Module 4
Learning and Memory
How does the brain learn and remember?

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Module 4 allows students to explore how our brains learn and remember, putting their brains to the test in a few exercises that highlight key functions of memory.

This module invites students to explore the questions:

How does the brain learn and remember?

While exploring this idea, students will:
- Understand which regions of the brain are responsible for learning and memory.
- Understand the different types of memory (working/short term and long term).
- Practice testing their memories using real protocols for memory research studies and analyzing the results.
- Begin to understand the anatomy of a neuron.

The [PowerPoint slides](#) that accompany this module are meant to help guide the lesson, transitioning between activities and providing relevant information when necessary. Frequently engage students in discussion by asking questions, eliciting their prior knowledge, experience, and ideas. Examples of probing and reflective questions are embedded throughout the curriculum guide, to scaffold meaningful and relevant experiences for students.

**Time Frame:** 2 hours

**Activities:**
- Free Recall Activity
- Videos of memory patient HM
- Neuron activity or Your Brain exhibit exploration

**Preparation:**
- Review the [Free Recall educator guide](#).
- Make copies of [Neuron Activity worksheet](#).
- Load [PowerPoint slides](#) on computer/tablet to project on screen.
- Ensure Internet access to be able to play HM video.
- Test out video before the session, to make sure bandwidth and connection are sufficient. Prep the video to start at the desired time: 40:29.

**Materials Needed:**

**Exploration 1: Learning & Memory**
- Computer/tablet with PowerPoint slides
- Large post-it paper, easel, markers
- Free Recall Educator Guide for teacher (extra copies for optional homework assignment)
Exploration 2: Case Study of HM & the Role of the Hippocampus

- **HM Video** Segment
- Journals
- Pens/pencils

Exploration 3: Neurons & Synapses

- Copies of Neuron Activity worksheet
- Computers/tablets for students to use online ([Interactive Neuron Demonstration](#))

Journal Reflection

- Journals
- Pens/pencils

Review (10 mins)

1. Review from last module – what did we do? What did we learn?
   a. Are there differences between the right & left hemispheres?
   b. What did we learn from the patient with a split corpus callosum?

Plearning & Memory (35 minutes)

Driving Question: What parts of the brain allow us to make and store memories?

1. Brainstorm prior knowledge about memory & learning: What is memory? What is learning? Are there different types of each?
2. Describe PHASES of memory: Short-term/working memory, long-term memory
3. Describe TYPES of memory: Declarative memory (events & experiences that we consciously think about like birthdays, when your next test is, etc.) & procedural memory (skills and abilities that we don’t consciously think about like riding a bike, solving a puzzle, driving a car)
4. Explain the regions/structures of the brain that are important for learning & memory:
   a. Hippocampus: Its name comes from the Greek word meaning “seahorse” because it’s shaped like a seahorse. This structure is responsible for storing declarative memories – events and facts. For example, “My sister’s birthday is on Thursday, or I went to my local science museum as a child and had a great time.”
   b. Striatum & cerebellum: Responsible for procedural memories such as motor skills, things we do with our bodies that we don’t have to consciously recall or think about in order to be able to do. For example, driving a car, riding a bike, walking, etc.
   c. Amygdala: Its name comes from the Greek word meaning “almond” because it’s shaped like an almond. This structure is responsible for processing emotion, and emotional memory. It’s very important in fear response and learning. When we are in fearful situations, we learn very quickly not to be in those situations again. Ask students, “Why do you think that would be?” (Survival mechanism)
   d. There are two of each of these structures in the brain.
5. Explain generally how learning works in the brain. First the outer lobes of the brain, all together called the “cortex”, is our conscious processing of information taking place in our working memories. Then the hippocampus translates this information from short-term to long-term memory. The hippocampus is very active during sleep. Ask students to reflect: Why do you think that would be?
6. Invite students to test their short-term or working memory, which is our memory for things that just happened.
   a. Introduce the Free Recall Experiment: This is an activity that researchers do to study what happens in people’s brains when they learn things they later remember, versus things that they later forget.
i. Explain the instructions to the group: Listen to list of 10 words without writing anything down. Use any strategy you want for trying to remember the words. Remember this is not a test of how smart you are, but a test of the strategy you use to remember the words. After I've read all 10 words, I'll tell you to write down all the words you can remember in any order you want.

ii. After the experiment, discuss the following with the students, and capture data from the group on chart paper:
   1. Which words did you recall?
   2. What strategy did you use to remember them?
   3. What do you notice about their positioning in the original list?

iii. Show results from similar study. There is a primacy and recency effect in free recall where people tend to remember the beginning and end of the list. Ask students to reflect: Was that true for us? Why do you think that would be? Younger participants also remembered more than older participants.

b. Ask students to reflect:
   i. Was this a challenging experiment? Why? What strategies did you use to remember?
   ii. Do you think you’ll remember these words tomorrow, or next? Why/why not?
   iii. Which strategy that people used do you think will last longer in their memories and why?

