temporal lobes

What is memory consolidation?

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 process is called ***memory consolidation.***

What is the role of the hippocampus in memory processing?

Cognitive neuroscientists have found that the **hippocampus**, a temporal-lobe neural center located in the limbic system, can be likened to a "save" button for explicit memories.

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)

How does sleep aid memory consolidation?

During deep sleep, the ***hippocampus*** processes memories for later retrieval.

Researchers have watched the ***hippocampus*** and brain cortex displaying simultaneous activity rhythms during sleep, as if talking.
(Euston et al., 2007; Mehta, 2007).

The brain may be replaying the day's experiences as it transfers them to the cortex for long-term storage.
(Squire & Zola-Morgan, 1991)

Bringing it all together…

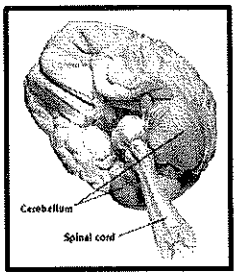
When our **learning** is distributed over days rather than crammed into a single day, we experience more **sleep-induced** memory **consolidation**.

And that helps explain the **spacing effect**.

Given time to consolidate new learning over many sleep cycles makes recall easier!

the cerebellum

the "little brain" at the rear of the brainstem; functions include processing sensory input, coordinating movement output and balance, and enabling nonverbal learning and memory.



So how are implicit memories processed?

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.

What role does the cerebellum play in memory processing?

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)

Consider this story…

A brain-damaged patient had amnesia which 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.
Having an ***implicit long-term memory,*** she felt what she could not explain.

What role do the basal ganglia play in memory formation?

The basal ganglia, deep brain structures involved in motor movement, facilitate formation of our procedural memories (nondeclarative or implicit) 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.

What is infantile amnesia?

As adults, our *conscious* memory of our first four years is largely blank, an experience called **infantile amnesia.**

In one study, events that 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)

What role does the amygdala play in memory processing?

Stress hormones focus memory.
Stress provokes the *amygdala* to initiate a memory trace that boosts activity in the brain's memory-forming areas.
(Buchanan, 2007; Kensinger, 2007)

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)

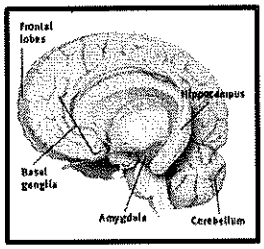
What are two influences that contribute to infantile amnesia?

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)

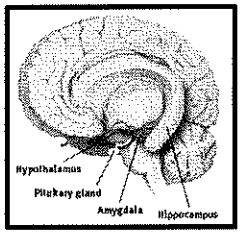
TRY IT

What role do each of the pictured structures play in memory formation and recall?



the Amygdala

two lima-bean-sized neural clusters in the limbic system; linked to emotion



1. What Would You Answer?

What two parts of the brain are most involved in implicit memory?

A. frontal lobes and basal ganglia
B. amygdala and hippocampus
C. amygdala and cerebellum
D. cerebellum and basal ganglia
E. frontal lobes and hippocampus

How do emotions affect our memory processing?

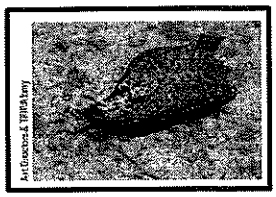
Emotional events produce tunnel vision memory.

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.

How can a sea slug help us understand memory?

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



TRY IT

Where were you when....

Donald Trump won the 2016 presidential election?

Did that event trigger emotional responses for you? Tears of happiness or perhaps, despair? If so, that memory may be a ***flashbulb memory***.

How does serotonin release at the synapse impact memory processing?

Eric Kandel and James Schwartz observed synaptic changes during learning in the neurons of ***Aplysia***.

When learning occurs, the slug releases more of the neurotransmitter ***serotonin*** into certain neurons.

These cells' synapses then become more efficient at transmitting signals.

Experience and learning can increase—even double—the number of synapses, even in slugs.
(Kandel, 2012).

