Uncommon Sense Teaching: Practical Insights in Brain Science to Help Students Learn

Images from the book.

A Note to Our Readers

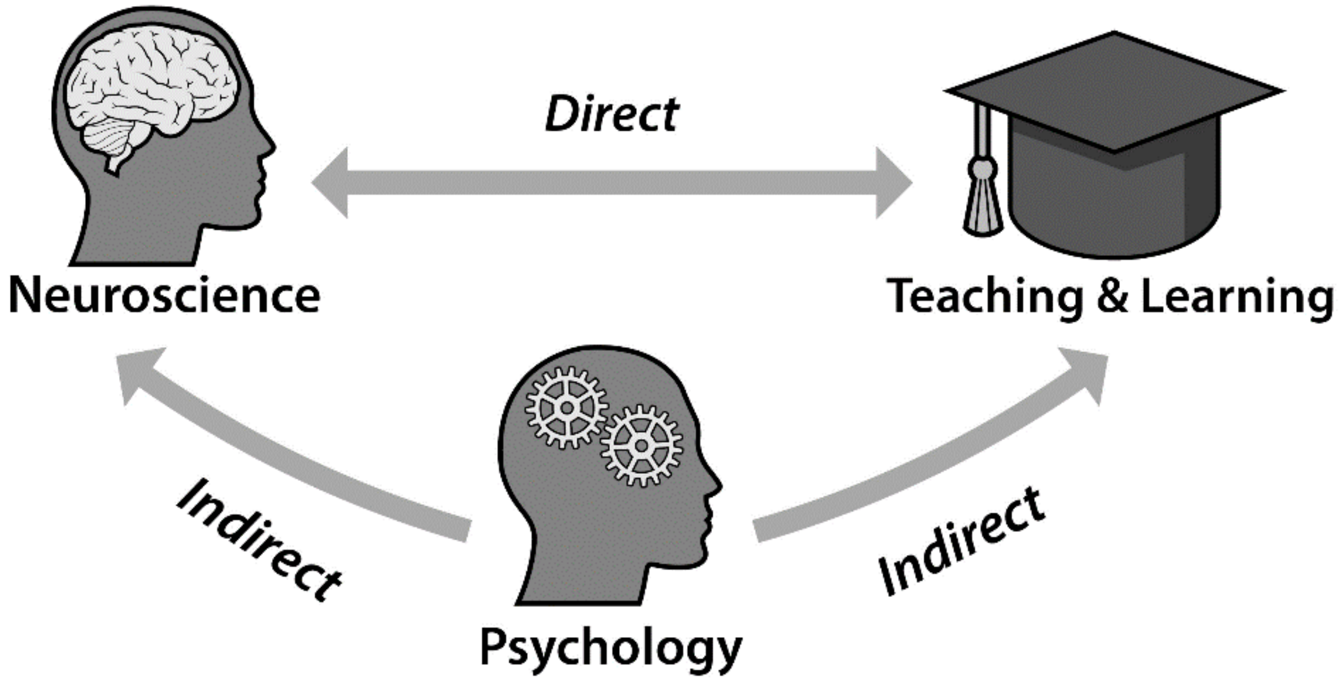
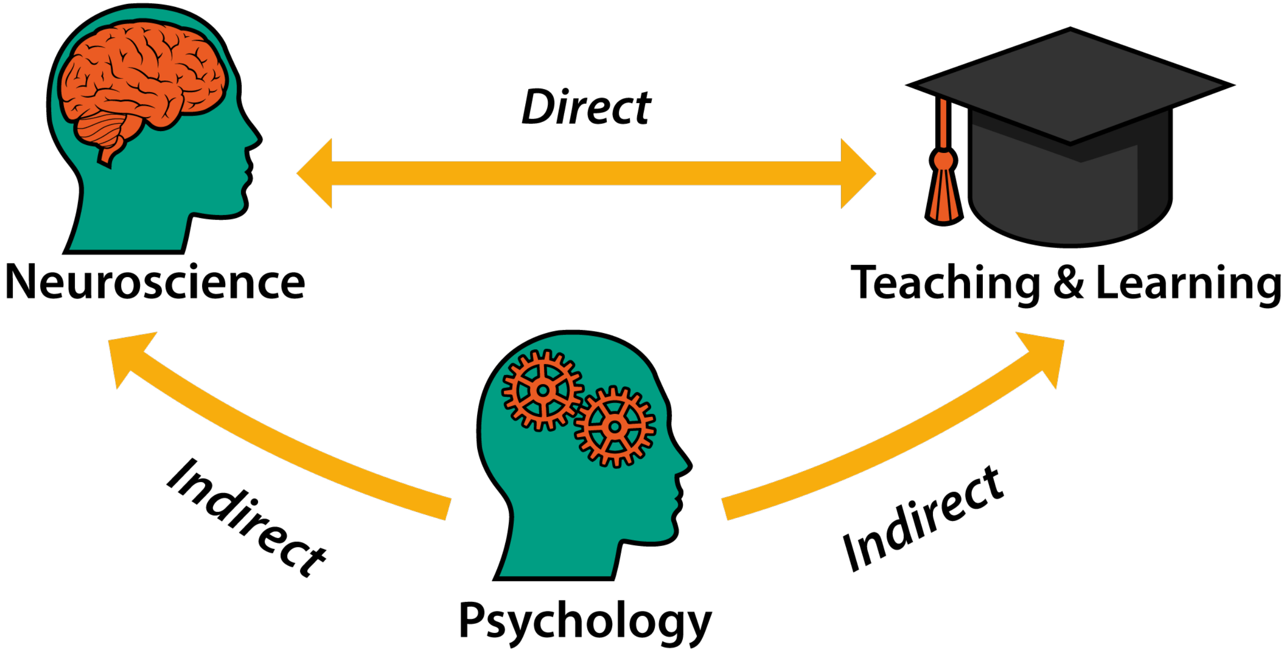


Figure 1: Neuroscience supports an understanding of teaching and learning (and vice versa) both directly and via its connections to psychology. Image after that from Thomas, *et al.*(2019).



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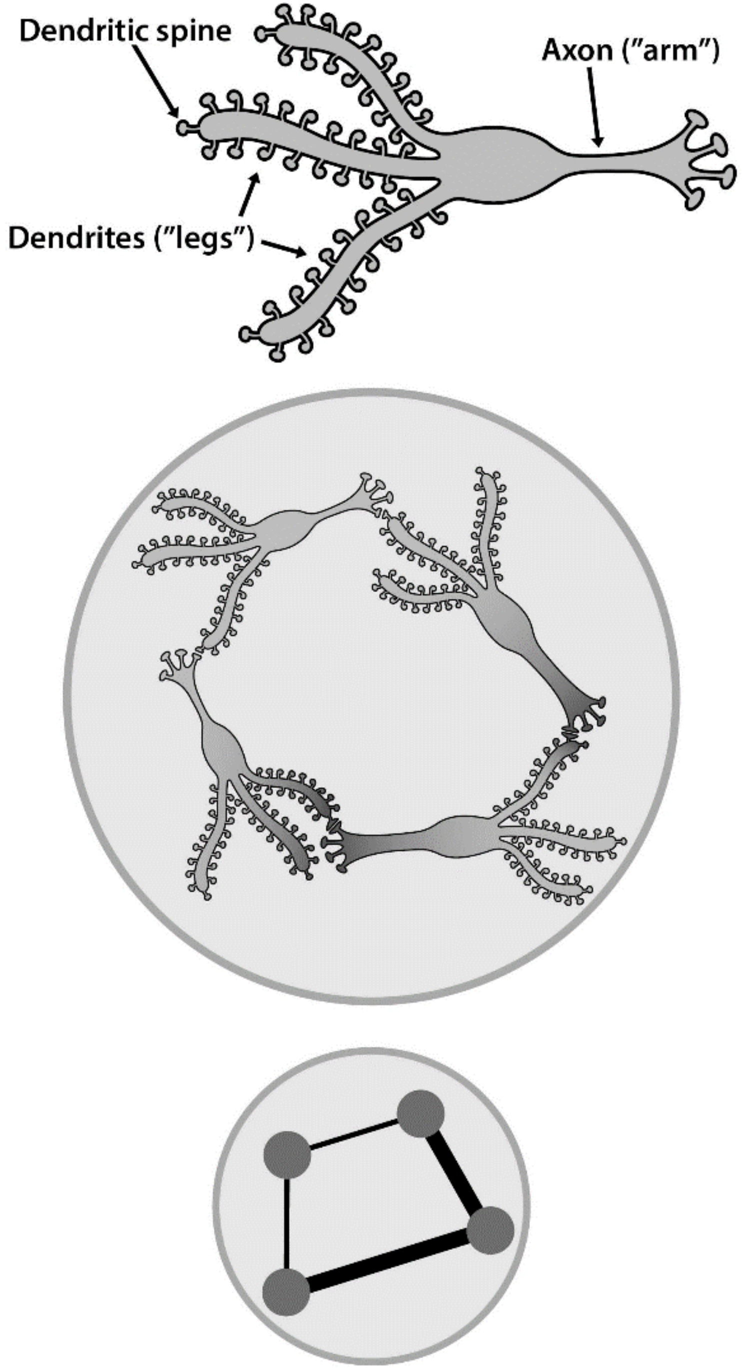
Chapter 1
Building Memory: How Students Fool Themselves into Thinking They're Learning

Figure 2 A. – C.



A. The main parts of neurons are easy to understand—they have spiny legs and an arm. (In the image, dendritic spines are on dendrites on the left, and an axon is on the right). We've dramatically enlarged certain features of the neuron in this drawing so that you can clearly see the axon, dendrite, and dendritic spines. If you'd like to get a sense of how real neurons look, go to Santiago Ramón y Cajal's entry on Wikipedia. There, you will find anatomically accurate, exquisitely drawn neurons by Cajal that are still used today to describe neurons, over a century after Cajal first drew them.

B. When students learn something, they form links between neurons—the spine of one neuron comes up against the axon of another neuron.

C. A set of connected neurons can be simplified as a connected set of dots. Stronger connections are shown with thick lines, and weaker connections with thin lines. A shaded circle is drawn around the set of links. This circle, with its "dot neurons" and links, represents a newly learned concept or idea.

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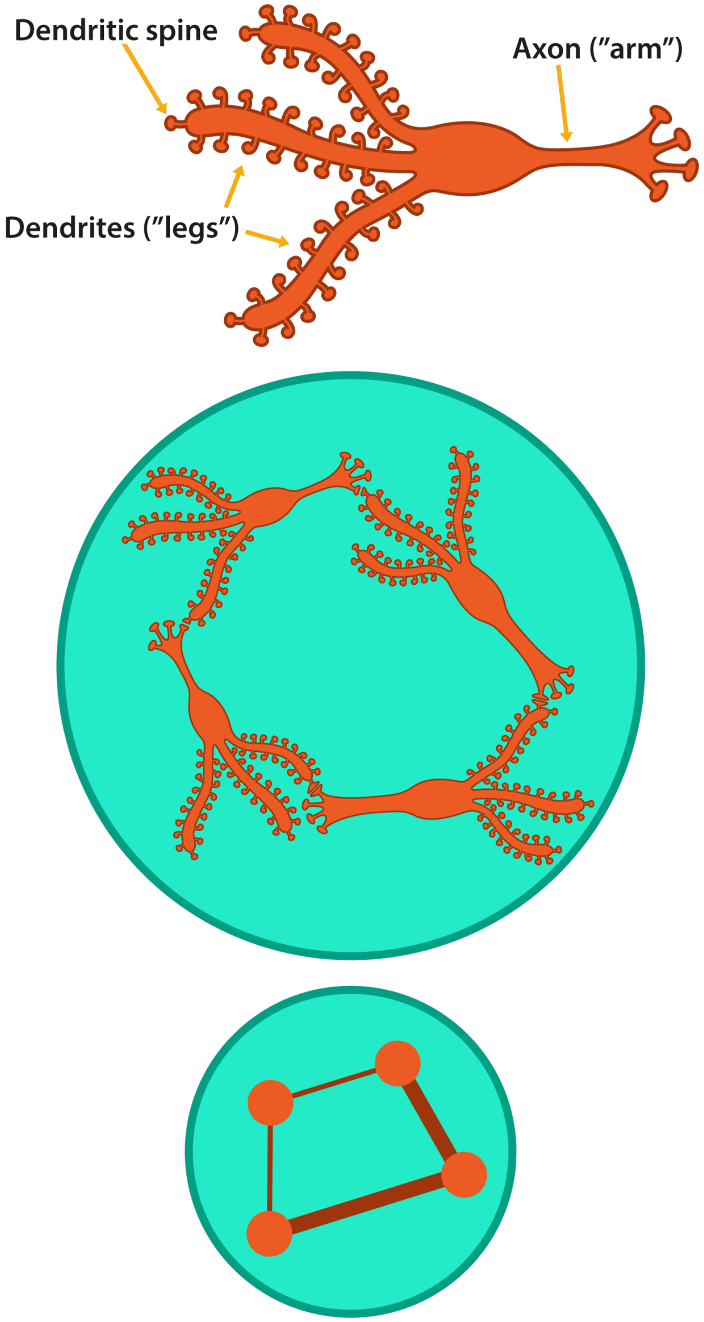

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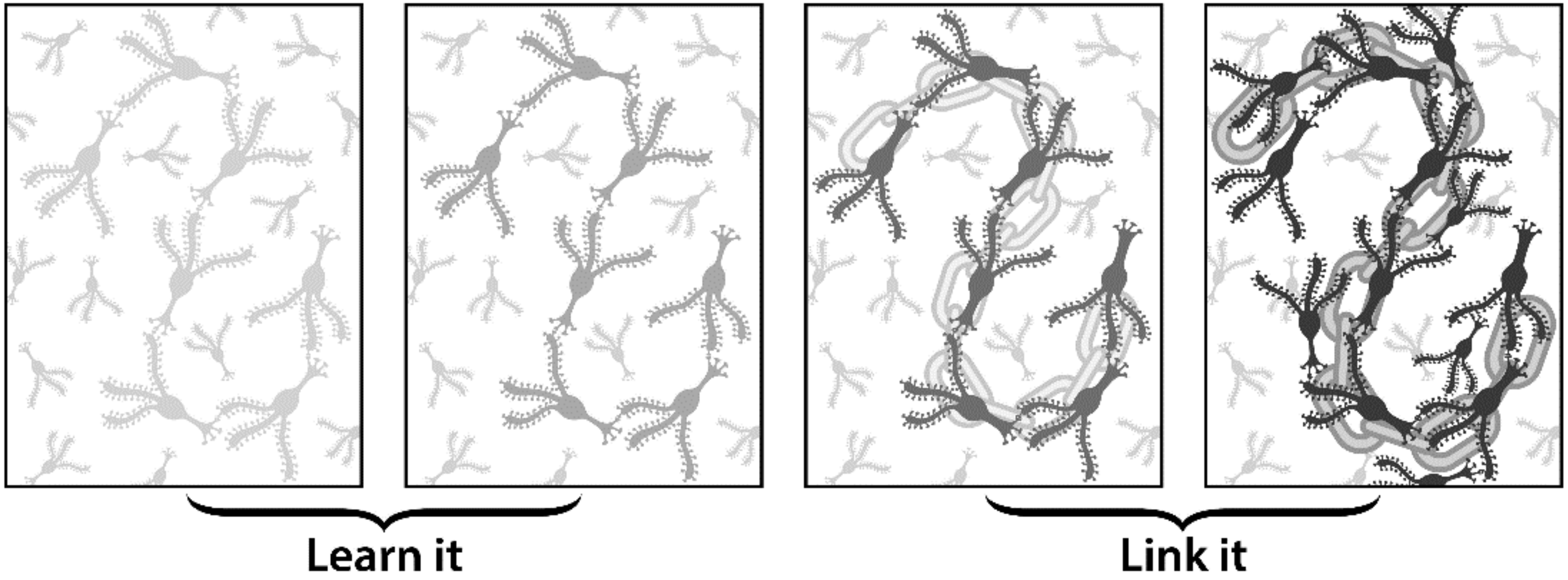

Figure 3 ***Learn it, Link it*****:** In the first "*Learn it*" image on the left, you can get a sense of neurons beginning to find one another as a student is introduced to a new concept, for example during a brief period of explanation by a teacher, or while reading a textbook or watching a video. Connections are made as a student follows along and practices the material (the second image). As a student works in active ways with the new idea, concept, or technique, links solidify in long-term memory and form the basis of proficiency (the third image). Still more practice in novel ways can extend the learning to new areas (image four), which allows the neurons to tie in with other neurons that underpin related concepts.

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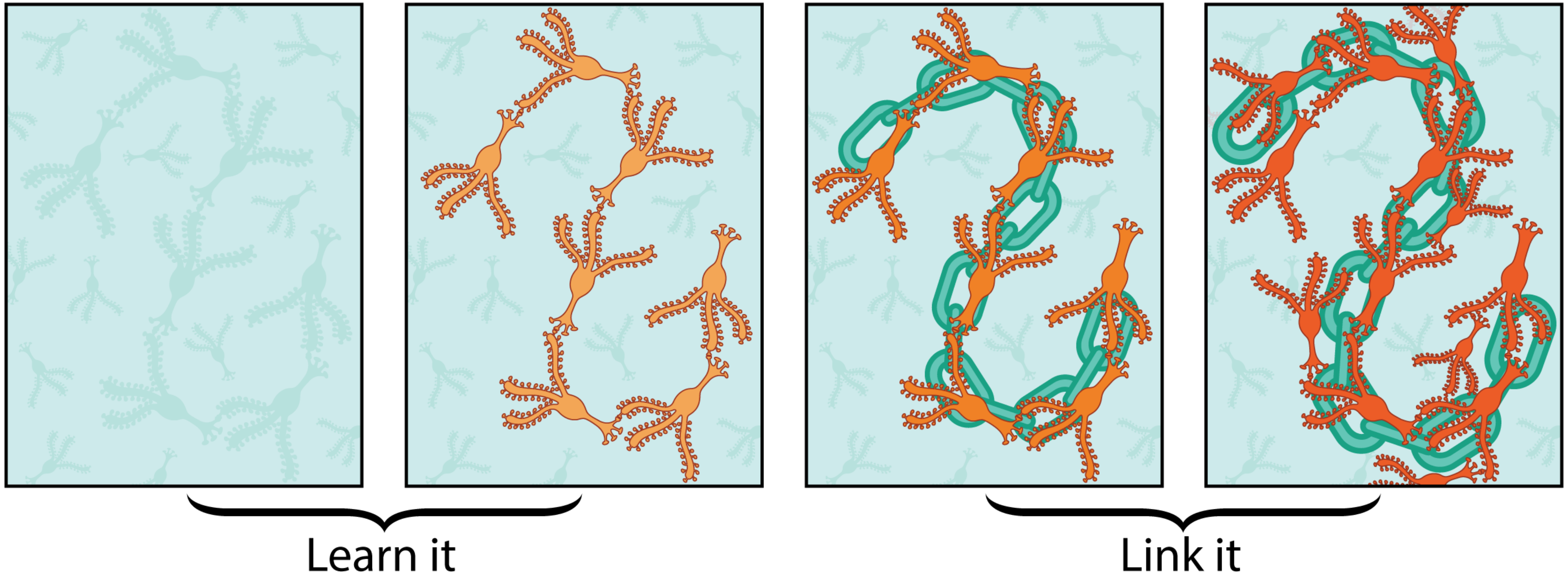

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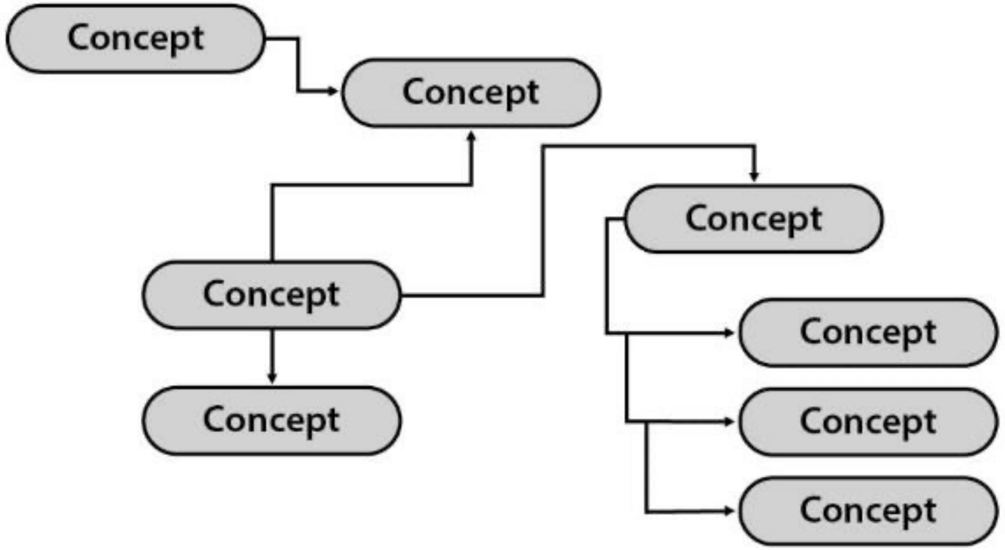

Figure 4: Sample concept map

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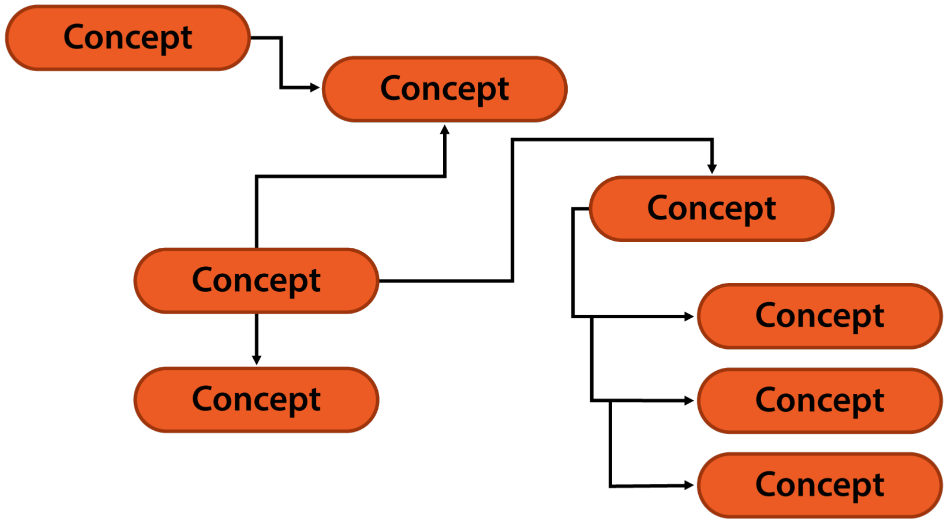

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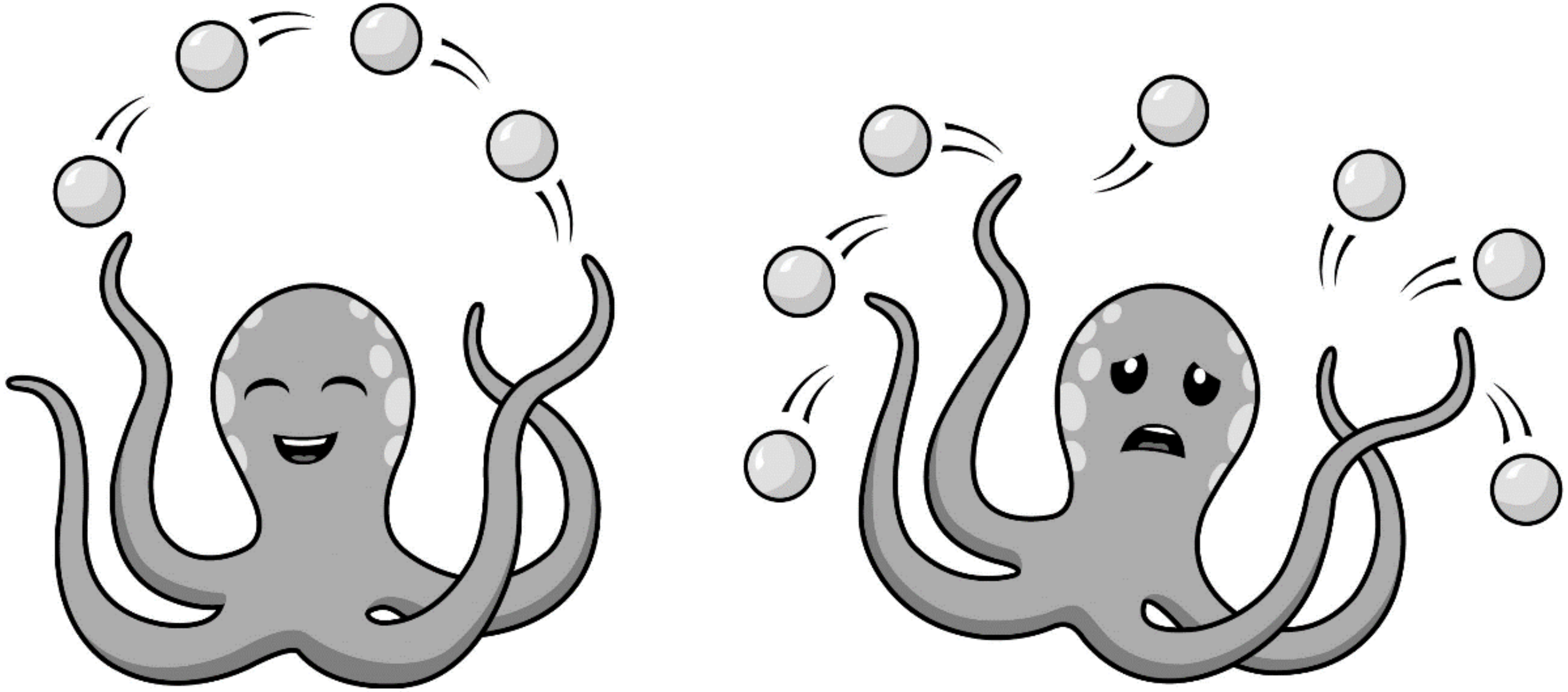

Figure 5: Most people can hold a maximum of about four pieces of information in working memory at once. But if they get distracted, or they try to keep too many balls in mind at once, the thoughts can all fall out!