Case Study of H.M. & the Role of the Hippocampus (20 mins)

Driving Question: What does the hippocampus do?

1. Explain that scientists made a major breakthrough in understanding memory in the brain through a patient who had part of his brain removed because of severe epilepsy, a condition where the brain had a lot of seizures that impacted his daily life.
   a. HM Video segment (40:29 – 50:08)
   b. Ask students to discuss:
      i. What was wrong with HM? What kind of memory did he not have after his surgery? Which part of his brain was removed?
      ii. What types of memory did he still have?
      iii. What conclusion did that lead scientists to?
   c. Explain that the hippocampus is responsible for forming “declarative” memories. Other regions are responsible for procedural memories – striatum & cerebellum.
      i. Retrieval of long-term declarative memories doesn’t require hippocampus (since HM could do this)
   d. Ask students to consider: What did you notice about the animal study? Molecules involved in remembering/forgetting in the hippocampus. Animals are often used for researching memory because they have similar structures to humans.

2. Journal Activity: What do you think life would be like if you didn’t have your hippocampi, and couldn’t make new memories? Encourage students to write their thoughts and reactions in their journals.

Short Break (10 mins)

Neurons & Synapses (15 minutes)

Driving Question: How can we understand what is going on in the brain to be able to make memories?

1. Elicit students’ prior knowledge about neurons:
   a. What is the brain made up of at the smallest level?
   b. Why do you think a neuron is shaped this way—long with a tail-like part—as opposed to normal basal body cells that are more spherical in shape?
c. Neurons are cells in the brain that carry messages through signals to other parts of the brain.

2. Discuss the structure of neuron:
   a. Cell body – contains nucleus and DNA (command center of the neuron)
   b. Axon – long extension from cell body through which electrical signal is carried, sends information to other neurons
   c. Myelin sheath – a fatty coating that insulates the signal traveling down the axon, like the insulation on a wire. If the insulation weren’t there, the signal might fray off. But the insulation helps the signal travel where it needs to go quickly and safely.
      i. Myelin grows thicker over time as the brain matures and develops more solid pathways (particularly in teen years).
   d. Dendrites – located near cell body, have receptors that detect chemical messengers from other neurons (neurotransmitters – transmit messages from other neurons)
   e. Synapse – end of axon, stores neurotransmitters that get released to the next cell when neuron fires/sends signal

3. Ask students to consider: How does the brain learn and make memories? [Connection between neurons called synapses]
   a. Explain that neurons send information through electrochemical signals. An electric signal is sent down the axon, and then that triggers a release of chemicals at the end, which is called the synapse. The yellow circles in the image are the chemicals, also called “neurotransmitters”. Examples of these are dopamine and serotonin that affect mood and behavior.
   b. Explain that the brain stores memories by strengthening signals at particular synapses and by creating new synapses.

4. Share the estimated number of neurons & synapses in the human brain. There are about 86 billion neurons in our brains, which is comparable to the number of stars in our galaxy the Milky Way. Each neuron has on average 7000 synapses. The complexity of this network for each of our individual and unique brains is enormous and amazing.

Neuron Activity (15-20 minutes)

Driving Question: What are the components of a neuron? How do neurons transfer signals?

1. Encourage students to complete the “Neuron Activity” sheet identifying the components of a neuron and describing how a signal travels through a neuron to the next neuron.
2. Allow students to collect information either from previous slides and online research, and explore The Franklin Institute’s online Interactive Neuron Demonstration.
3. Collect the activity sheets as formative assessment for students’ understanding of a neuron and how a signal travels between them.

Journal Reflection (10 mins)

Driving Question: What are you thinking about after today’s session?

1. Encourage students to think about what they did and learned today. Ask them to consider and write about:
   a. What does that make you think?
   b. Where do you feel confused?
   c. What are you still curious to learn more about?

Optional Homework Assignment: Conduct the free recall experiment with an adult at home. Are their results different than yours? Is this true for one or both of the experiments? Have extra copies of the Free Recall Experiment Procedure to share with students.