What is a *flashbulb memory*?

A ***flashbulb memory*** is a clear, sustained long-term memory of an emotionally significant moment or event.

- For instance, those born in the 1940's and 50's can usually remember exactly where they were when President Kennedy was shot.
- Those who experienced the explosion of the Challenger space shuttle in January 1986, can typically recall exactly where they were.
- And sadly, many Americans can recount precisely where they were and what they were doing on the morning of September 11, 2001.

How does Kandel's research impact human memory processes?

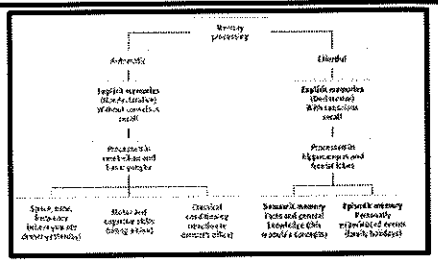
In experiments with people, rapidly stimulating certain memory-circuit connections has increased their sensitivity for hours or even weeks to come. The sending neuron now needs less prompting to release its neurotransmitter, and more connections exist between neurons. This increased efficiency of potential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

What is *long-term potentiation (LTP)*?

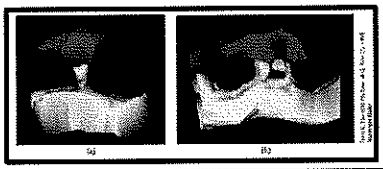
an increase in a cell's firing potential after brief, rapid stimulation; a neural basis for learning and memory

TRY IT

Review the diagram below, then look away and see how much of it you can recreate.



How does LTP impact receptor sites?



An electron microscope image (a) shows just one receptor site (gray) reaching toward a sending neuron before ***long-term potentiation.***
Image (b) shows that, after LTP, the receptor sites have doubled.
(From Toni et al., 1999)

How do cues help with memory retrieval?

When you encode into memory a target piece of information, such as the name of the person sitting next to you in class, you associate with it other bits of information about your surroundings, mood, seating position, and so on.
These bits can serve as *retrieval cues* that you can later use to access the information. The more retrieval cues you have, the better your chances of finding a route to the suspended memory.

What research confirms LTP as a physical basis for memory?

Drugs that block LTP interfere with learning.
(Lynch & Staubli, 1991)

Drugs that mimic what happens during learning increase LTP. *(Harward et al., 2016)*

Rats given a drug that enhanced LTP learned a maze with half the usual number of mistakes.
(Service, 1994)

What are the best retrieval cues?

The best retrieval cues come from associations we form at the time we encode a memory—smells, tastes, and sights that can evoke our memory of the associated person or event.

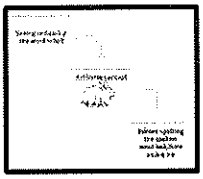
To call up visual cues when trying to recall something, we may mentally place ourselves in the original context.

What is *priming*?

the activation, often unconsciously, of particular associations in long-term implicit memory

TRY IT

Can you explain the relationship?



How does your understanding of long-term implicit memory help you understand *priming*? Explain the relationship.

AP® Exam Tip

perceptual set	priming
a tendency to perceive or notice some aspects of the available sensory data and ignore others	the implicit memory effect in which exposure to a stimulus influences response to a later stimulus

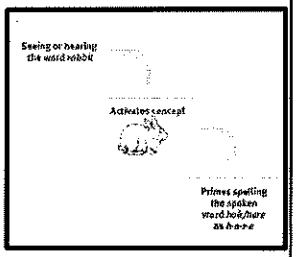
What is an example of priming?

If, walking down a hallway, you see a poster of a missing child, you may then unconsciously be primed to interpret an ambiguous adult-child interaction as a possible kidnapping. *(James, 1986)*

Although you no longer have the poster in mind, it predisposes your interpretation. Implicit memory of the poster impacts your later response to the situation.

How does priming work?