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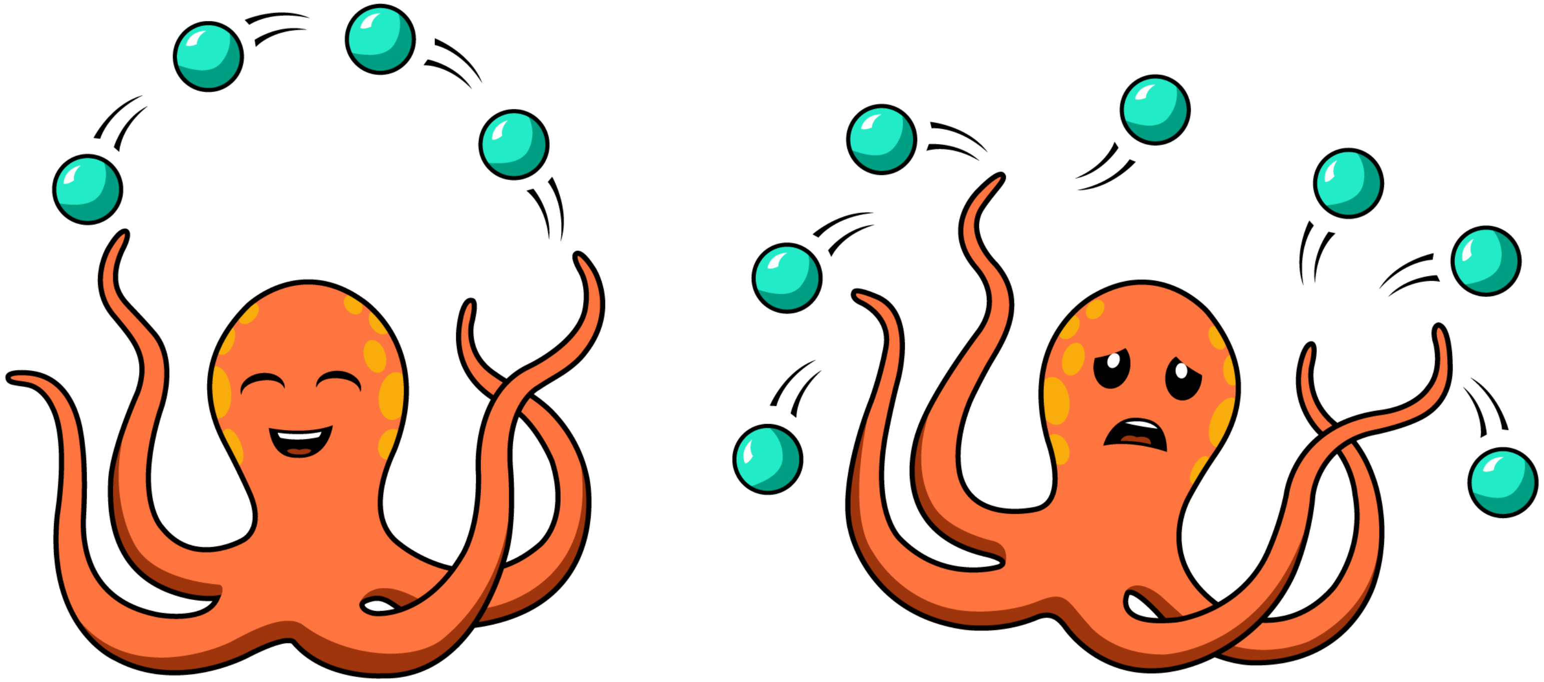

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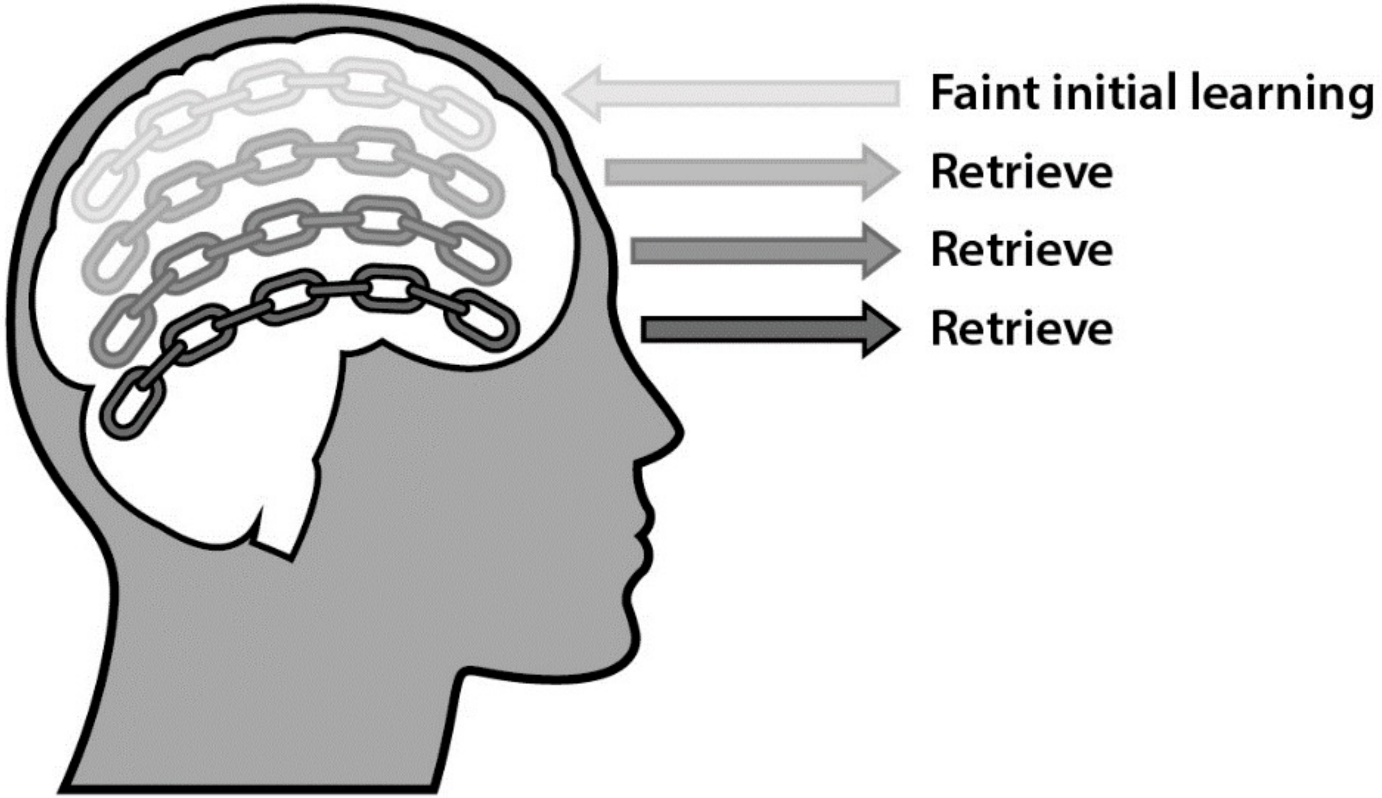

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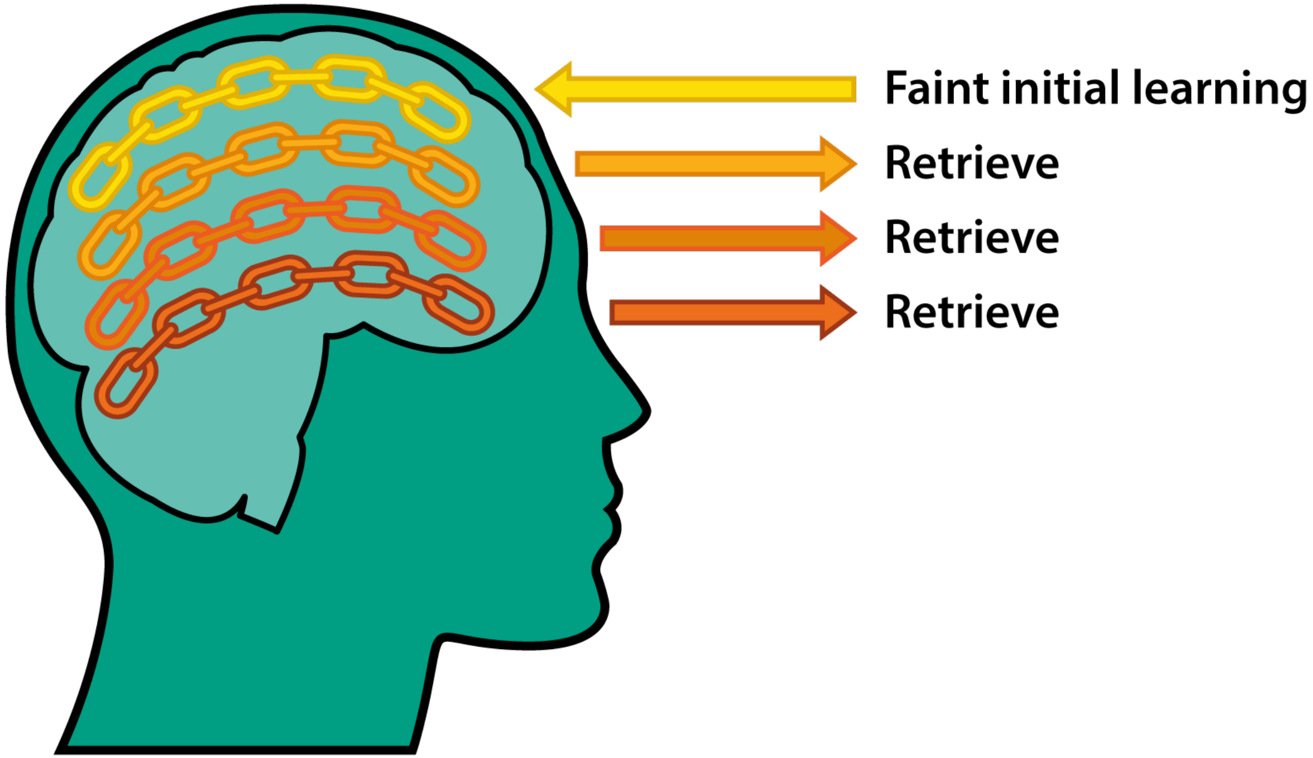

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Chapter 2
Teaching *Inclusively*:
The Importance of Working Memory Capacity

Figure 7

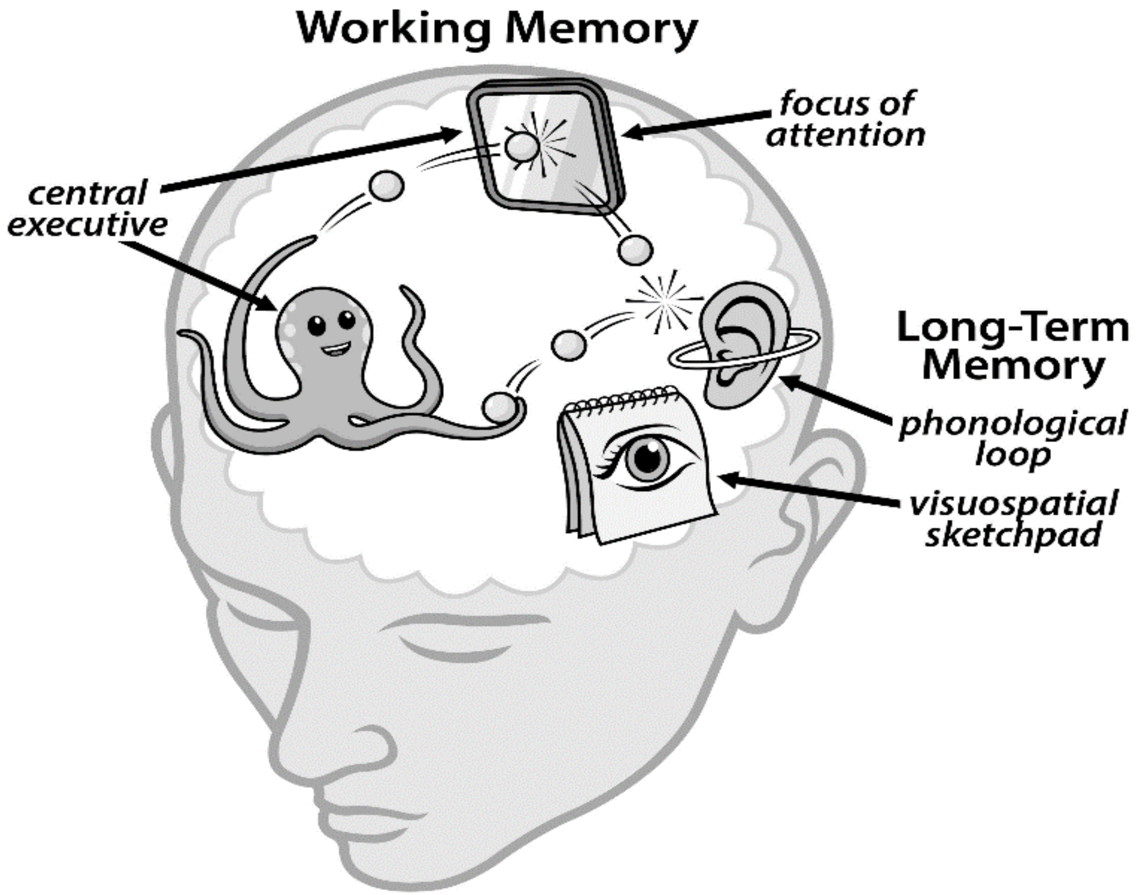

Figure 7: Working memory is like an octopus (or quadropus!) in the front of your brain that keeps tossing the thoughts toward the back of the brain. Those thoughts reverberate back around again to the front of the brain as you focus your attention on them—that's what keeps the thoughts alive in working memory.*

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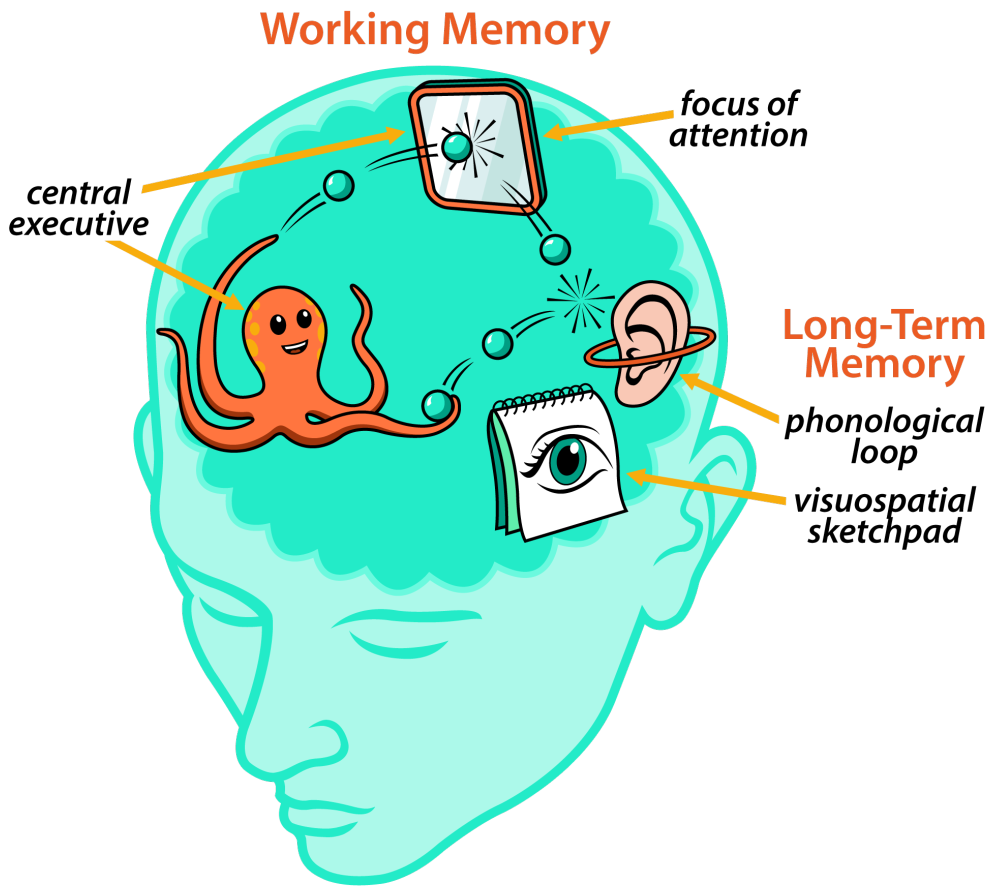

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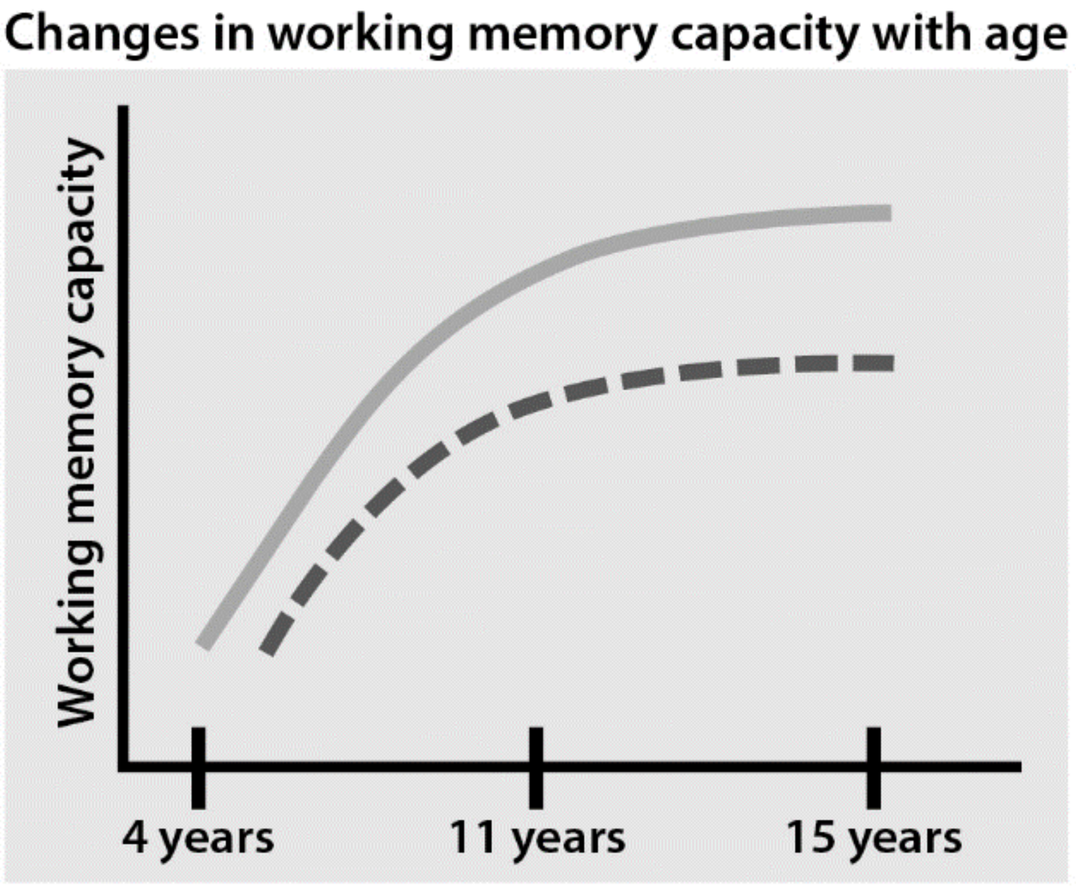

Figure 8: The changes in working memory capacity with age for an average child are shown by the solid line. Scores of a child with lesser working memory capacity are represented by the broken line.[5]

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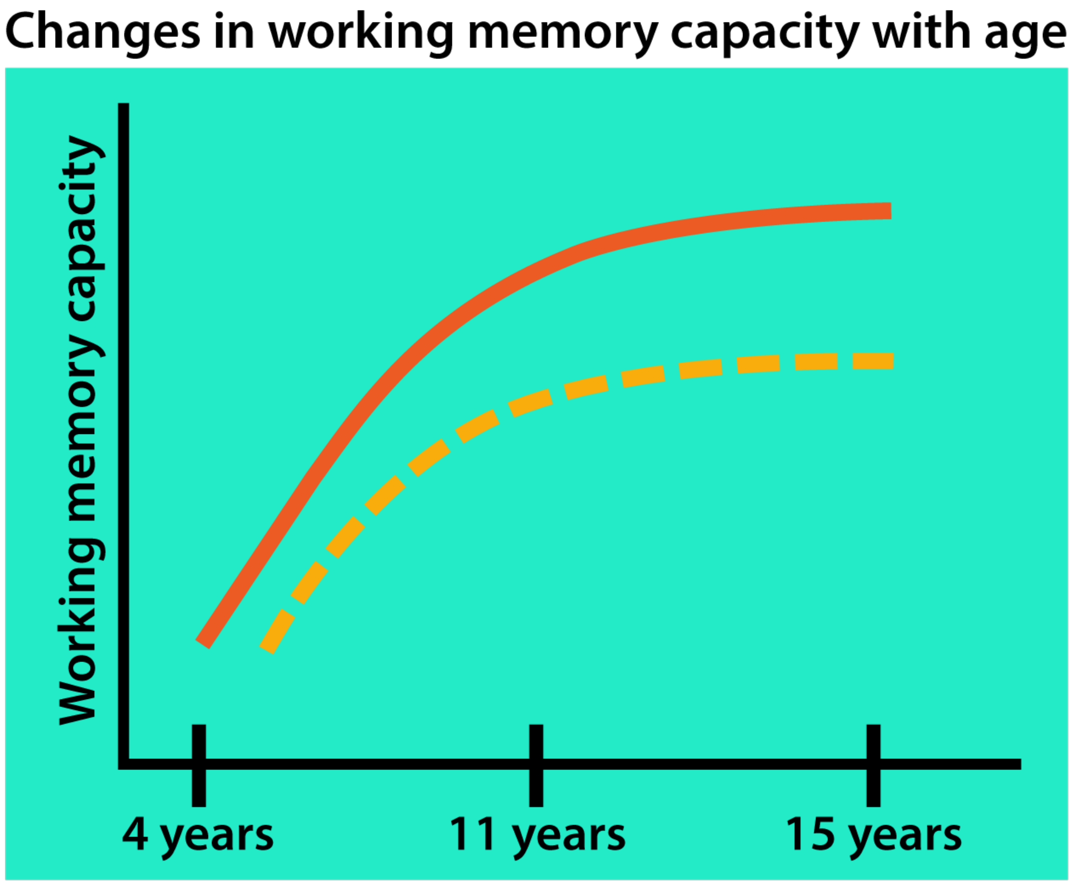

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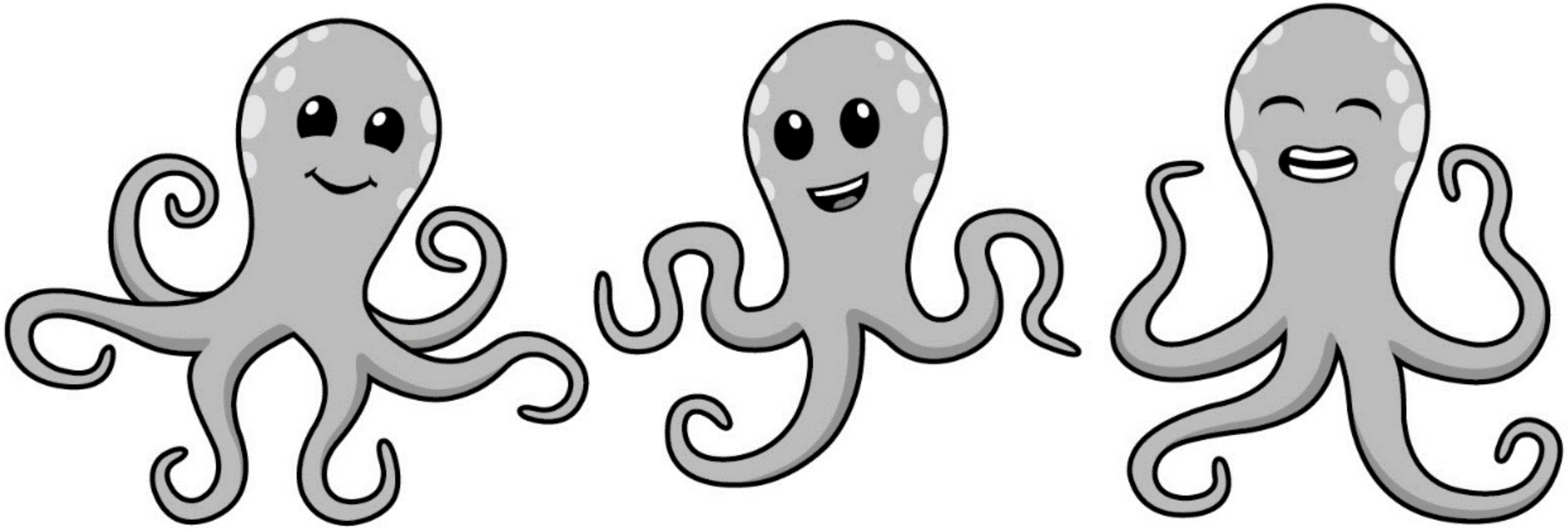

Figure 9: Students can vary substantially in their working memory capacity. Although the average is four “arms” on their attentional octopuses (that is, four pieces of information they can hold in mind), some students may have only three arms, while still others can have six or more arms.

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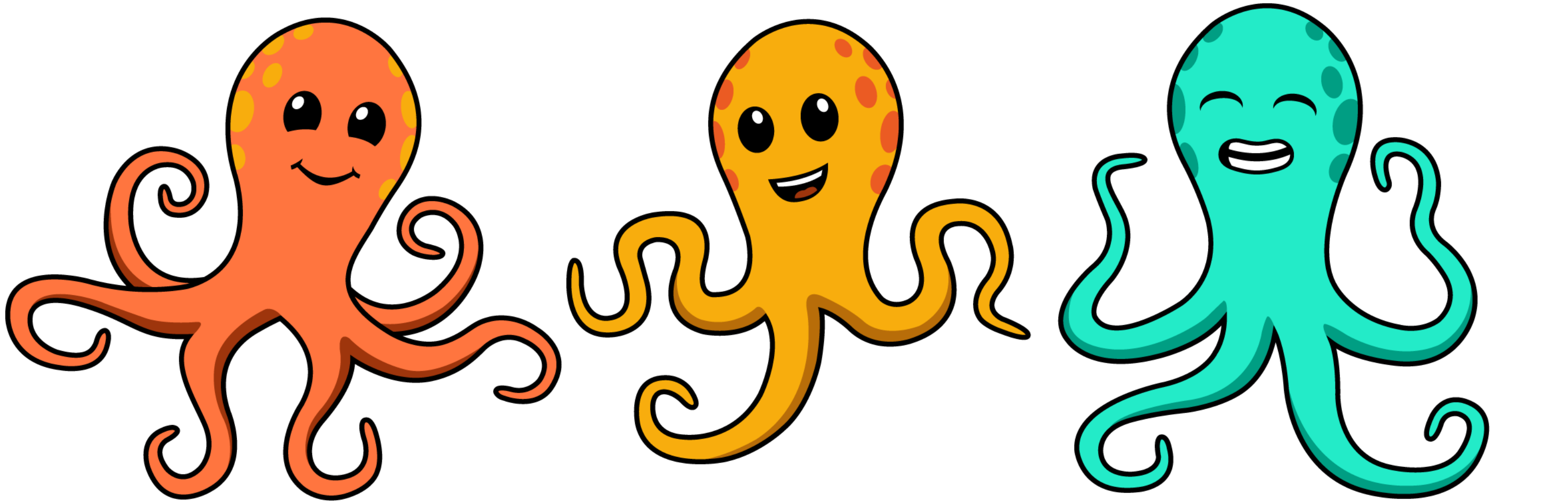

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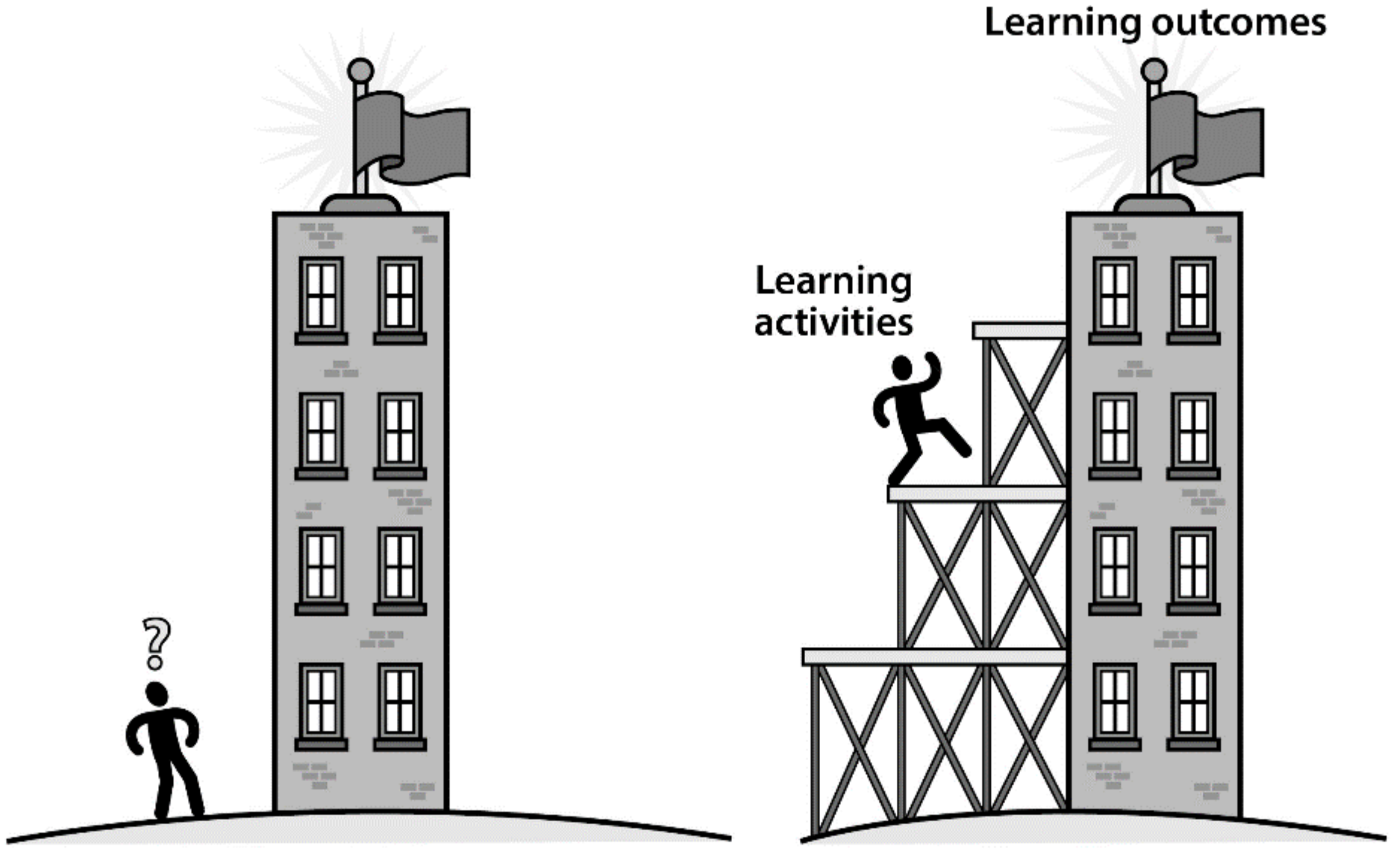

Figure 10: Scaffolded instruction allows students to gradually climb to heights that might at first seem insurmountable.

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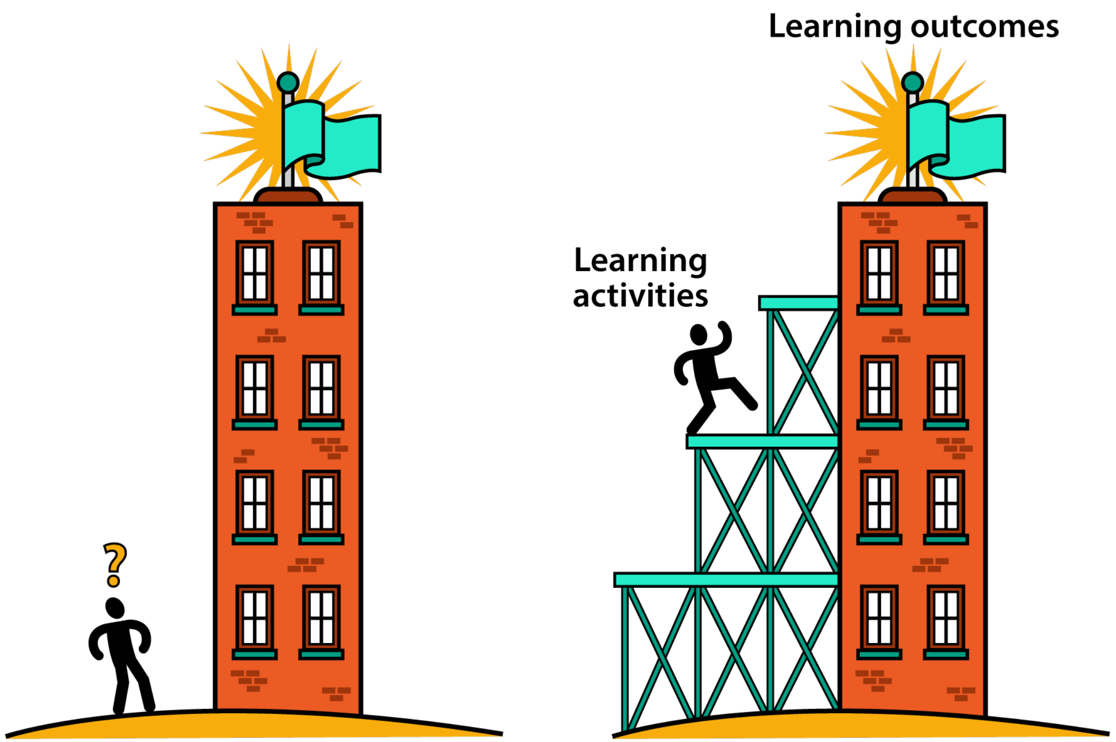

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Active Learning: The Declarative Pathway

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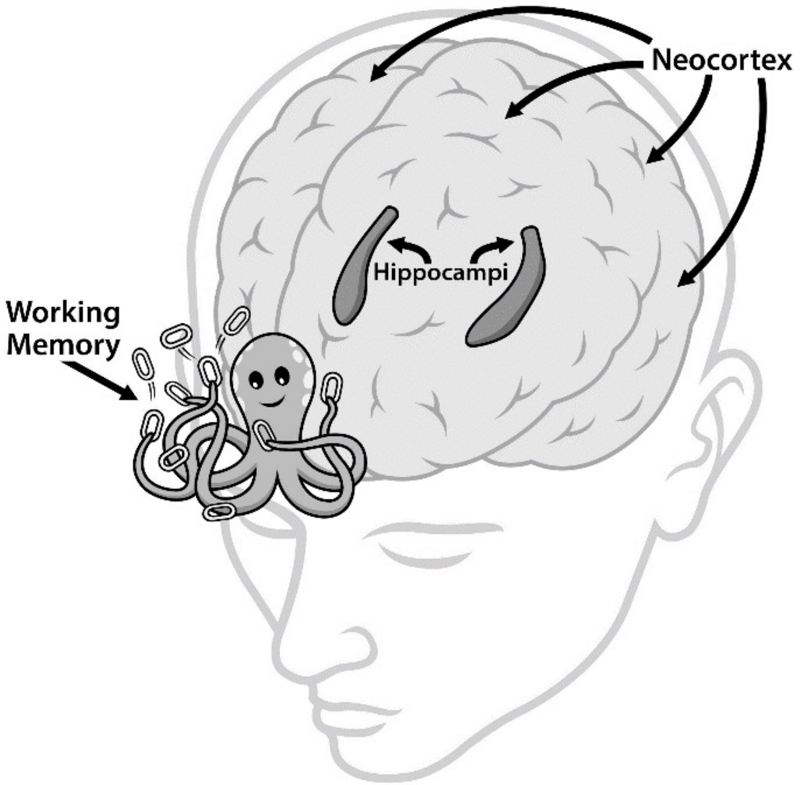

Figure 12: The brain has two major structures that "learn" from *working memory*: the *hippocampus* and the *neocortex*.

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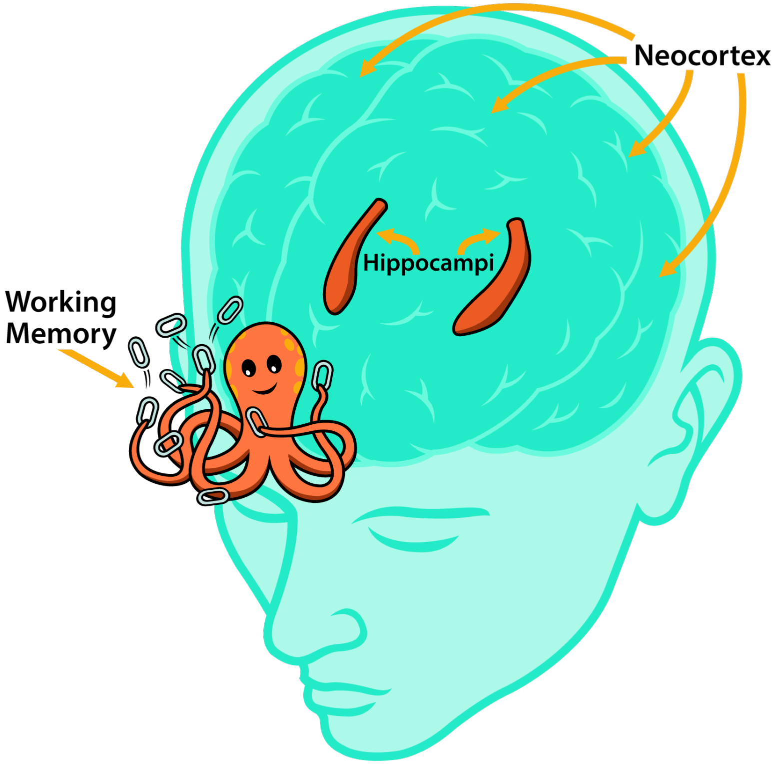

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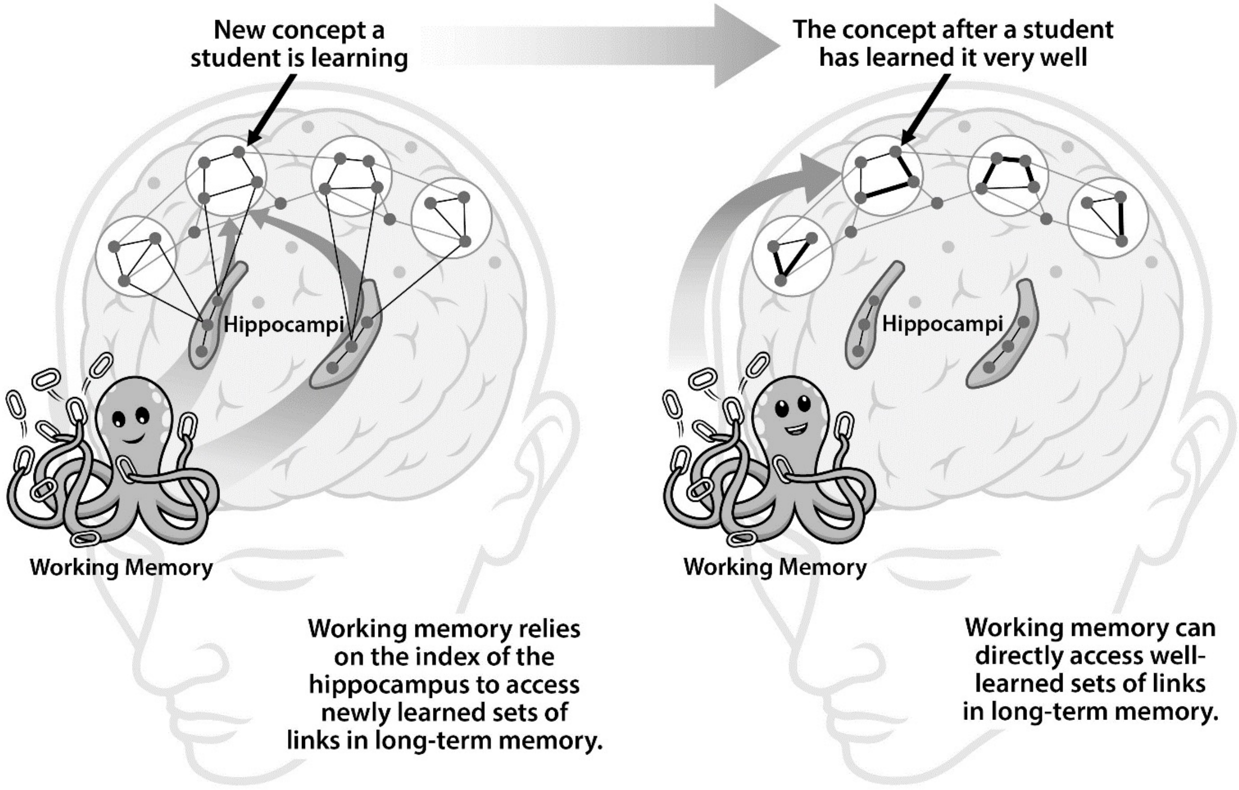

Figure 13: (Left) Recall from Figure 2 that each dot represents a neuron. The circles surrounding the sets of neural links ("dot links") represent different new ideas a student is learning and storing in long-term memory. Working memory sends the information to the dot-links of long-term memory mostly by means of the hippocampus. (Right) As material becomes better-learned, working memory can reach and grab the information directly from long-term memory without using the hippocampus.

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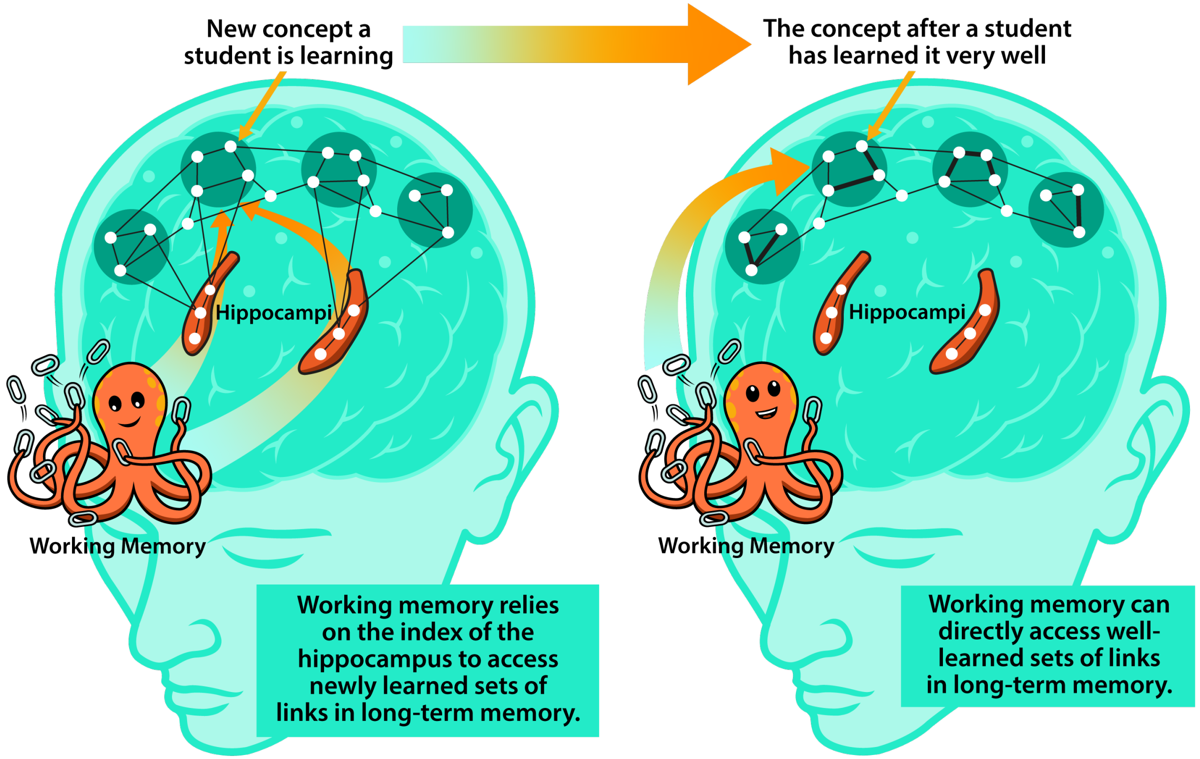

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Figure 14: The brain is like a little choir with the Conductor (working memory), Hip (the hippocampus), and Neo (the neocortex). Here, Hip sings his indexing song to Neo. This helps remind her which of her many scattered new connections she needs to strengthen, and which to weaken.

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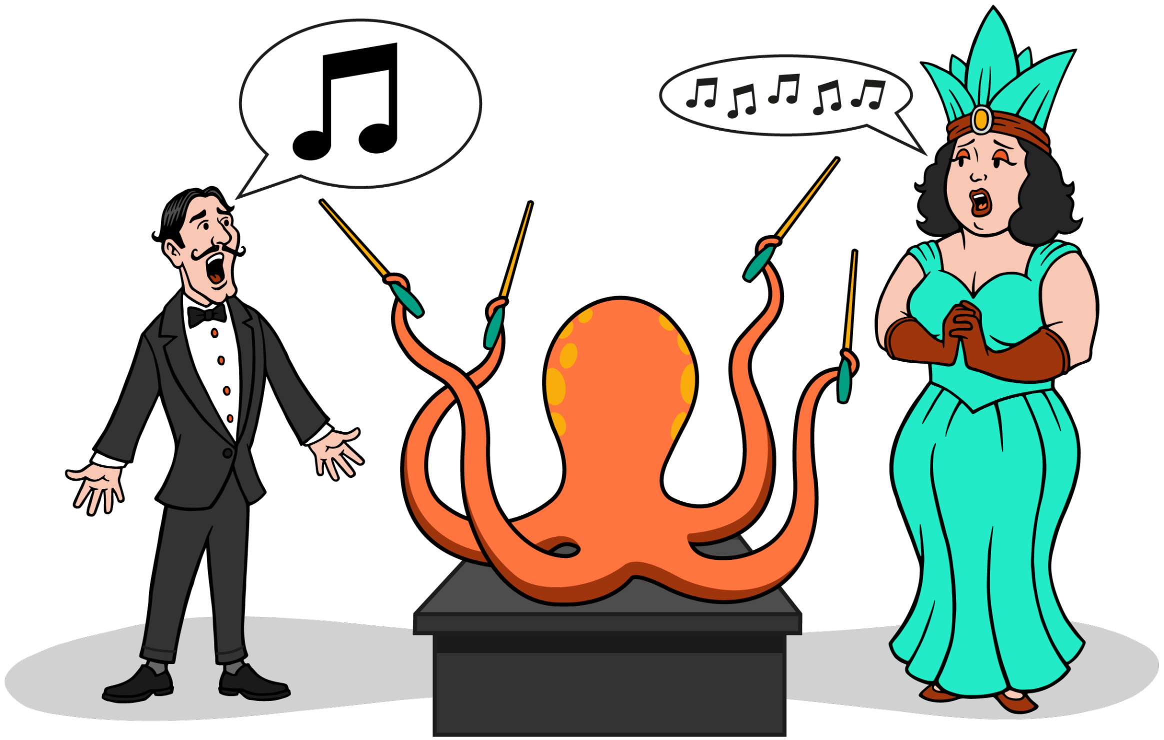

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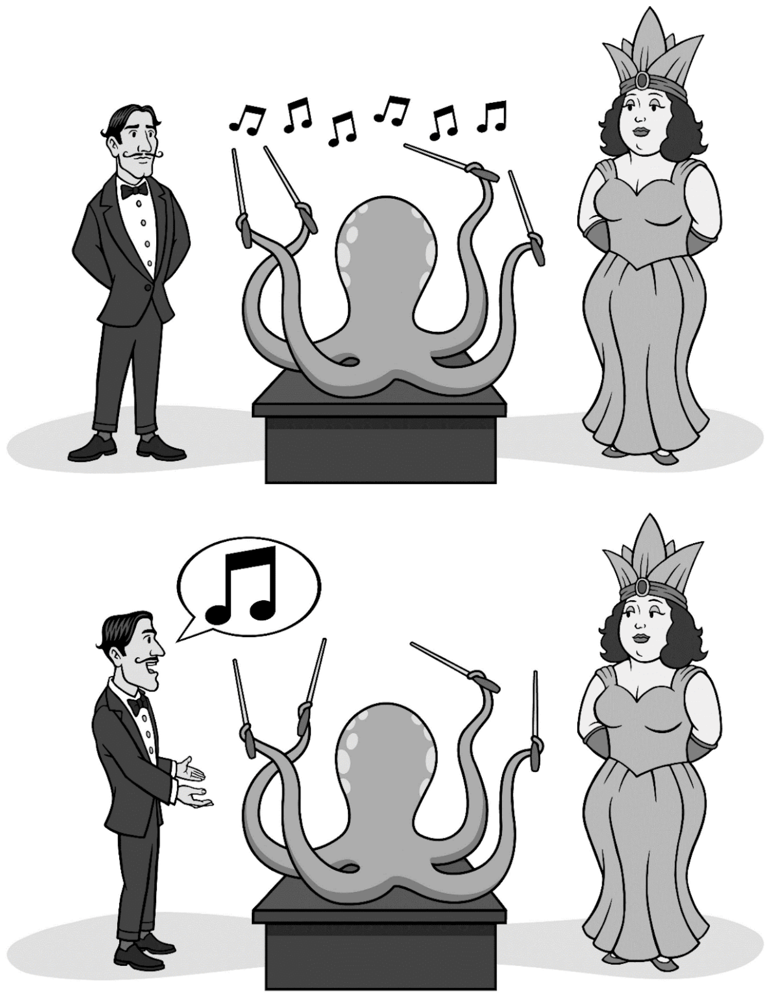

Figure 16: Metaphorically speaking, Hip can be in only one of two positions. In the first position, Hip is facing the Conductor and learning something new (getting the index links). In the second position, Hip is facing Neo during mental break times—he's urging her to connect her song together so she can sing the right notes. *Hip can't both learn and repeat at the same time.*

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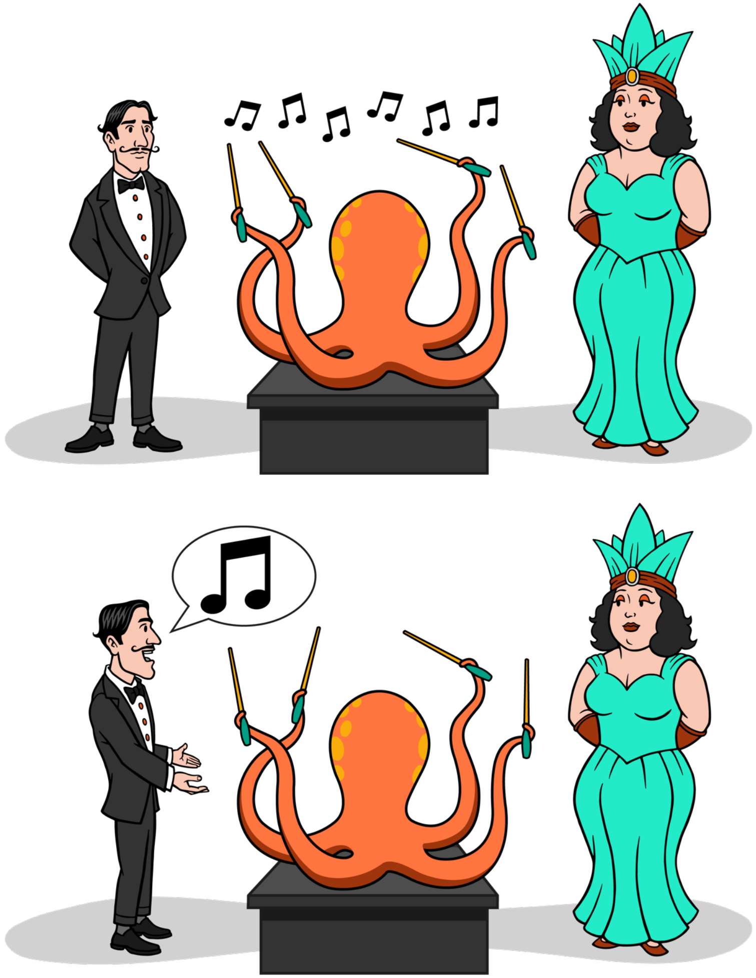