After seeing or hearing the word *rabbit*, we are later more likely to spell the spoken word *hair/hare* as *h-a-r-e*, even if we don't recall seeing or hearing *rabbit*.



What is context-dependent memory?

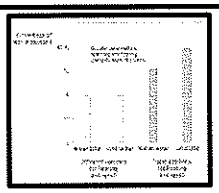
Putting yourself back in the context where you earlier experienced something can prime your memory ***retrieval***.

Remembering, in many ways, depends on our environment. *(Palmer, 1989)*

When you visit your childhood home or neighborhood, old memories surface.

How does context enable recall?

When scuba divers listened to a word list in two different settings (either 10 feet underwater or sitting on the beach), they ***recalled*** more words if tested in the same place.
(Godden & Baddeley, 1975)



What is the encoding specificity principle?

the idea that cues and contexts specific to a particular memory will be most effective in helping us recall it

2. What Would You Answer?

John noticed that he did better on his chemistry exams when he takes them in the same seat that he sits in during class. If he is properly prepared for each exam, then _____ may explain his difference in scores.

A. recall
B. context effects
C. explicit memory
D. the serial position effect
E. flashbulb memory

What is state-dependent memory?

What we learn in one physiological state—be it drunk or sober—may be more easily recalled when we are again in that state.

What people learn when drunk they don't recall well in any state (alcohol disrupts memory storage). But they recall it slightly better when again drunk.

If you study while on the treadmill, increasing your heart rate, you will likely have better recall of the material when your heart rate is accelerated again.

TRY IT

Has this happened to you?

Have you ever run into a former teacher in an unusual place, such as at the store or park?

Perhaps you recognized the person but struggled to figure out who it was and how you were acquainted.

Experiencing something outside the usual setting can be confusing.

What is *mood-congruent* memory?

the tendency to recall experiences that are consistent with one's current good or bad emotional state (mood)

How does *mood-congruency* impact the duration of our moods?

Mood effects on ***retrieval*** help explain why our moods persist.

When happy, we recall happy events and therefore see the world as a happy place, which helps prolong our good mood.

When depressed, we ***recall*** sad events, which darkens our interpretations of current events.

For those of us predisposed to depression, this process can help maintain a vicious, dark cycle.

Why does the *serial position effect* influence memory retrieval?

Subjects briefly recalled the last items especially quickly and well (a *recency effect*), perhaps because those last items were still in working memory. Recall that echoic information remains in the sensory memory for about 4 seconds.

But after a delay, when their attention was elsewhere, their recall was best for the first items (a *primacy effect*). This is likely due to enhanced rehearsal of the first items.

What is the *serial position effect?*

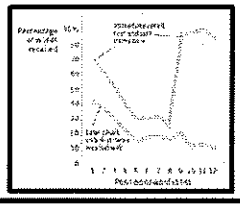
our tendency to recall best the last *(recency effect)* and first *(primacy effect)* items in a list

3. What Would You Answer?

Which of the following is an example of the serial position effect?

A. remembering the most important assignment you have to complete for school tomorrow
B. remembering the skills you learned early in life, such as walking
C. remembering the beginning and end of your grocery list, but not the items in the middle
D. remembering the names of the first two co-workers you met on the first day of your new job
E. remembering where you left your cell phone when you cannot find it

What does research show about the *serial position effect?*



In experiments, when people viewed a list of items (words, names, dates, even experienced odors) and immediately tried to recall them in any order, they fell prey to the ***serial position effect***. *(Reed, 2000)*

Learning Target 32-1 Review

Discuss the capacity of and location of our long-term memories.

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

Learning Target 32-2 Review

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

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

Learning Target 32-5 Review

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

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

Learning Target 32-3 Review

Describe the roles of the cerebellum and basal ganglia in memory processing.

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

Learning Target 32-6 Review

Analyze how external cues, internal emotions, and order of appearance influence memory retrieval.

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

Learning Target 32-4 Review

Discuss how emotions affect our memory processing.

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