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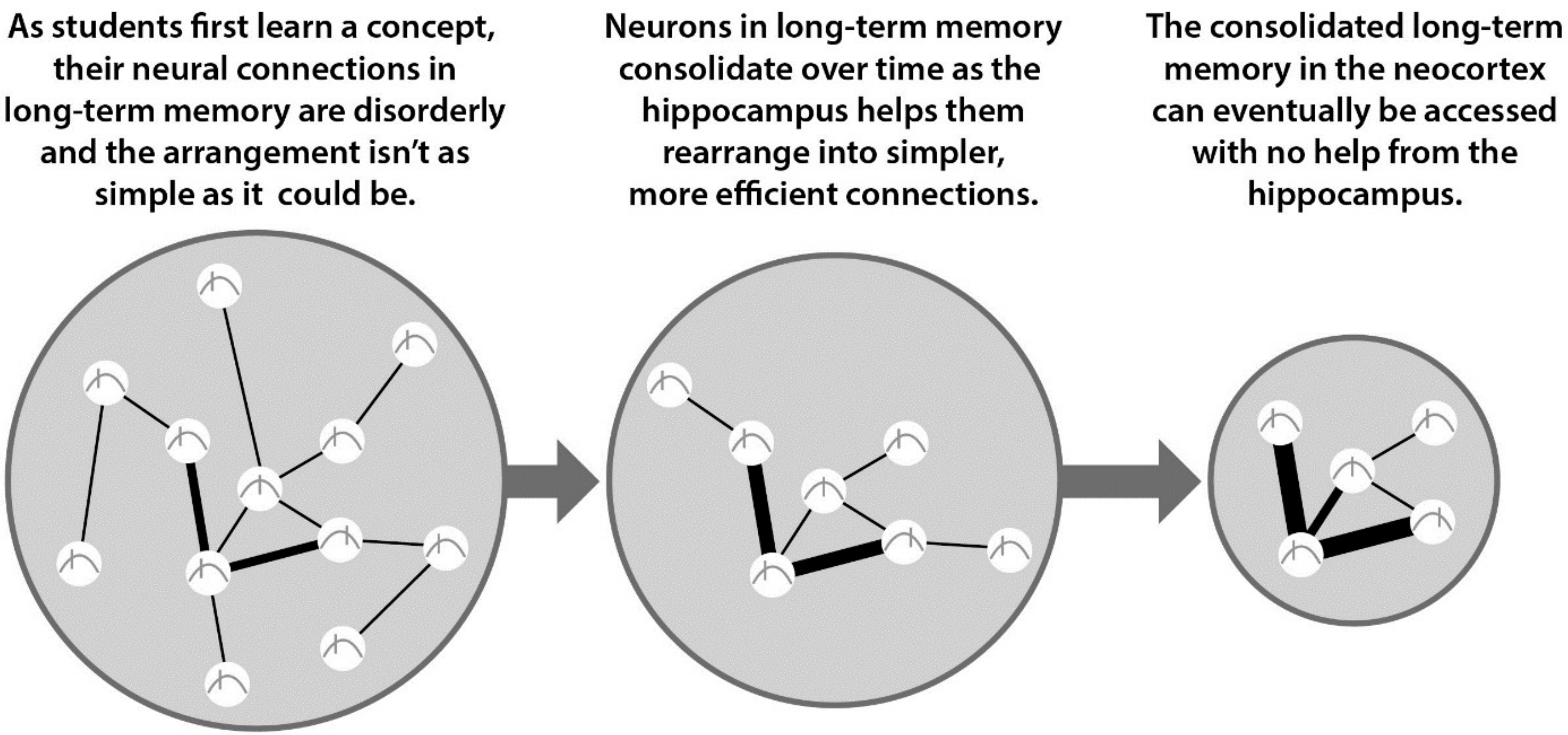

Figure 17: The consolidation process. When a student first learns something, the neural sets of links are still weak and very disorganized, as symbolized by the illustration on the left. It can take several days for those connections to stabilize and strengthen. Gradually, through the hours, days, and months of the consolidation processes links keep tweaking and rearranging themselves. The hippocampus, which contains the index, guides this process.

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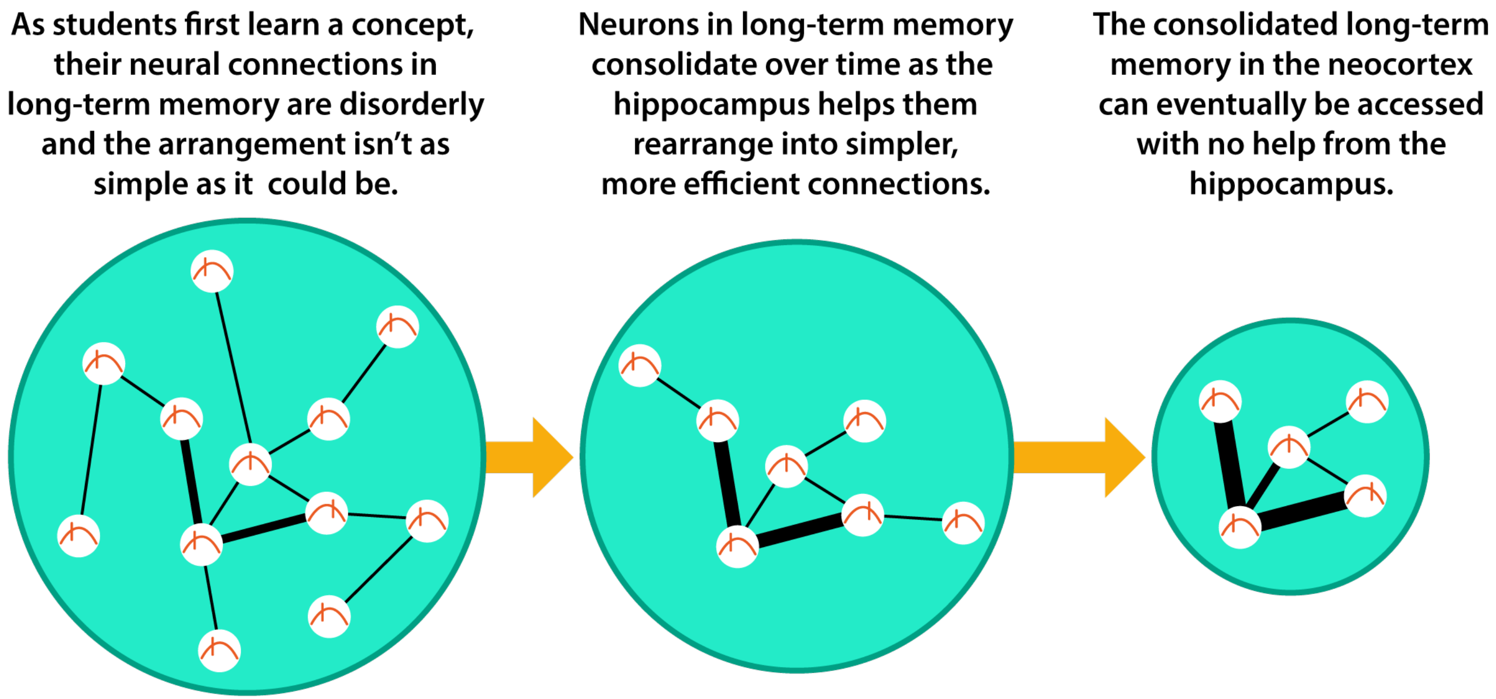

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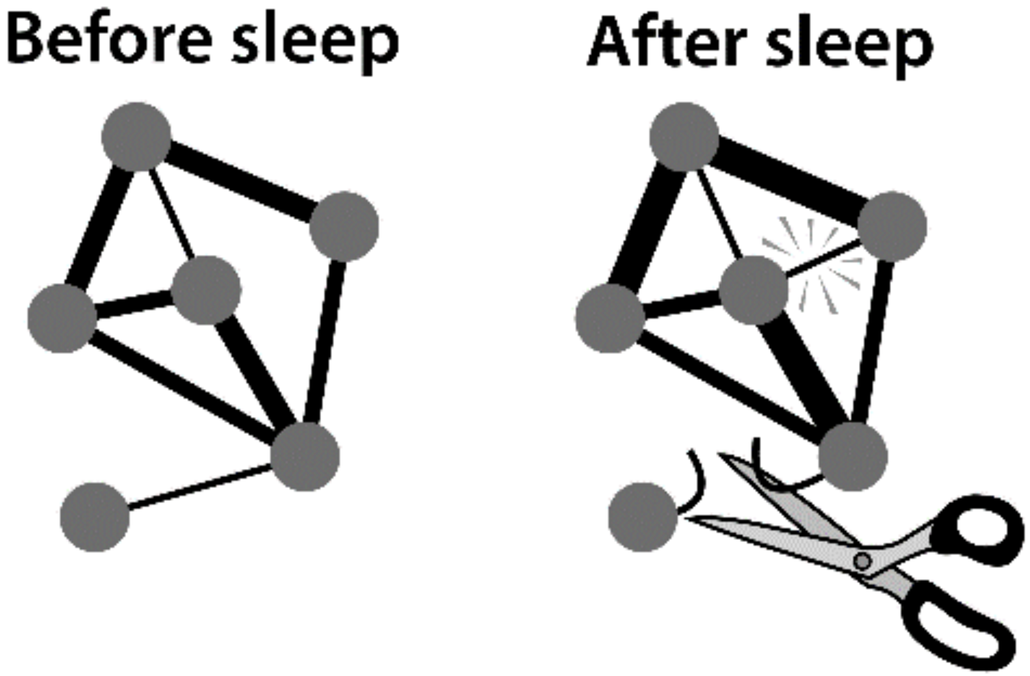

Figure 18: During sleep, new synapses (connections) are formed between neurons. Some pre-existing connections are strengthened, others are weakened. Some connections are pruned away altogether, as shown by the “scissors” cutting the connection. As you can imagine, sleep facilitates and is part of the consolidation process.

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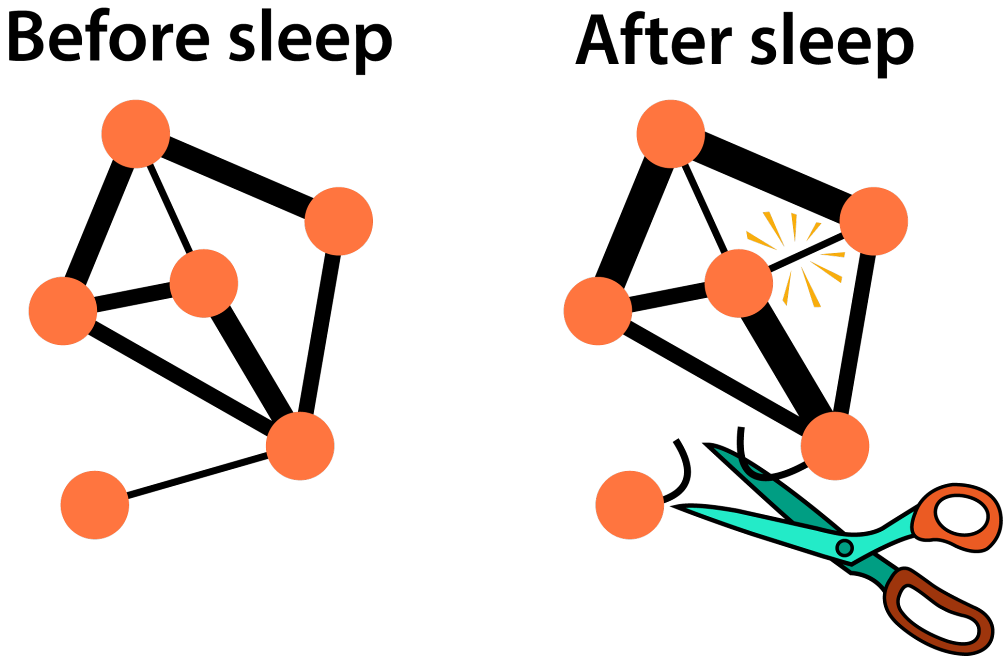

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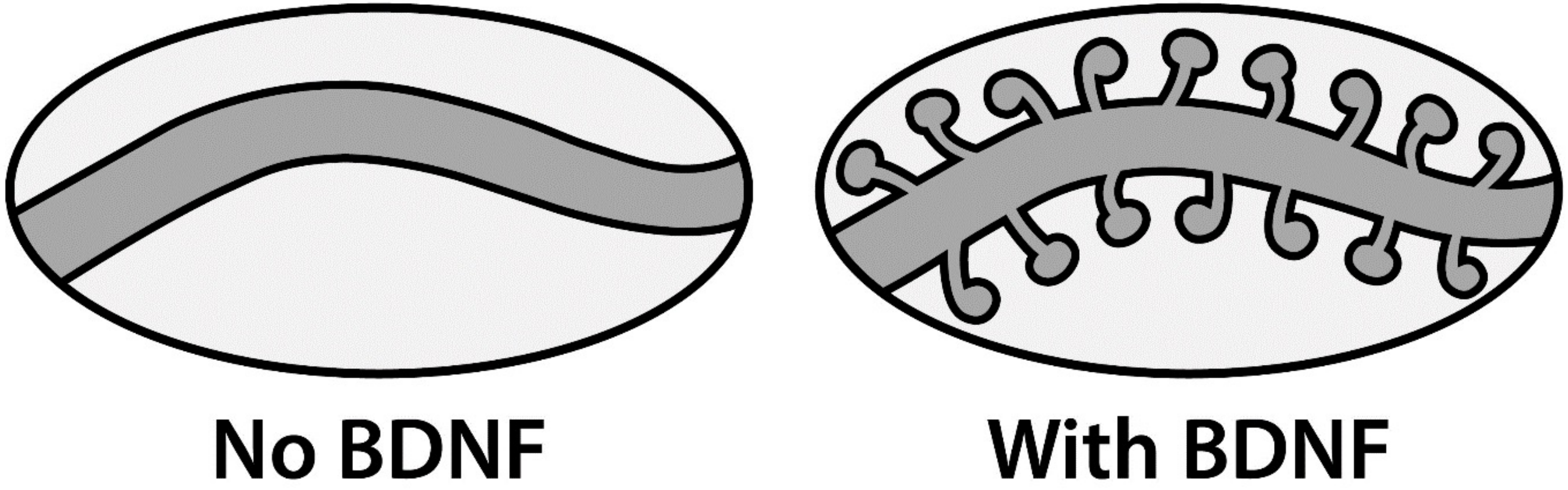

Figure 55: While sleep strengthens pre-existing connections, exercise produces a substance called BDNF that helps new dendritic spines emerge. In other words, exercise helps neurons grow important extensions that can easily be hooked to other neurons. This is why exercise is such a valuable enhancement for learning.

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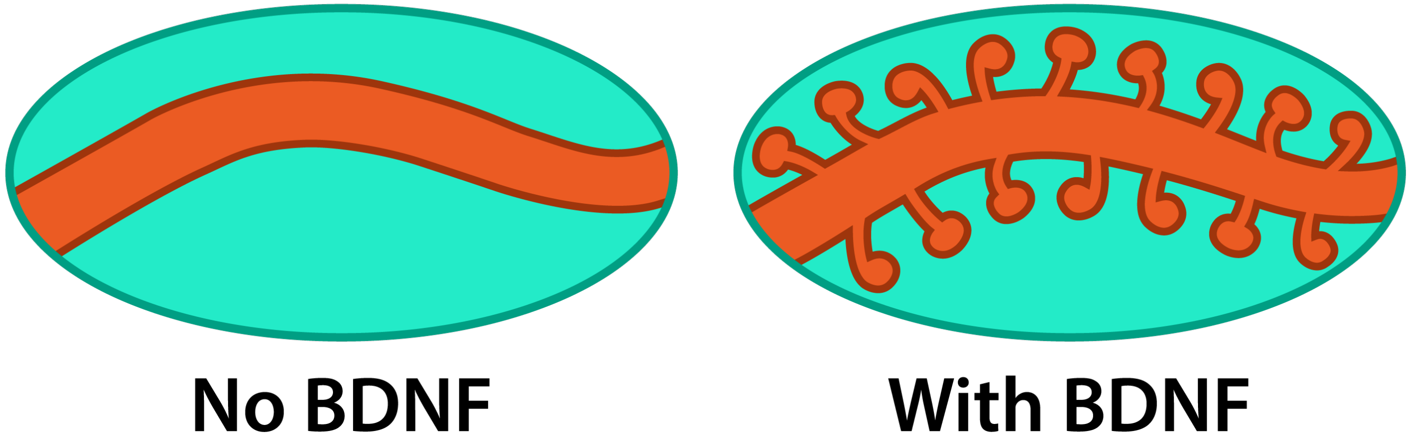

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Chapter 4
Remedies for Procrastination

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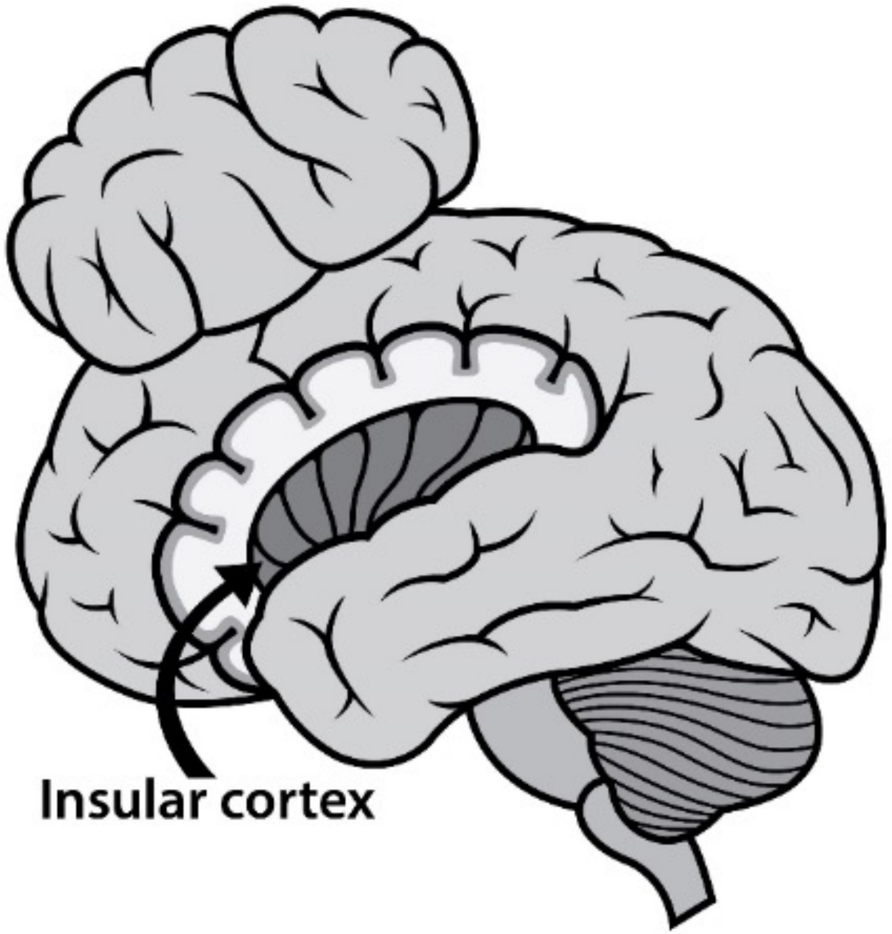

Figure 19: When students just think about something they don’t like or don’t want to do, feelings of discomfort and pain pop up from the insular cortex—a pain processing center of the brain.

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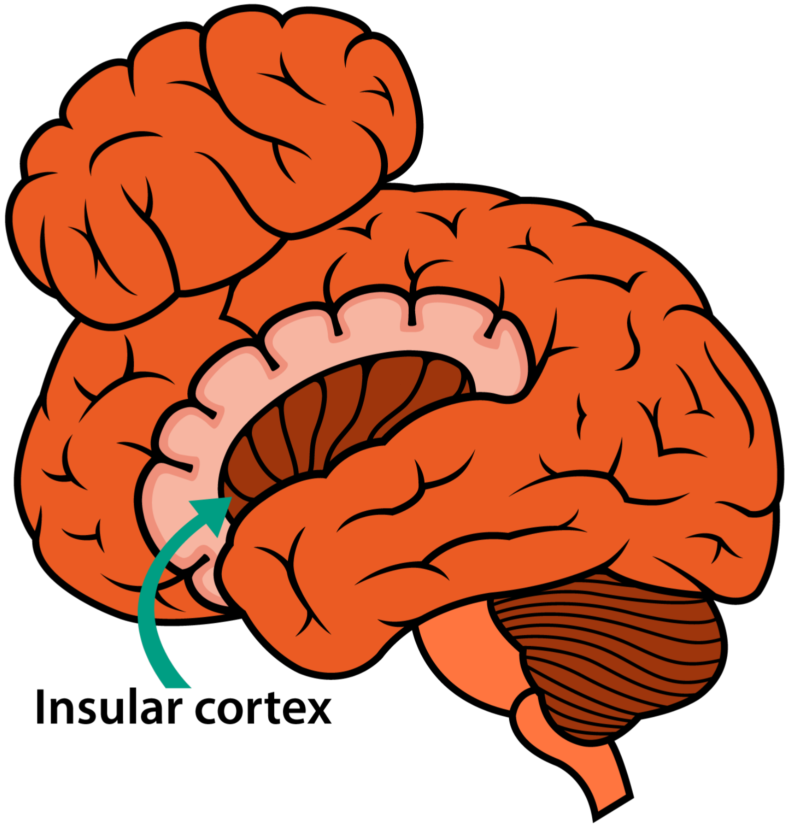

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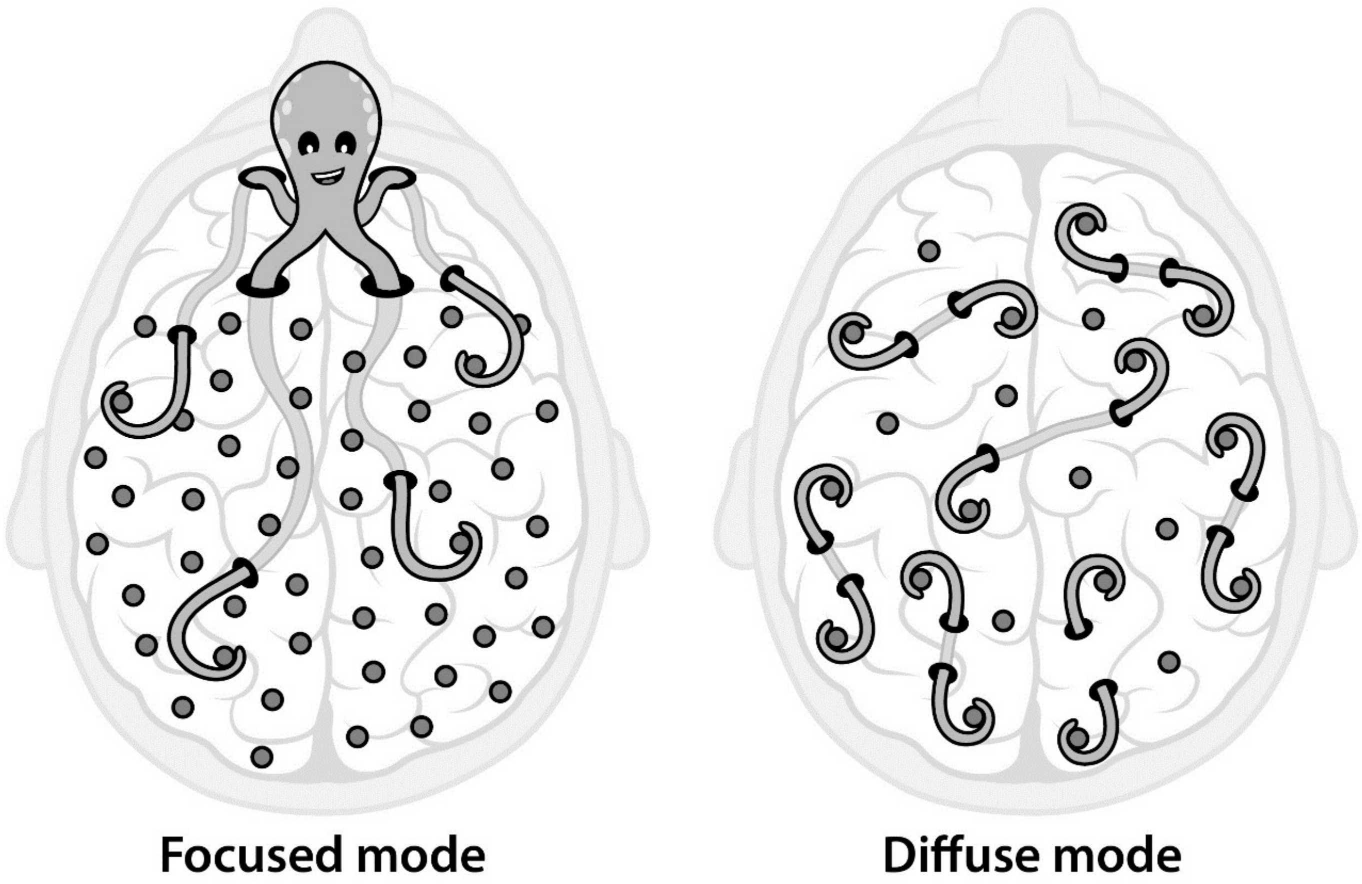

Figure 20: Switching between *focused mode* (where working memory is focusing as it reaches toward the sets of links in long-term memory) and *diffuse mode* (where random connections can form), helps students to grapple mentally with tough new ideas.

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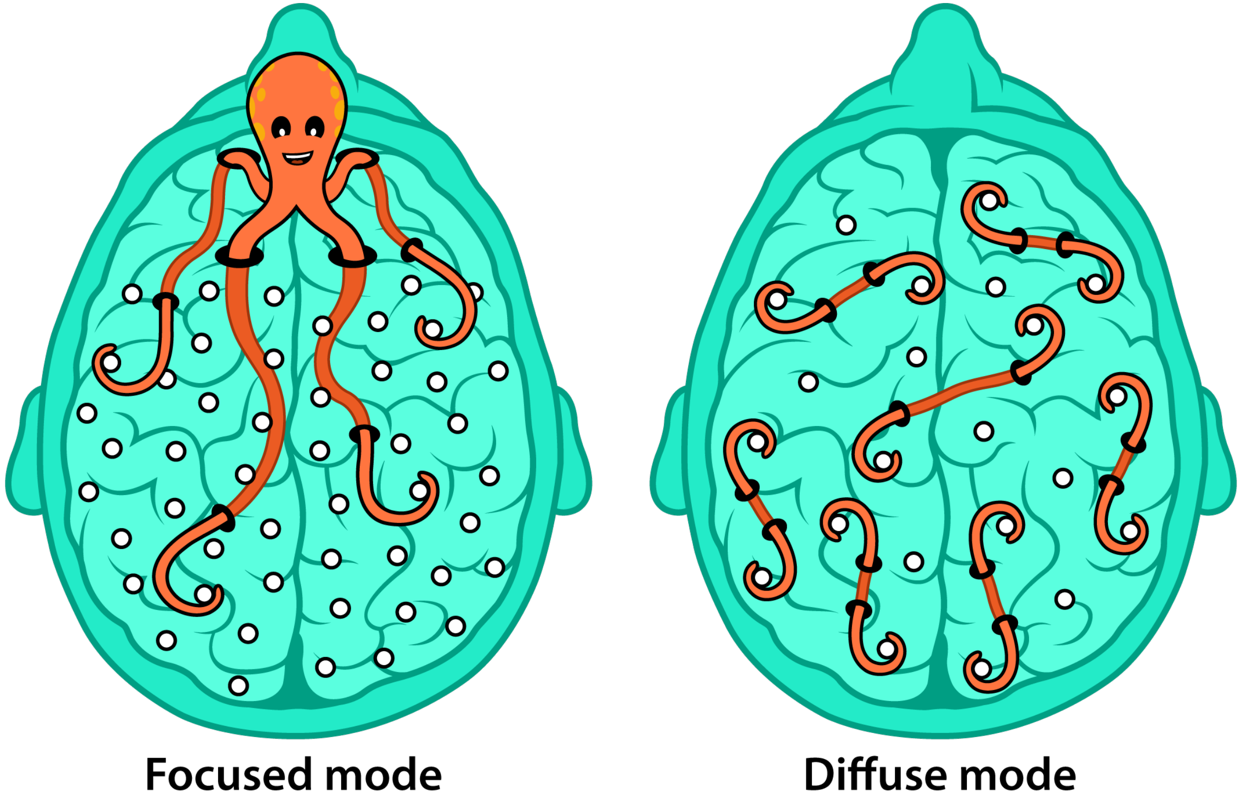

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Figure 21: Analyze Your Teaching: Break It Down—Teaching Students Tough Assignments

The Setup

Figure 22

Figure 22: Soviet soldiers on the attack at the Battle of Stalingrad. Sometimes it can feel like a battle just trying to communicate these important historical events and make them stick in students' minds.

Chapter 5
How Humans Evolved—and Why This Matters for Your Teaching

Figure 23

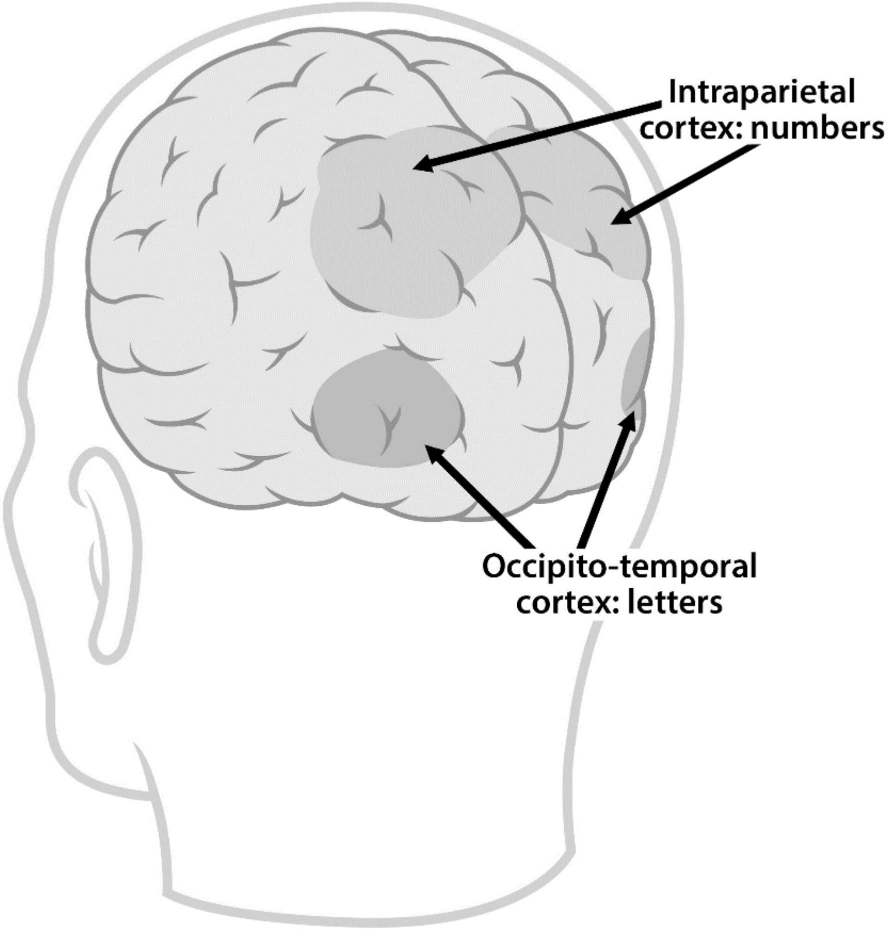

Figure 23: Letters always seem to invade the occipito-temporal cortex, which ordinarily detects features of objects and scenes. Number representations invade the bilateral intraparietal cortex, a part of the brain that codes for a rudimentary sense of quantity. These invasions occur no matter what culture a person is raised in—like migrating birds that always return to the same areas.

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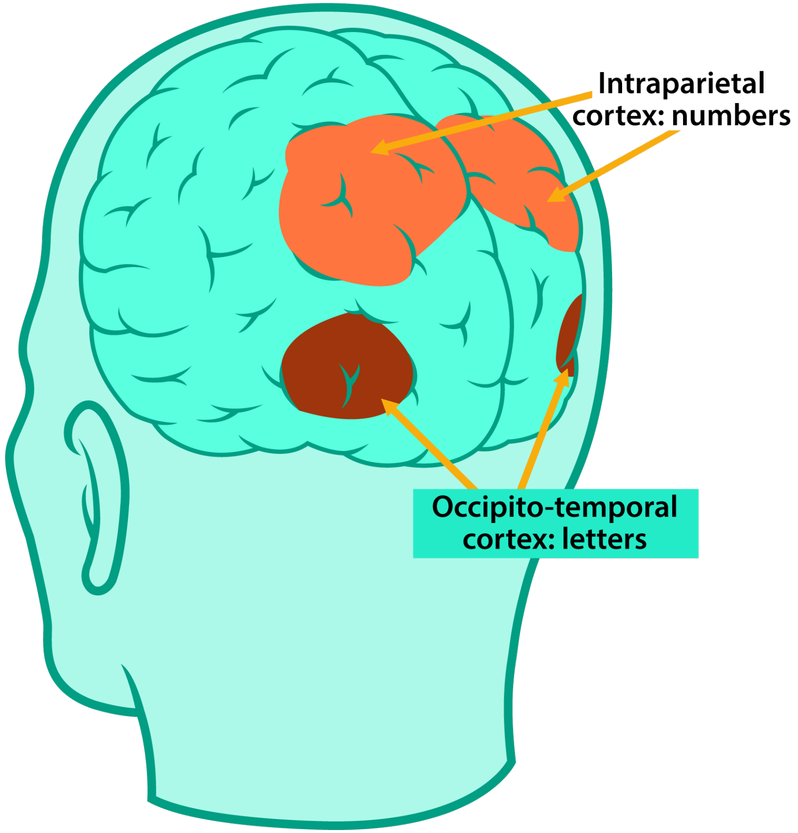

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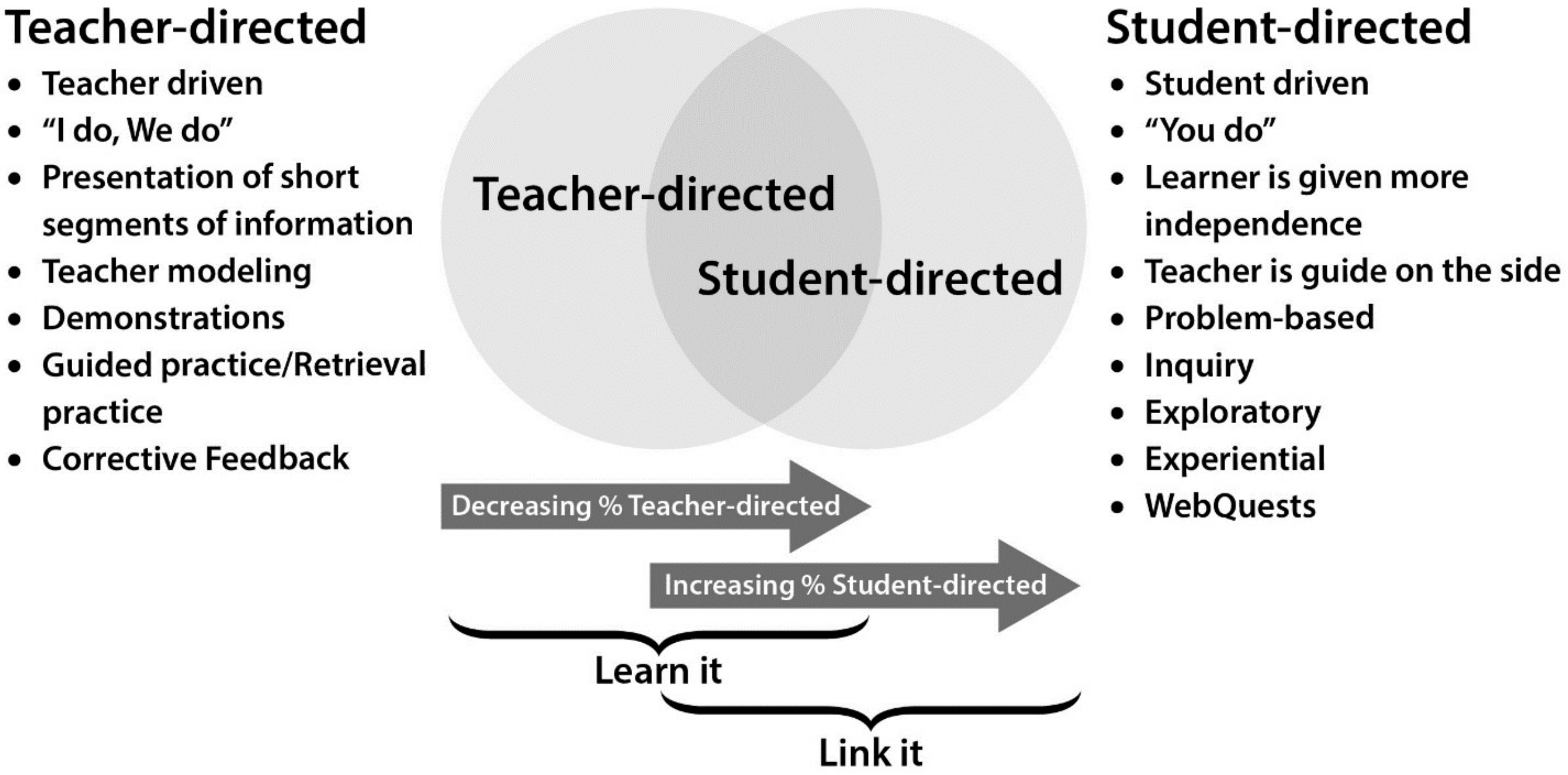
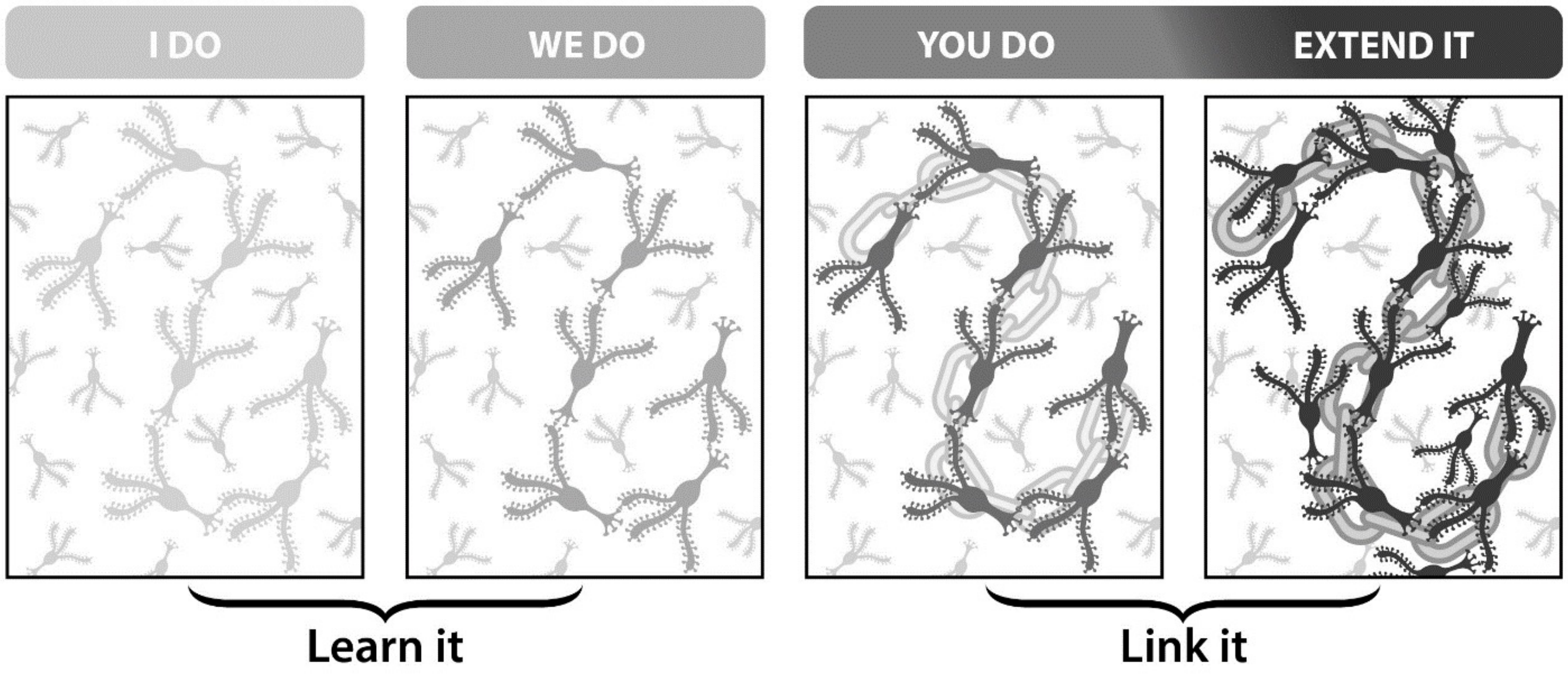


Figure 11: Often, teacher-directed instruction and student-directed instruction are viewed as opposing methodologies. But in practice teacher-directed instruction sets students up for successful student-directed learning. The more difficult (biologically secondary) the material, the more that students need coaching (teacher-directed approaches) to launch them toward independence (student-directed approaches). As students strengthen their neural links, they gain autonomy in their learning.

Figure 54



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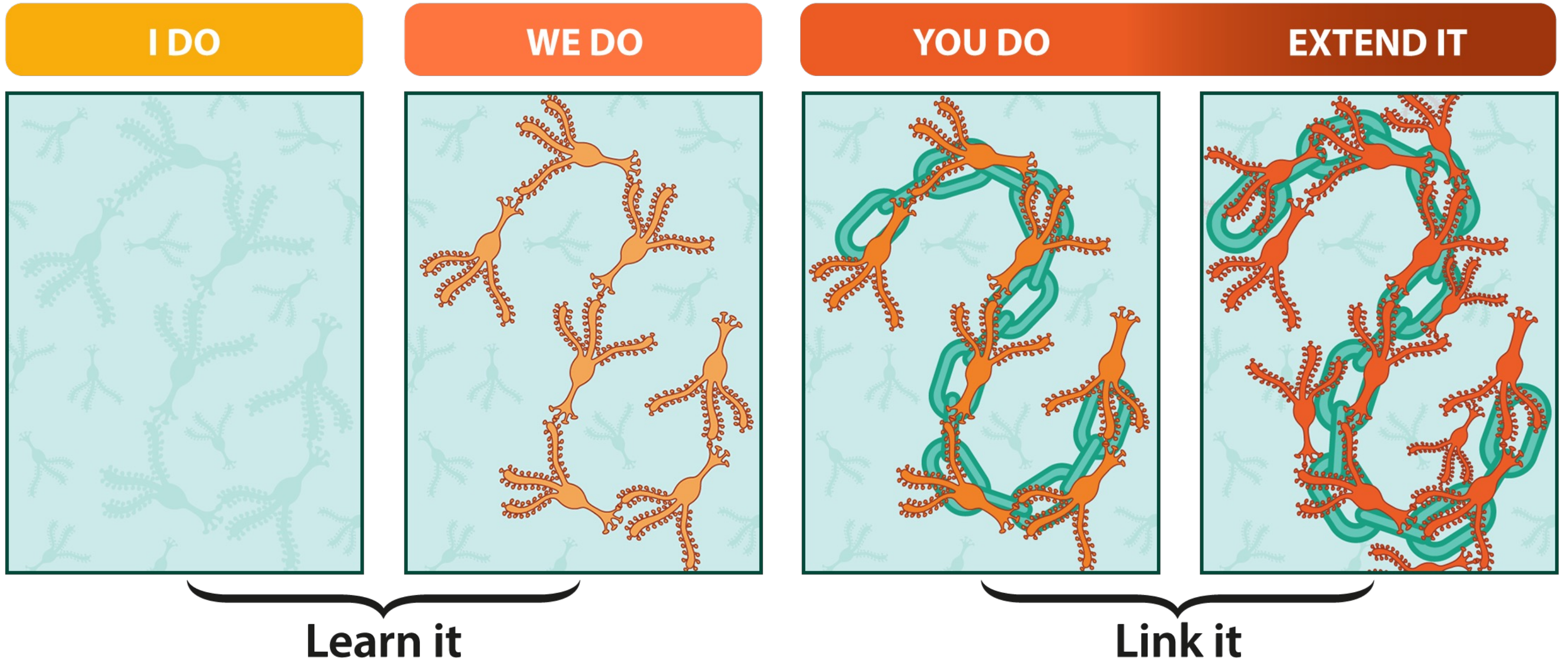

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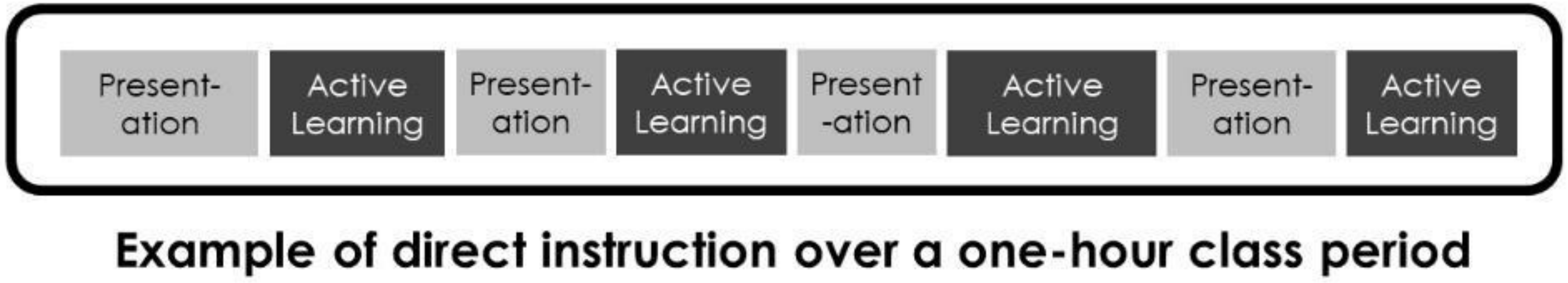

Figure 52: Direct instruction intermixes presentation (or demonstration) with plenty of active learning, as this illustration shows. What's the optimal mixture of active learning to presentation? There are no definitive conclusions from research—but we do know that mixing it up is important!

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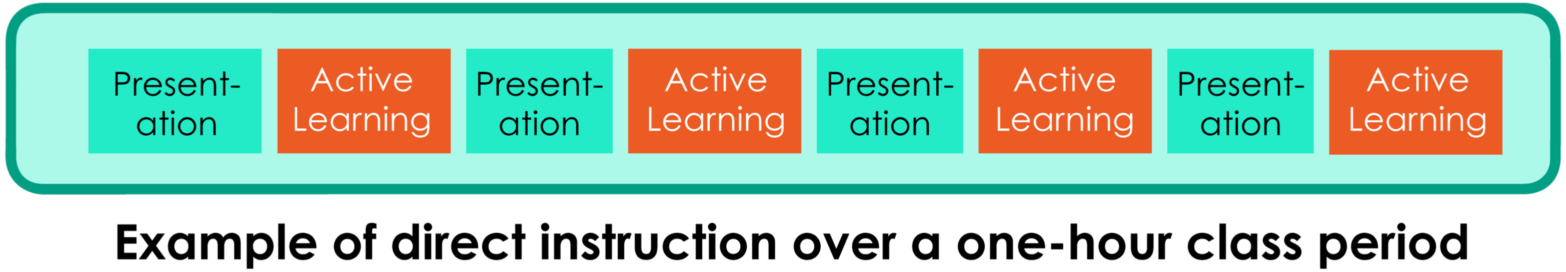

Figure 52: Direct instruction intermixes presentation (or demonstration) with plenty of active learning, as this illustration shows. What’s the optimal mixture of active learning to presentation? There are no definitive conclusions from research—but we do know that mixing it up is important!

Figure 24

Figure 24: You can think of primary learning as involving neural pathways that very nearly lay themselves—it's easy to see where the paths should go in the lovely, bright landscape, as shown on the left. But secondary learning is like trying to carve out a pathway in a dense neural jungle. Not only is it hard to scramble through the vines and sprawling dendritic trees, but it's also difficult to even know what direction you are supposed to be going in. Each step provides further opportunity for confusion and error—within just a few steps, you can find yourself going in circles.

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Figure 25

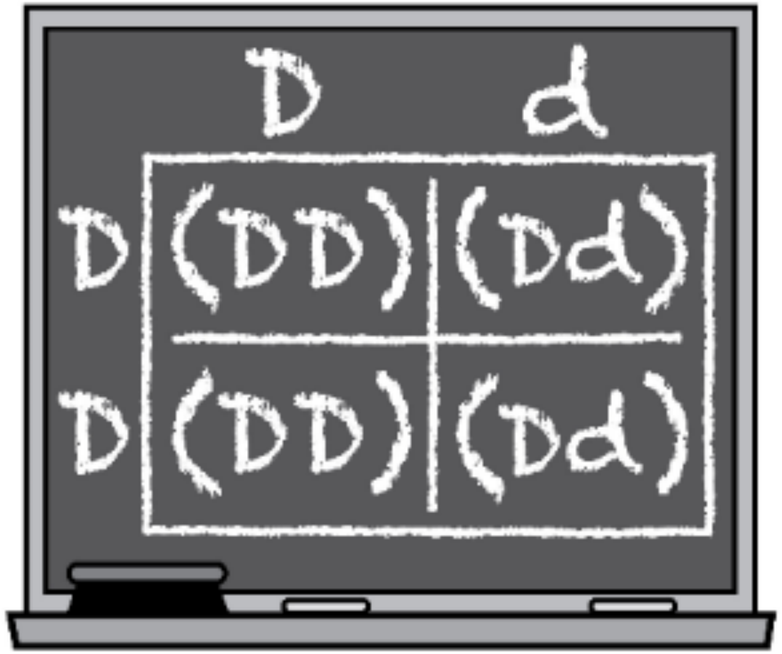
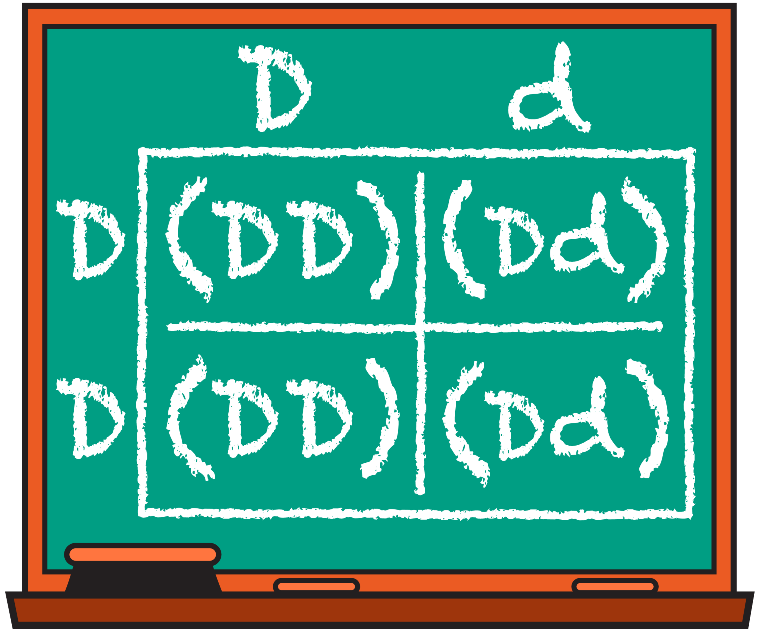


Figure 25: A Punnett Square. The mother's genotype shown on the far left, and the father's genotype just above the square. Alleles are coded using a capital letter for dominant alleles and lowercase for recessive.

Figure 25



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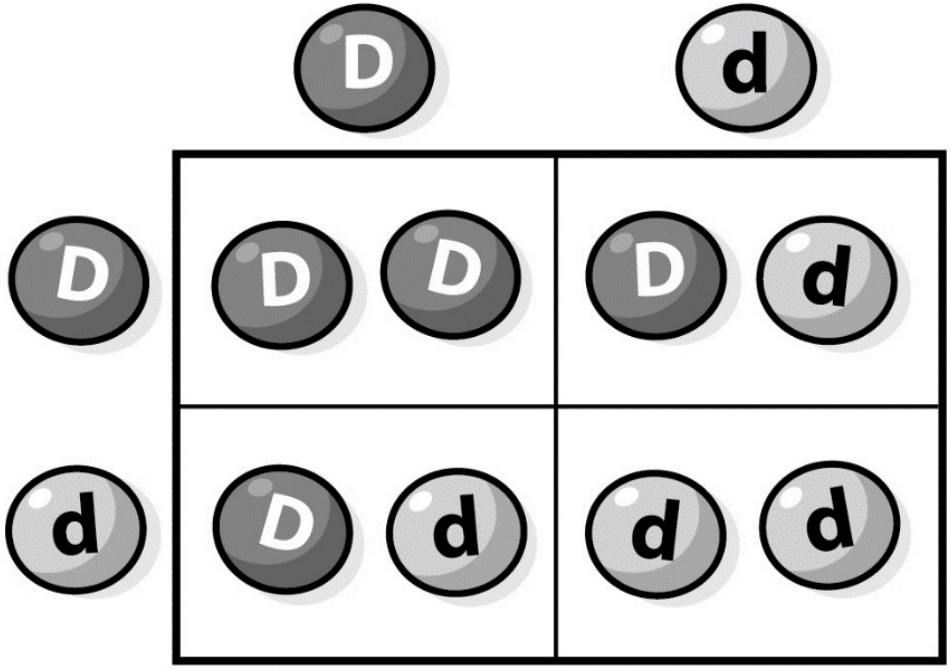
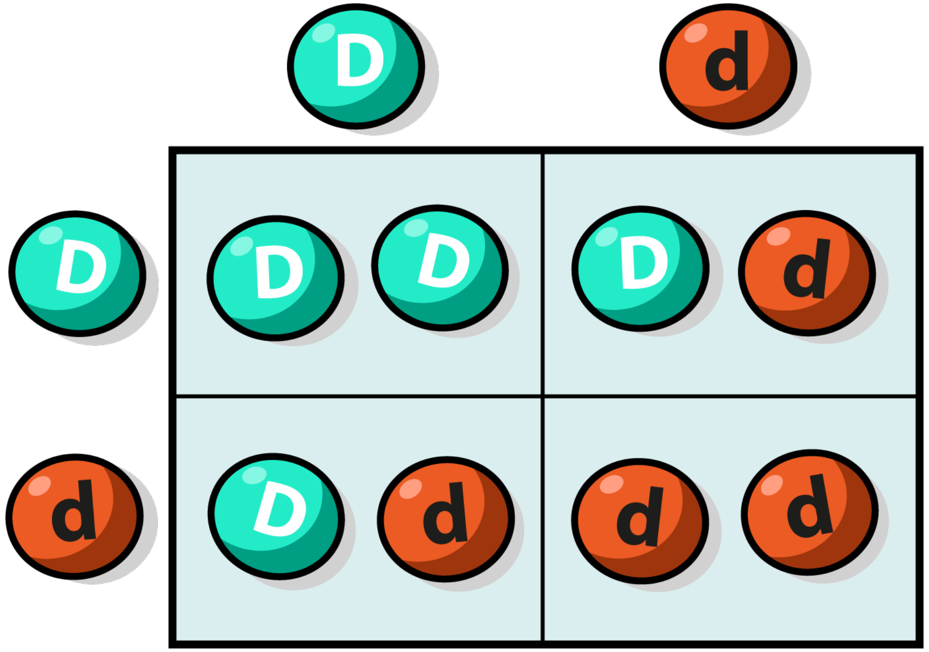


Figure 26: The genotype reveals a 25% chance for homozygous dominate, 50% chance for heterozygous, and 25% for homozygous recessive—making it a 1:2:1 ratio. The phenotype is inferred from the genotype, making it a 75% chance for dimples and 25% chance for no dimples.

Figure 26



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Chapter 6
Active Learning-–The Procedural System; Merging the Declarative and Procedural Pathways

Figure 27

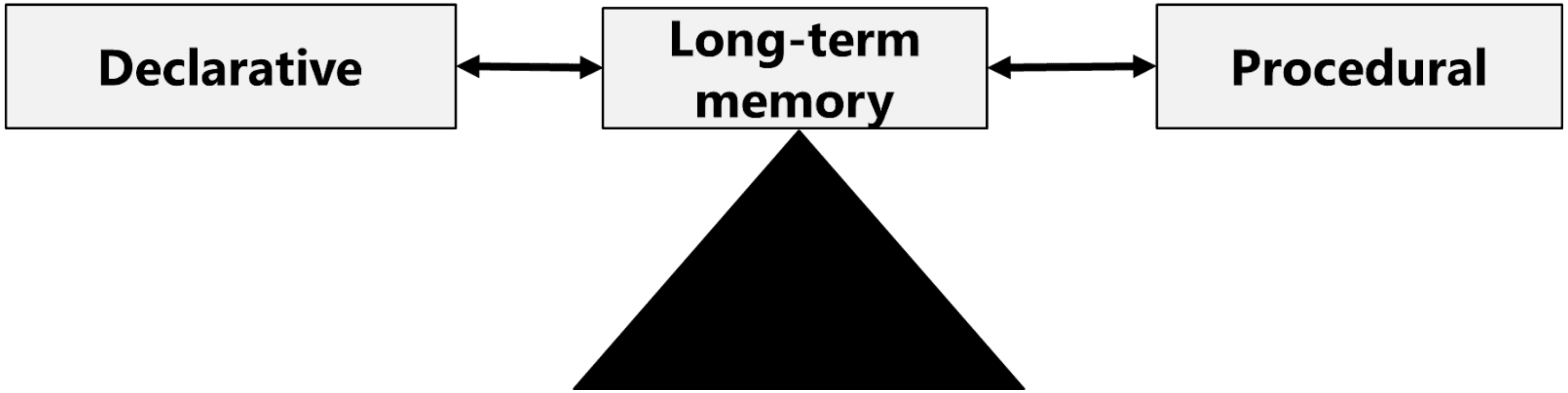
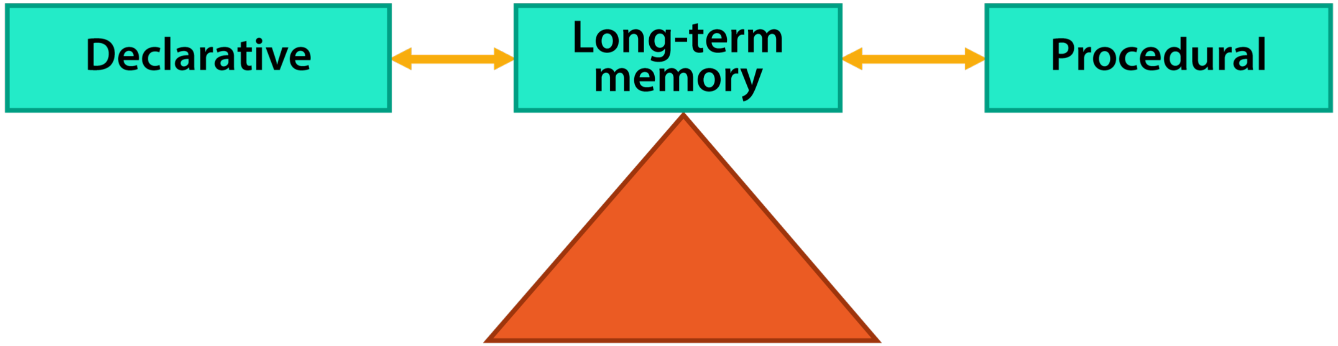


Figure 27: You can think of declarative and procedural learning as being like a see-saw. When one system is being used to learn, the other system is on standby. But ultimately, information learned with both systems forms the most powerful, flexible learning.

Figure 27



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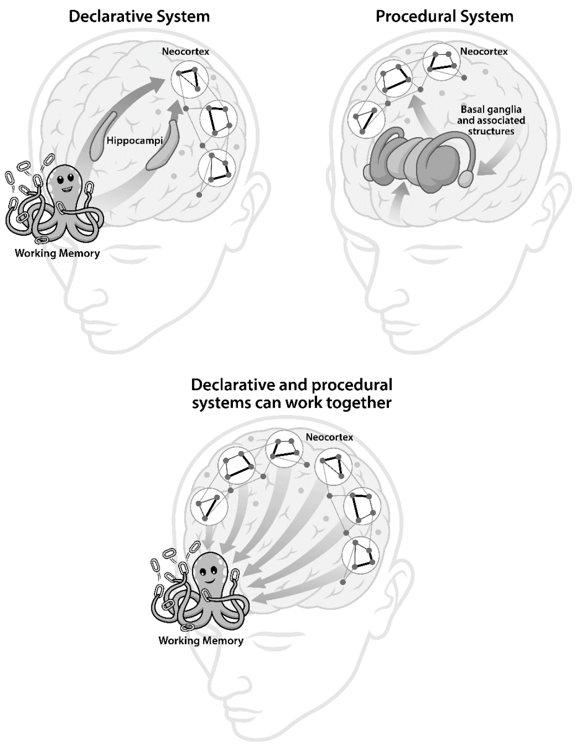
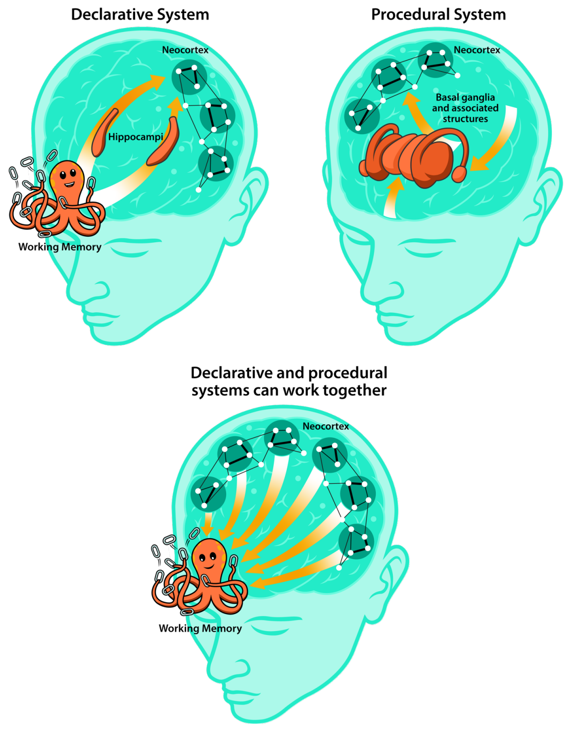


Figure 28:
Top left: The *declarative system* goes primarily from your working memory through your hippocampus into long-term memory in the neocortex.
Top right: The *procedural system* of the basal ganglia takes input from the entire cortex, including the "sensory input areas" (the habitual part of the procedural system that begins with, for example, your visual or auditory systems toward the back of the brain) and the prefrontal cortex (the goal-directed part of the procedural system), through the basal ganglia and associated structures, to finally create a set of links in long-term memory. Working memory can access links deposited by the procedural system.
Bottom: Working memory can grab well-established sets of links that have been created by either the declarative or procedural systems.

Figure 28



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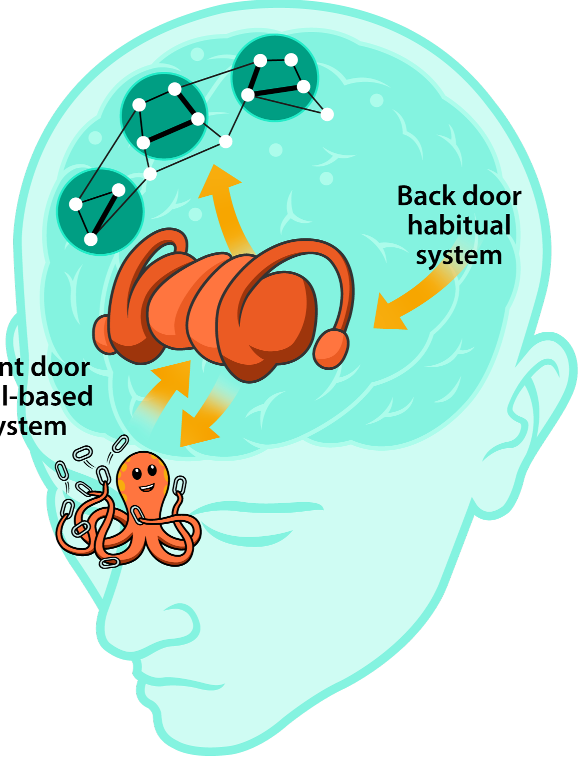

Figure 29: The procedural memory system has a front door, which is for goal-directed activities, and a back door, for habitual actions.

Figure 29

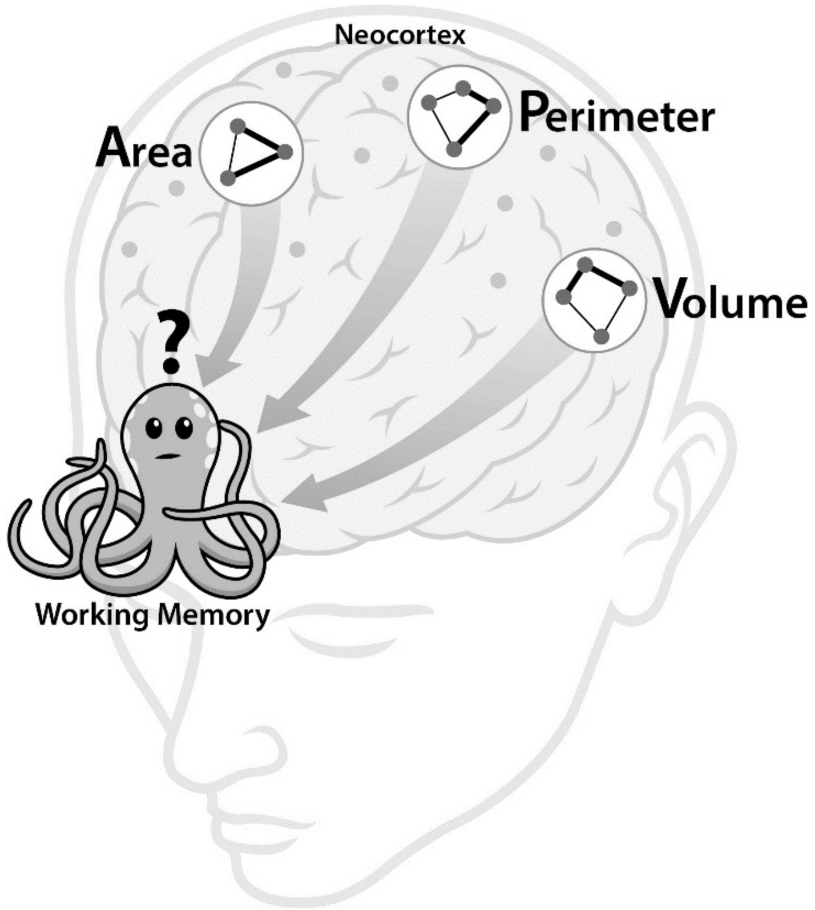

Figure 29: Recall that each round "dot" represents a neuron. Calculating **A**rea, **P**erimeter, or **V**olume each involves different sets of neural links. Interleaving helps students recognize the subtle differences between these sets of links, so they know which set of neural links to call into play for a particular problem. Interleaved practice would look more like APVPAPVAVPA.

Figure 29

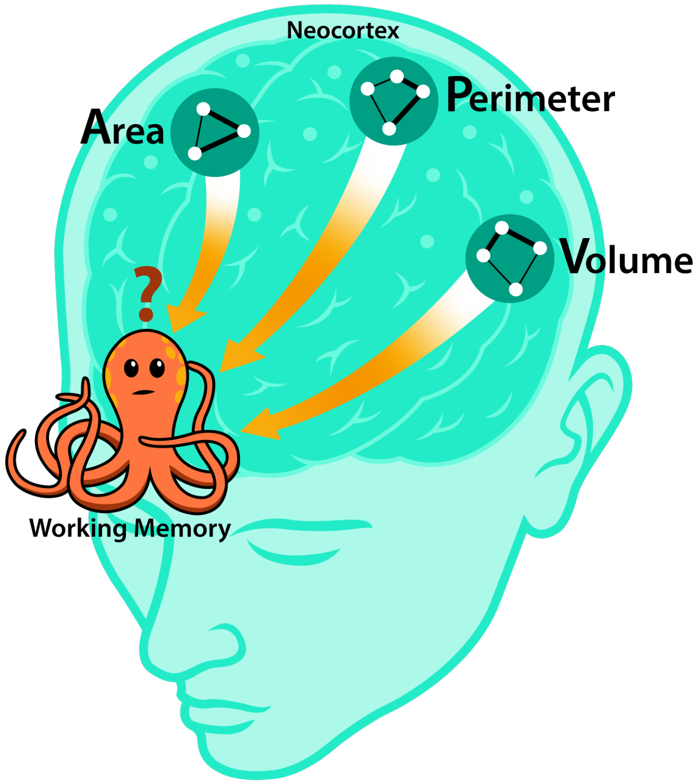

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Figure 30

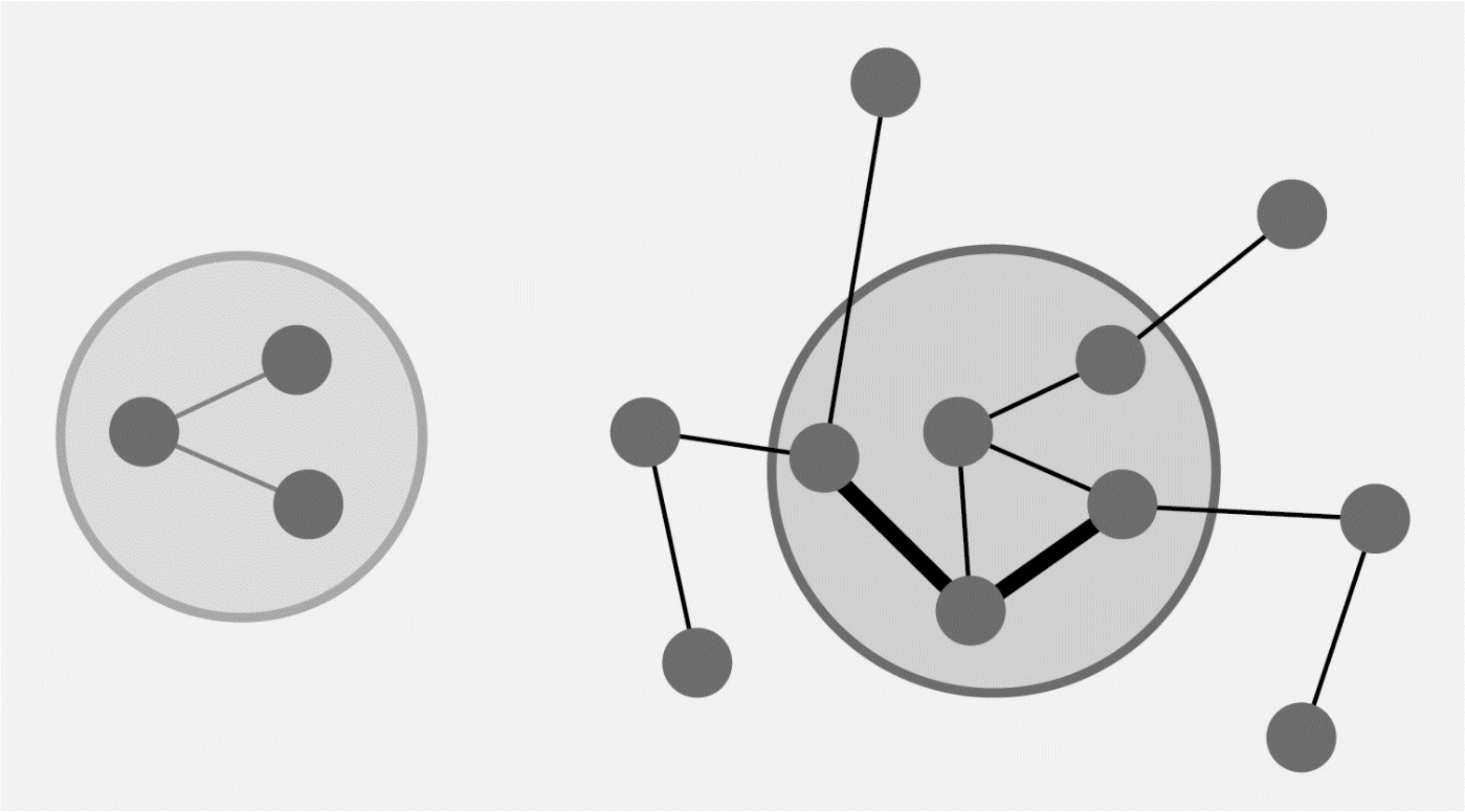

Figure 30: The term “desirable difficulties” means the mental effort of building a strong set of neural links to understand and remember a concept. Building a strong set of neural links can be hard work compared to just scanning the information! For example, if a student is trying to learn

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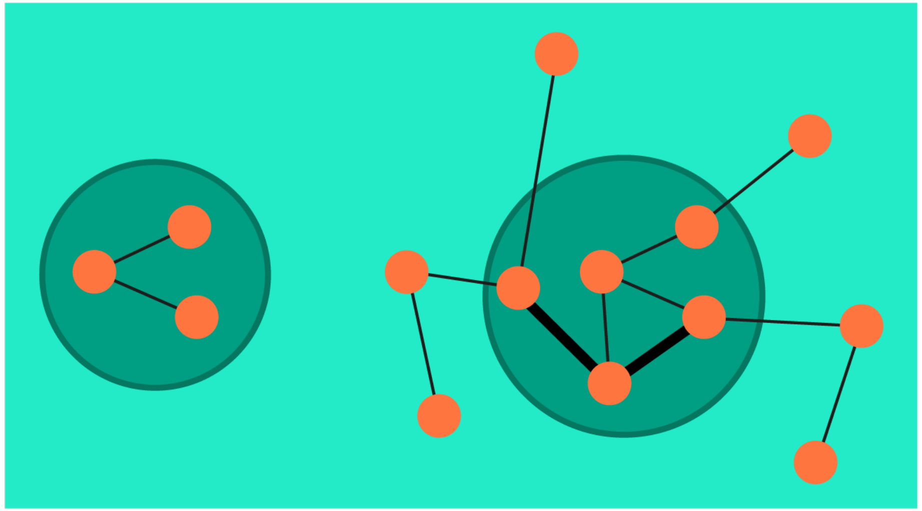

Figure 30: The term "desirable difficulties" means the mental effort of building a strong set of neural links to understand and remember a concept. Building a strong set of neural links can be hard work compared to just scanning the information! For example, if a student is trying to learn the character 人 (rén), which means *person* in Chinese, she might take a few seconds to glance at the character. At best, this creates a weak set of connections, as shown at the left. These weak connections can disappear by the time she next tries to retrieve the word and character.

But if she takes the time to imagine that 人 is a person with two legs, "running" (*rén*), and she even moves her fingers (or her own legs), then she's encoded the new word more strongly into what she already knows. This greater "conceptual elaboration," which takes time and effort, is more likely to create a strong set of links that will stick. You can think of it as a building a larger spider web that catches more flies. Of course, desirable difficulties apply as well to far more complex concepts. Successful students frequently develop their own desirably difficult approaches to study.

Incidentally, making meaningful gestures while learning a new foreign word seems to be particularly helpful for students in allowing them to remember that word and lock in its meaning. For example, while trying to remember the word for *high* in a foreign language, the teacher (and the students) can raise their right hands up high while saying the word. To remember the word *bond*, the students can "join" fingers of each hand so they just touch. New written or spoken words in a foreign language activate little neural activity in a foreign language learner. Pictures accompanying those new words activate more neural activity.

Figure 31

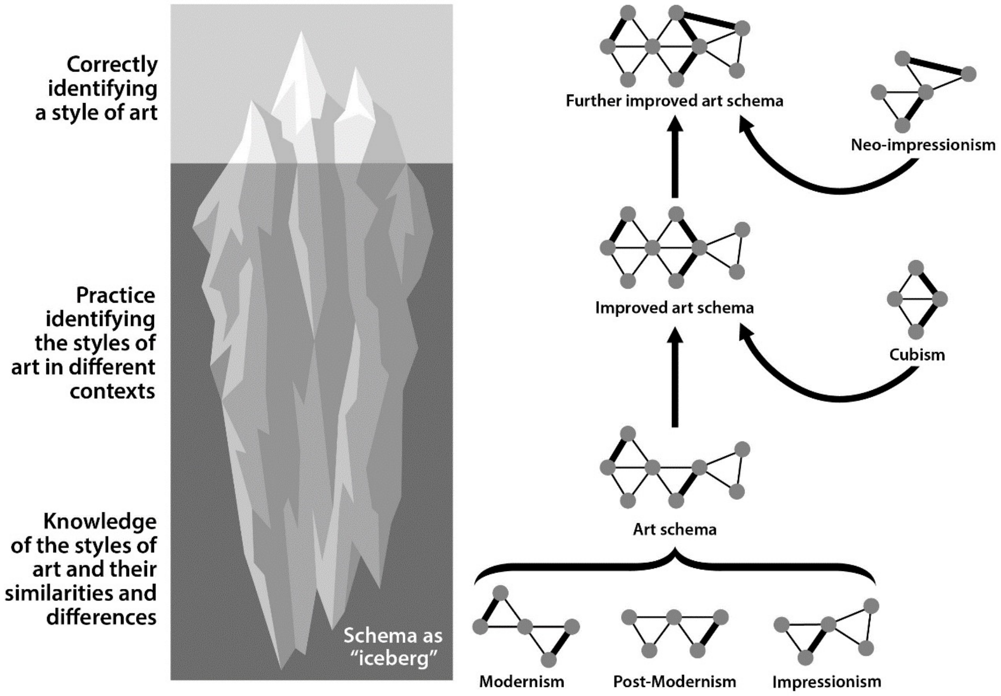

Figure 31: Students gradually develop schemas regarding what they are learning. In this example, a student is gradually improving her "art styles" schema. You can think of the individual sets of links, for example, involving modernism, post-modernism, and impressionism in the bottom row, as mini-schemas that arise as students practice with the concepts (interleaving between the different styles helps speed the practice and development of the mini-schemas). Learning these three styles helps students to develop a simple art schema. This simple schema allows the student to move on to learn about the key concepts of cubism slightly more easily. In other words, the student has a neural structure that allows cubism to tuck more readily in beside the other, previously learned mini-schemas. Likewise, having the pre-existing schema allows the student to tuck the new style of neo-impressionism into place. Each new style slides into place slightly more easily as a schema gets bigger and stronger with more practice and learning.

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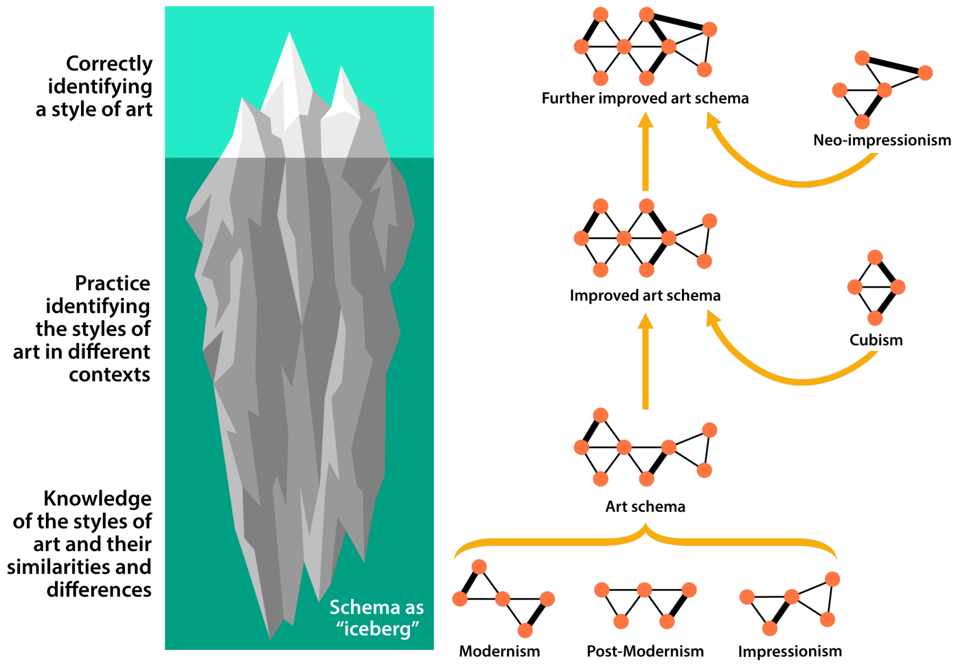

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Figure 32

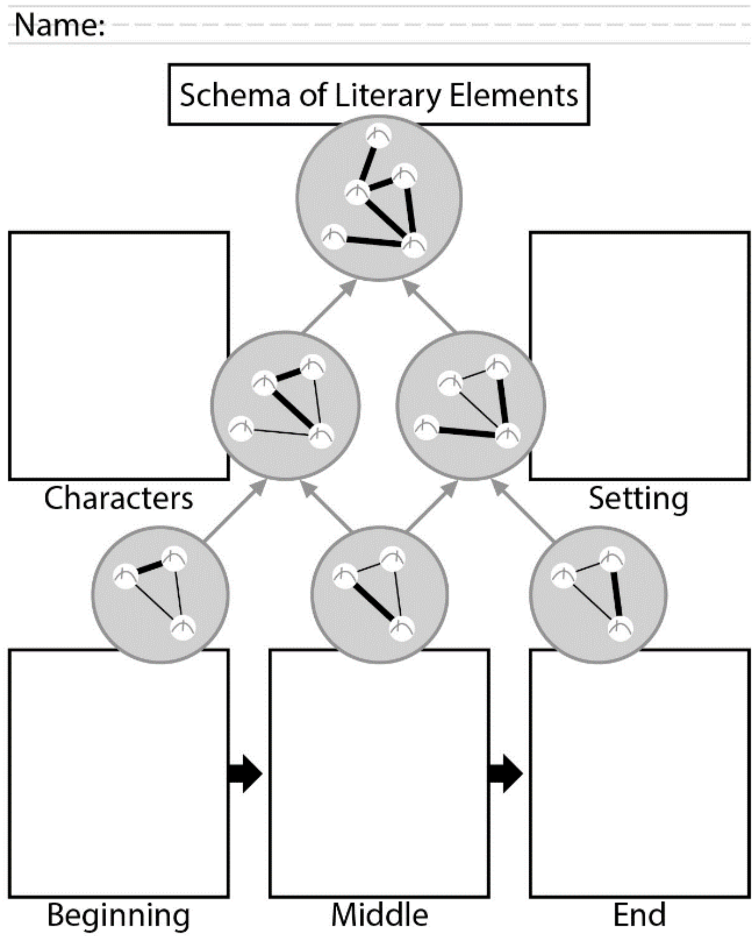
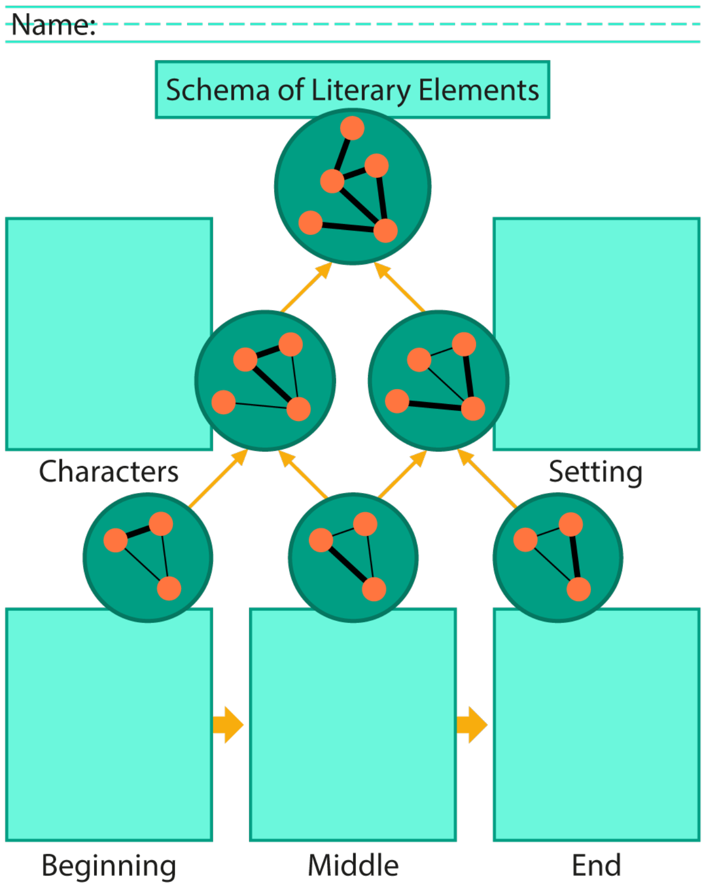


Figure 32: Graphic organizers, where the key characteristics of a schema are laid out on paper, can help students develop their internal schemas. The story map above helps students identify and visualize the key literary elements of a short story. This graphic organizer helps students to build their internal schemas as they practice with many stories.

Figure 32



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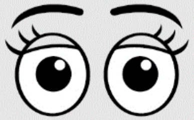
Chapter 7
Building Community through Habits

NICE

	
Participating in activities	Speaking clearly and with appropriate volume and tone
Sitting upright	Answering questions when asked
Providing eye contact to the speaker	Listening quietly to the speaker
Cleaning up after yourself	Saying "Please" and "Thank you"
Raising your hand to speak	
Having materials on your desk	

NASTY

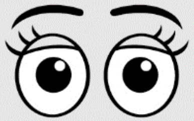
	
Having side conversations	Interrupting others
Leaving someone out	Calling someone names
Using a device, app, or tool without permission	Complaining
Leaving materials in your locker	Making snide comments

Figure 33

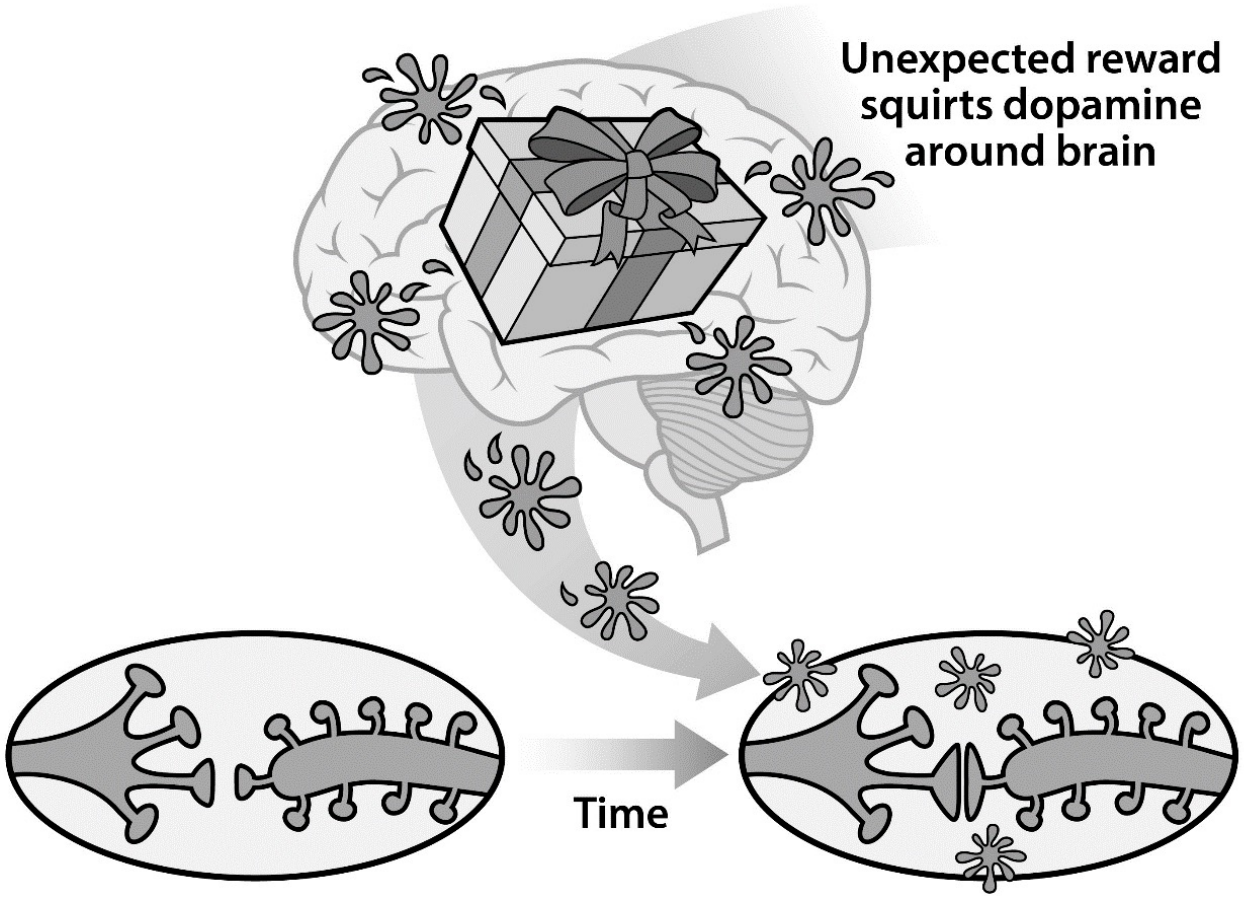
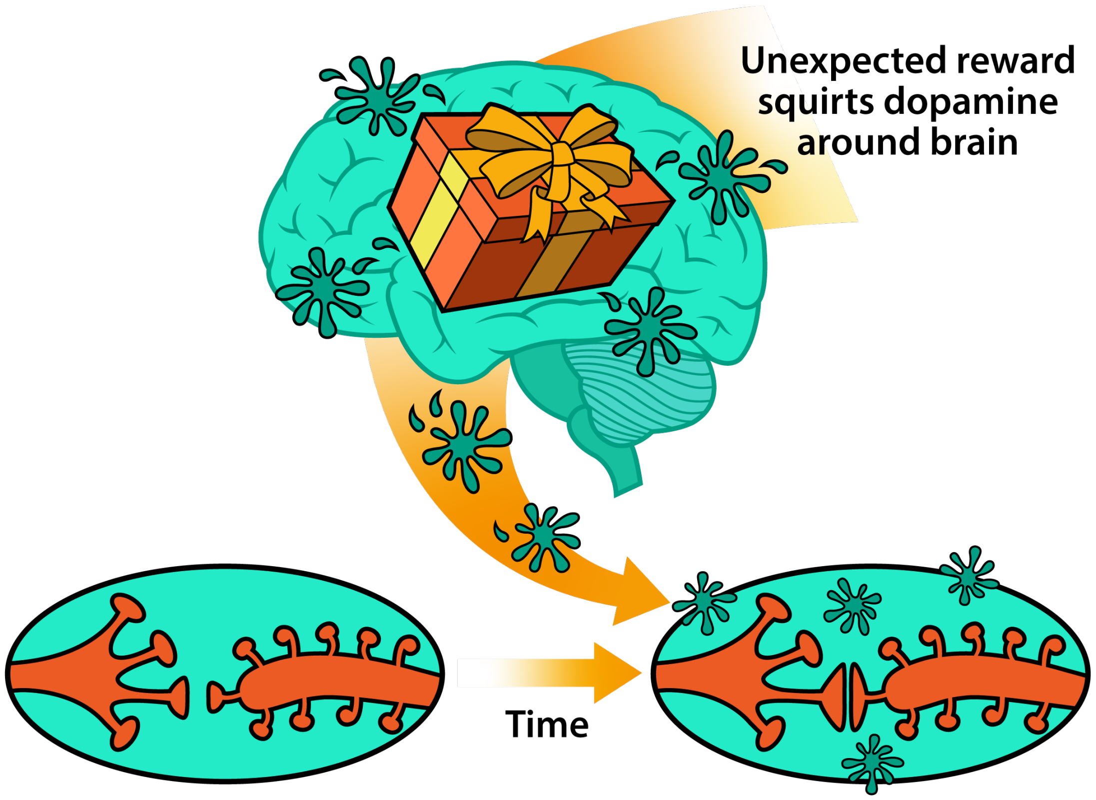


Figure 33: When an unexpected reward arrives, it triggers sprays of dopamine in areas of the brain where the new links of learning are being formed across the synapses (the gaps between the neurons). This dopamine assists in strengthening the links that were developing before, during, and after the unexpected reward.

Figure 33



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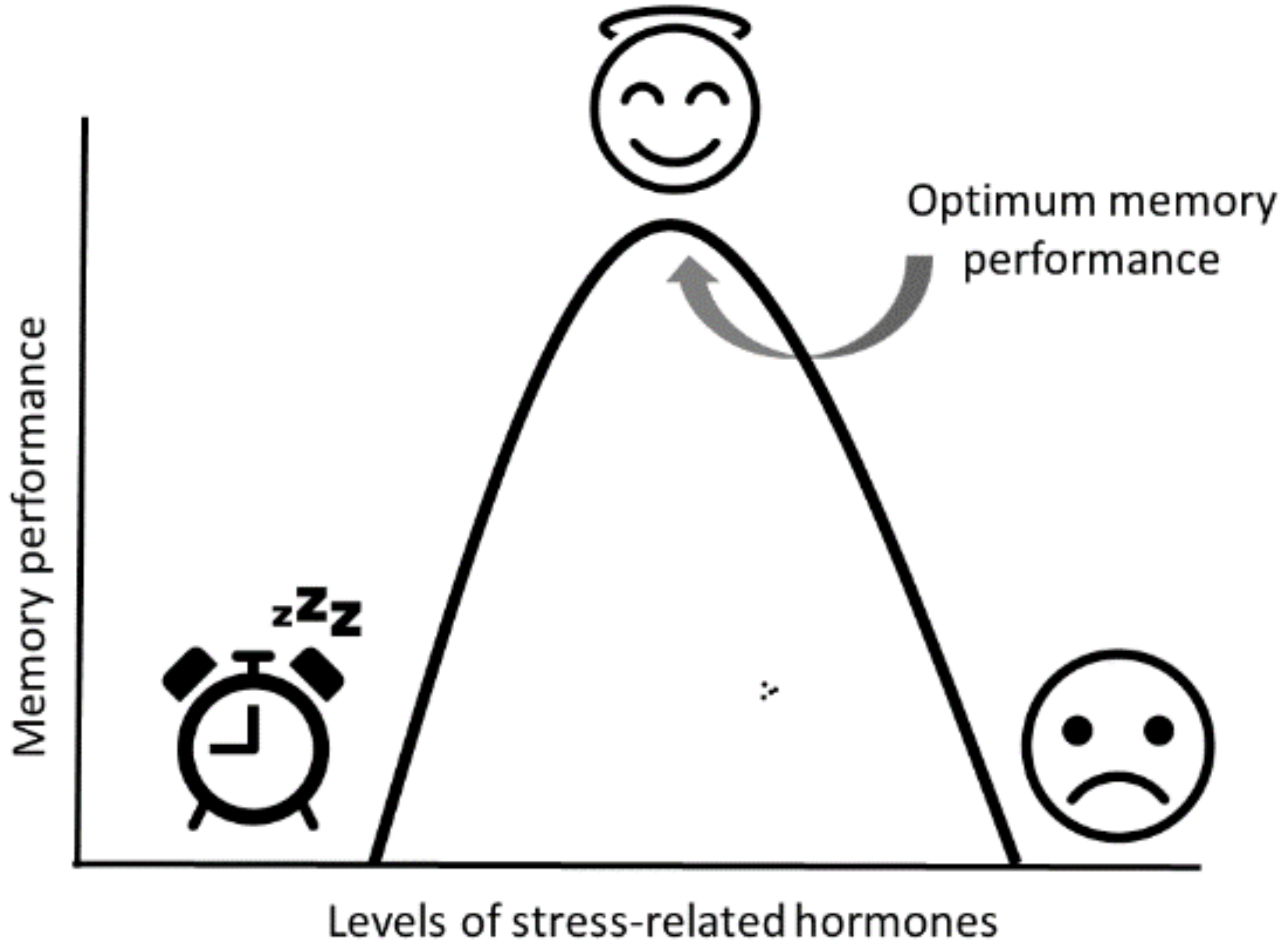
Chapter 8
Linking Learners—The Power of Collaborative Learning


Optimum memory performance
Memory performance
Levels of stress-related hormones

Chapter 9
Online Teaching with Personality and Flair

Figure 36

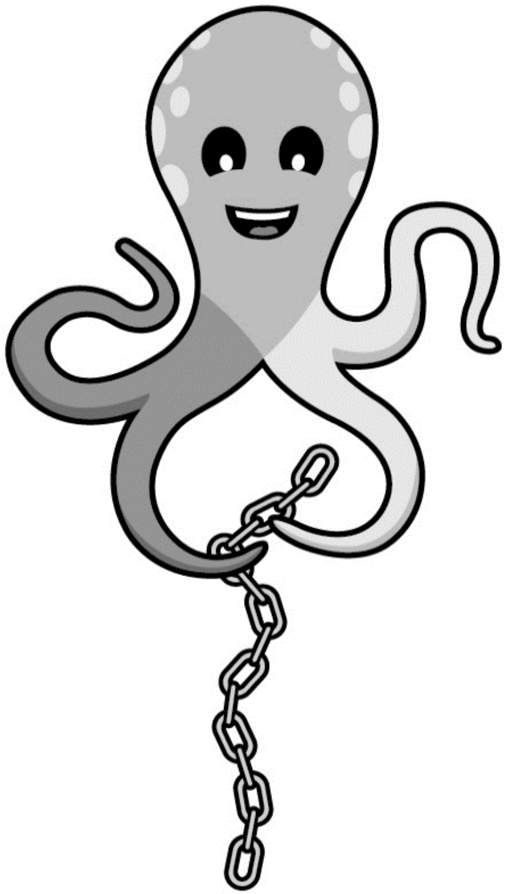
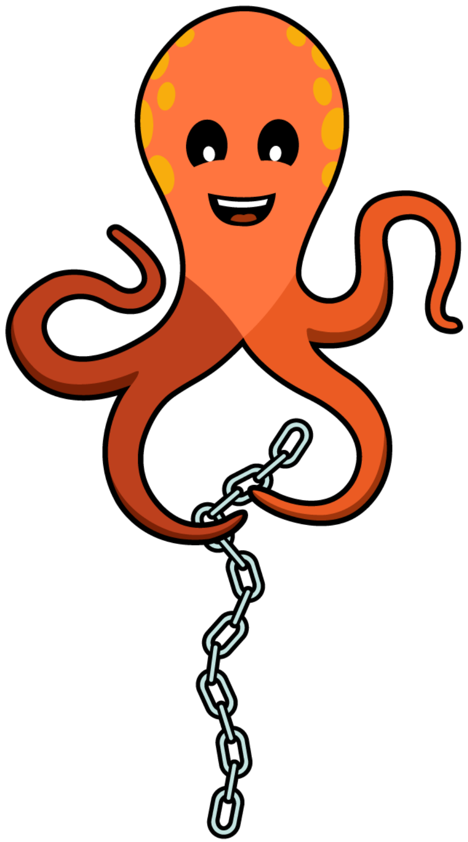


Figure 36: Working memory has both a hearing and a seeing component (symbolized here by the different shades of the arms of the “attentional octopus” you met in previous chapters). If you teach so that students simultaneously *hear* and *see* what you are explaining, it’s much easier for students to engage with the ideas (sets of neural links).

Figure 36



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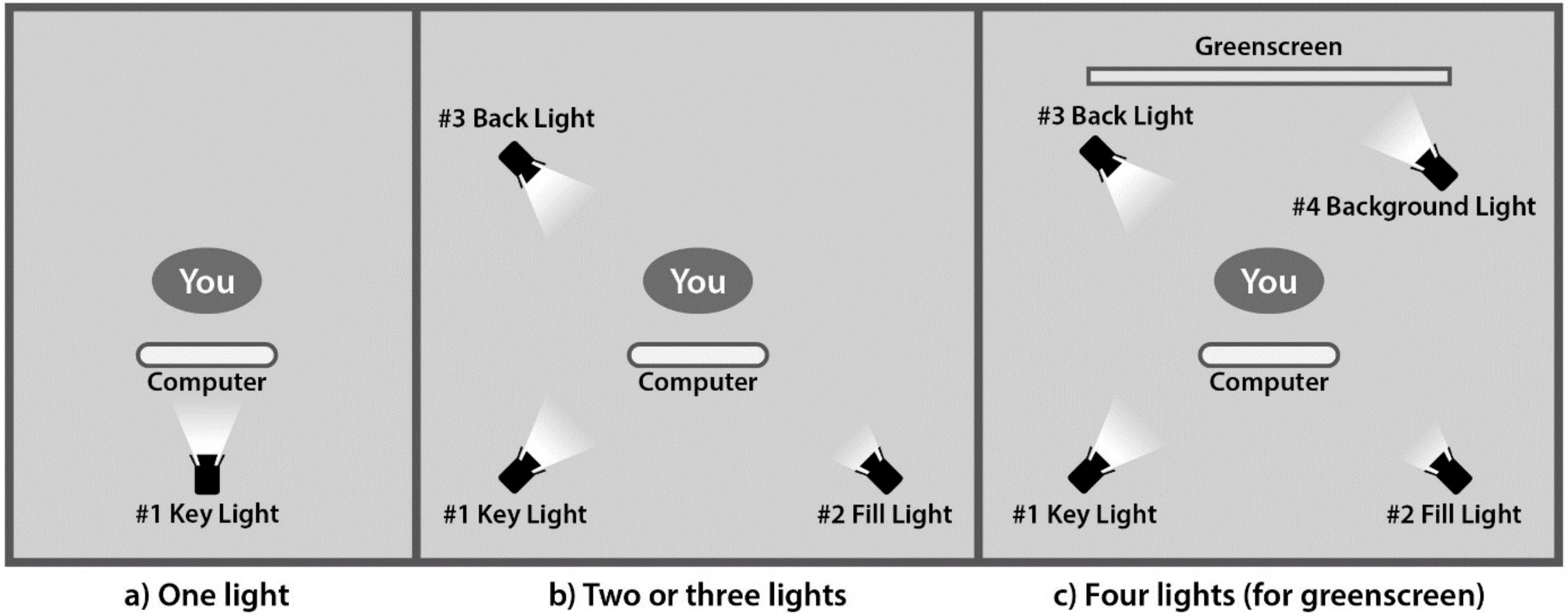

Figure 37: A typical home video recording set up. You can use from one light to four lights. (Four lights are preferable for green screen, which makes it easy to substitute in another background.)

Figure 37

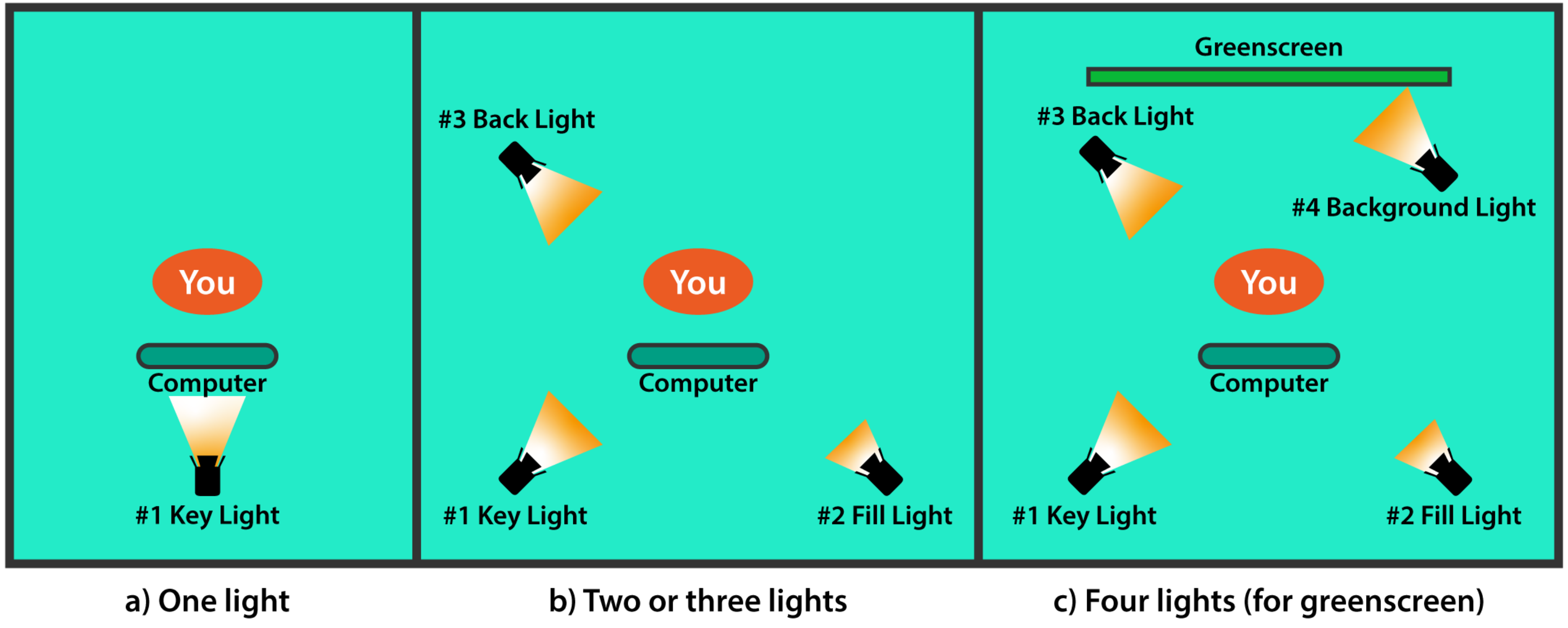

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Figure 56a Beth's face is too close to the camera, so her hands are cut off—removing a valuable teaching tool. Notice the glare on her glasses, which is invisible to her, but obvious to her viewers. She's also slightly underexposed—her face is a little shadowy.

Beth's virtual background is a photo of her campus. Although the photograph is cluttered, the familiar building and mascot helps her students feel at home even while they are in the virtual world.

- **Figure 56b** Barb models the common mistake of slumping down in her chair while centering her face in the frame (aka, “the prairie dog effect’). This inadvertently cuts off her hands. She’s also overexposed—there is too much light hitting her face.

- **Figure 56b** Barb models the common mistake of slumping down in her chair while centering her face in the frame (aka, "the prairie dog effect'). This inadvertently cuts off her hands. She's also overexposed—there is too much light hitting her face.

- **Figure 56c** Here, Terry's head is perfectly positioned in the upper part of the frame. (High up, but without the "Frankenstein effect" of cutting off the top of the head.) There is plenty of room in the lower part of the image frame for his hands.

Figure 41

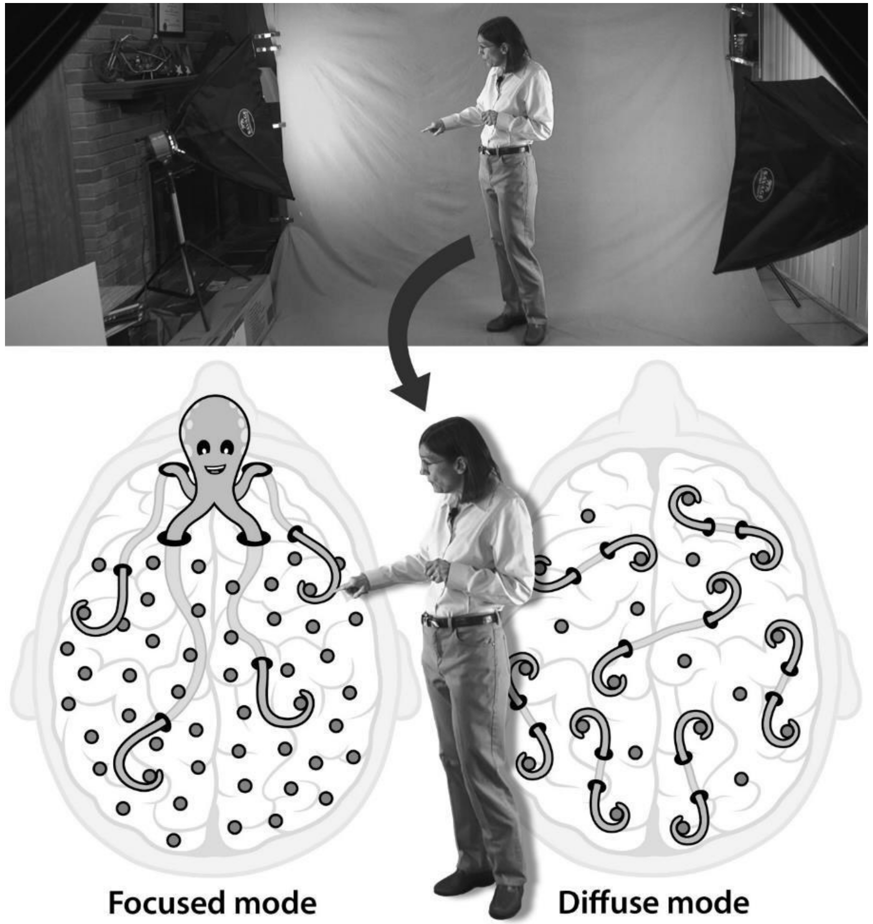


Figure 41: If you want to get extra fancy, you can film yourself in front of a plain background (traditionally, it's called a "green screen") and then use editing tricks to insert yourself into your video. Modern video wizardry mean that you can do this even while sitting in an ordinary background in your office. This image shows Barb filming the massive open online course *Learning How to Learn* in her basement. The advantage of this approach is that you are integrated into what you are trying to point out, which reduces the load on your students' working memory.

Figure 41

Figure 39: Occasional use of humor, as with memes like this one, gifs, or snippets from movies or television shows, can help spice up your teaching. Just check the rules for your country and institution.

Figure 40

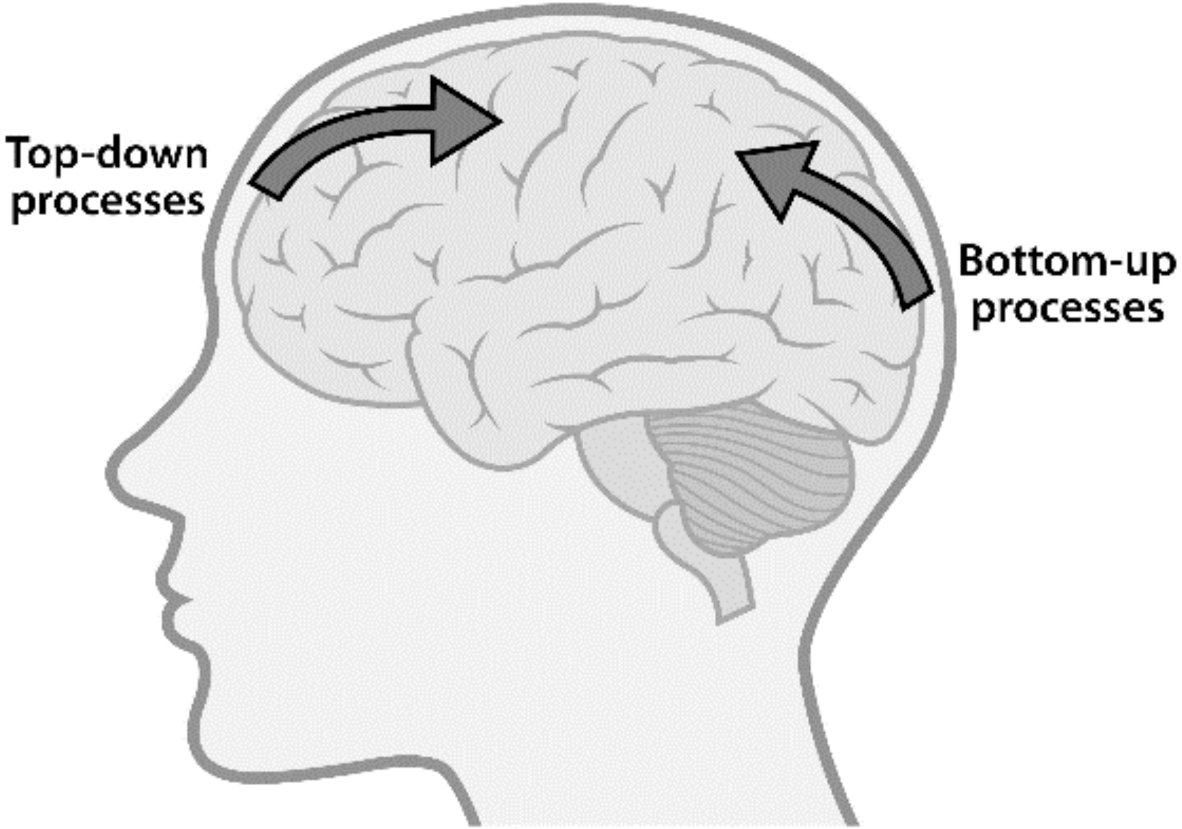
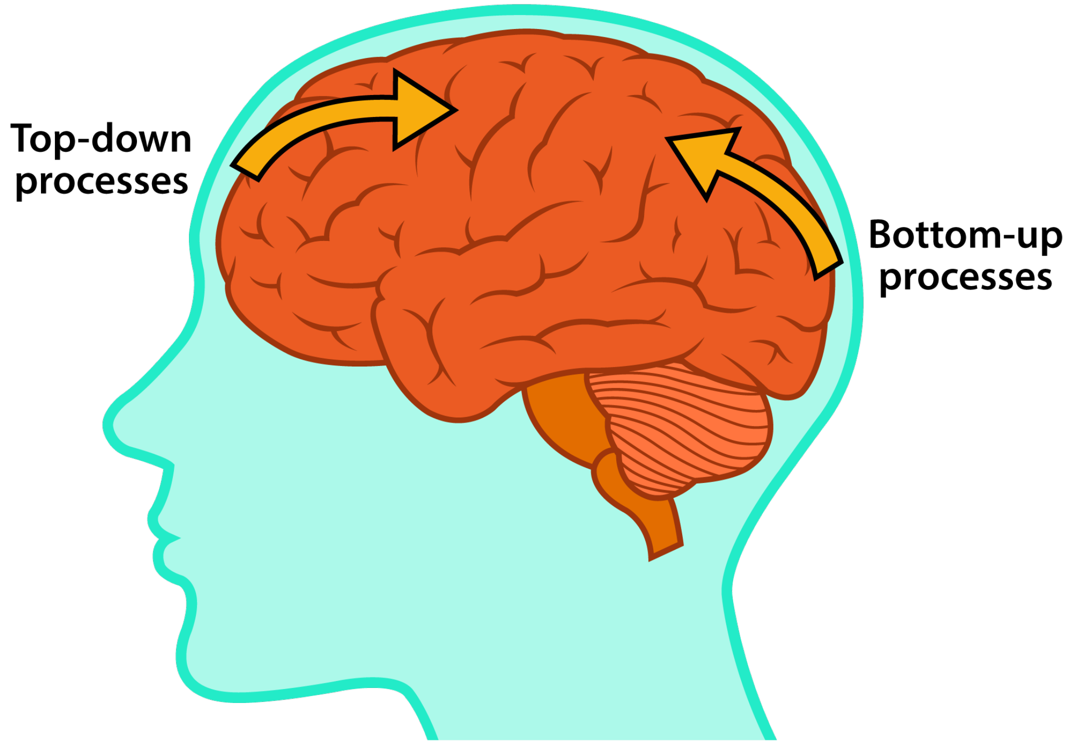


Figure 40: Top-down (left arrow) versus bottom-up (right arrow) attentional processes control the direction of a student's' focus.

Figure 40



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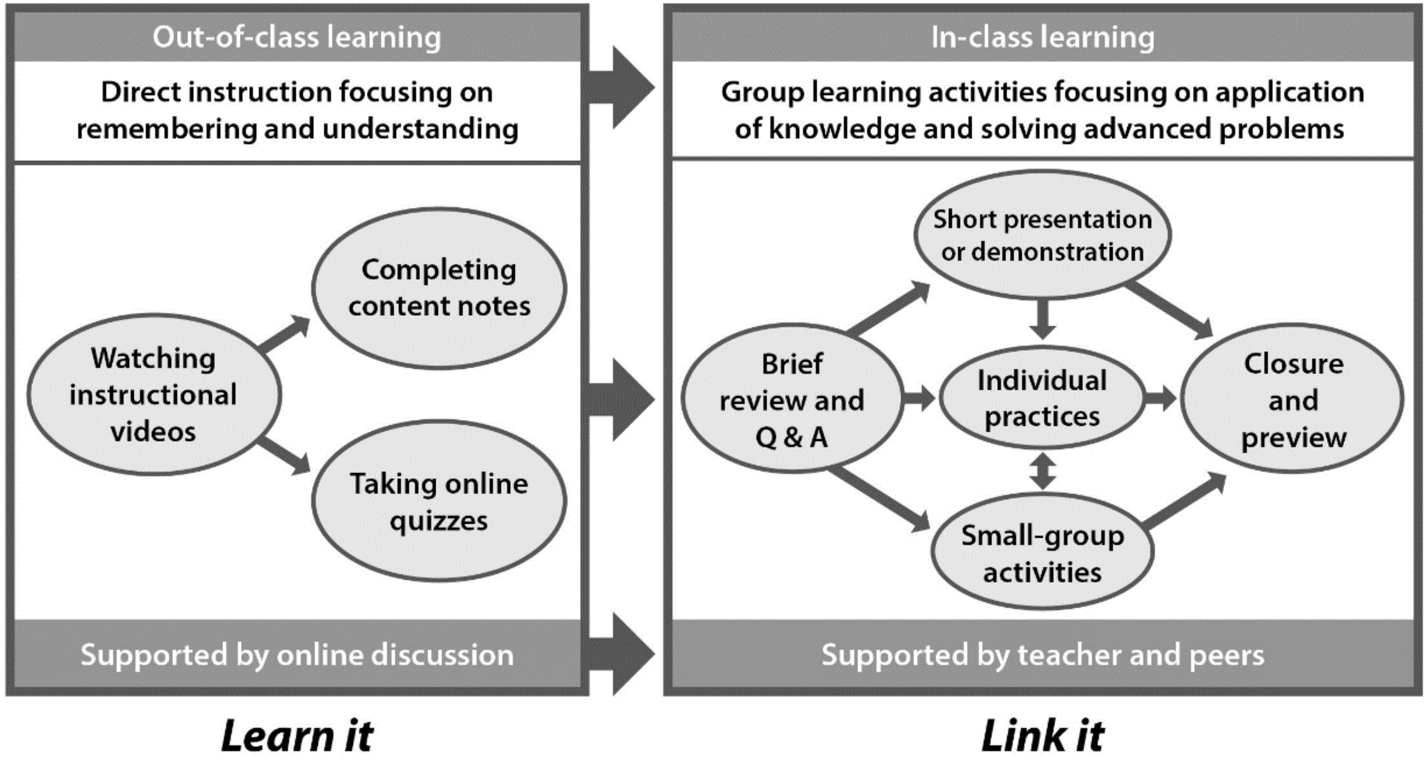

Figure 42: Integrating asynchronous with synchronous or face-to-face teaching—a "*learn it, link it*" approach.

Figure 42

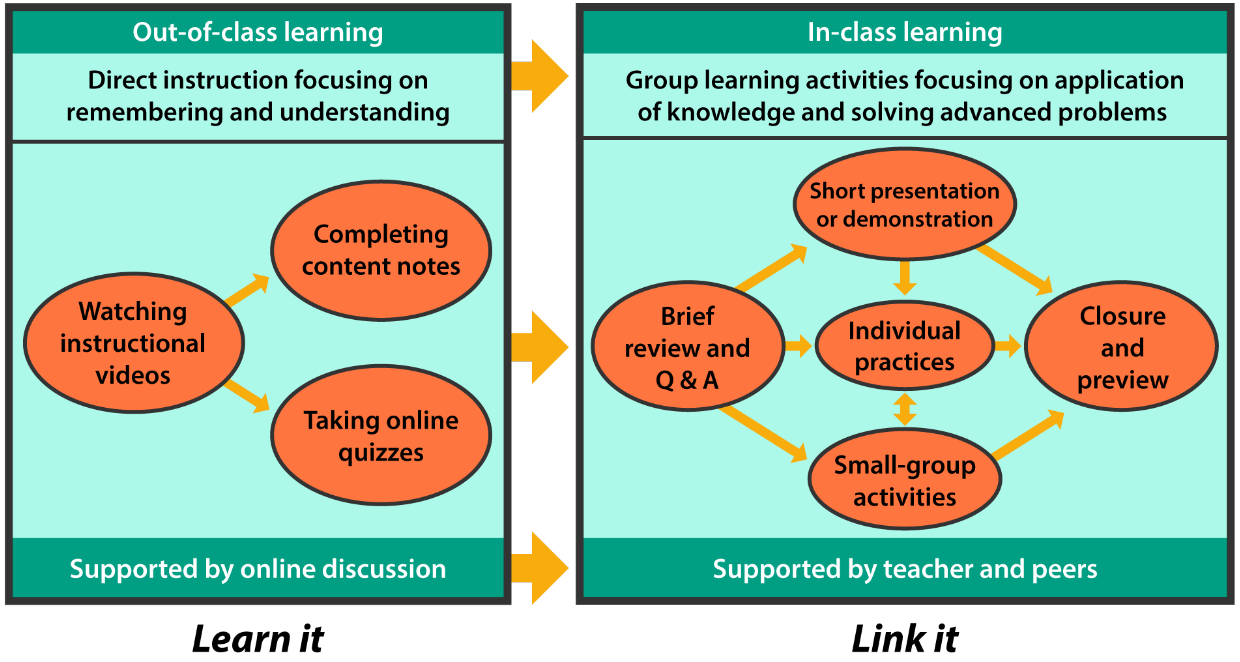

Figure 42: Integrating asynchronous with synchronous or face-to-face teaching—a "*learn it, link it*" approach.

Chapter 10
Charting Your Course to the Finish Line—The Power of Lesson Plans

Figure 44

Figure 44: The objective is the top of the mountain, but there are several ways to get there: Declarative or procedural; hiking or racing.

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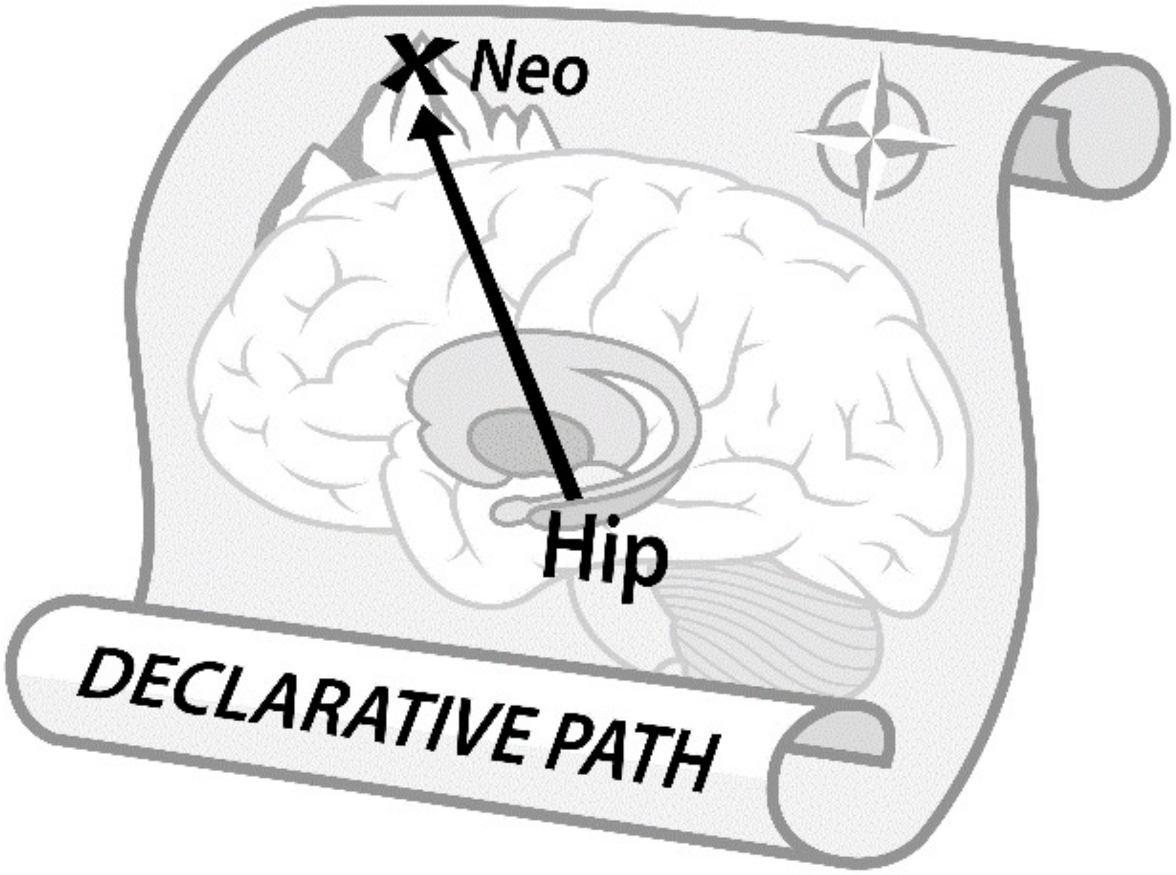

Figure 45: The declarative path climbs to the top of the mountain (long-term memory in the neocortex) via the hippocampus.

Figure 45

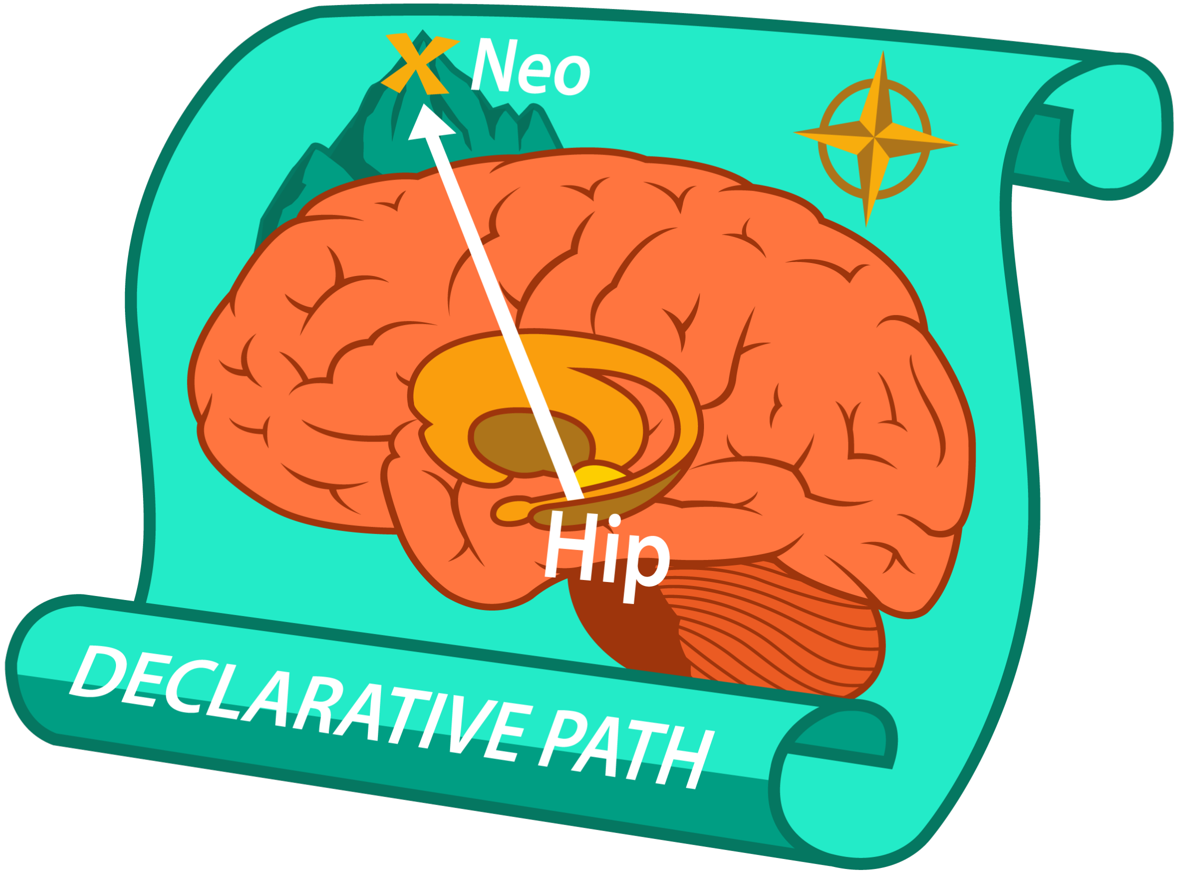

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Figure 46

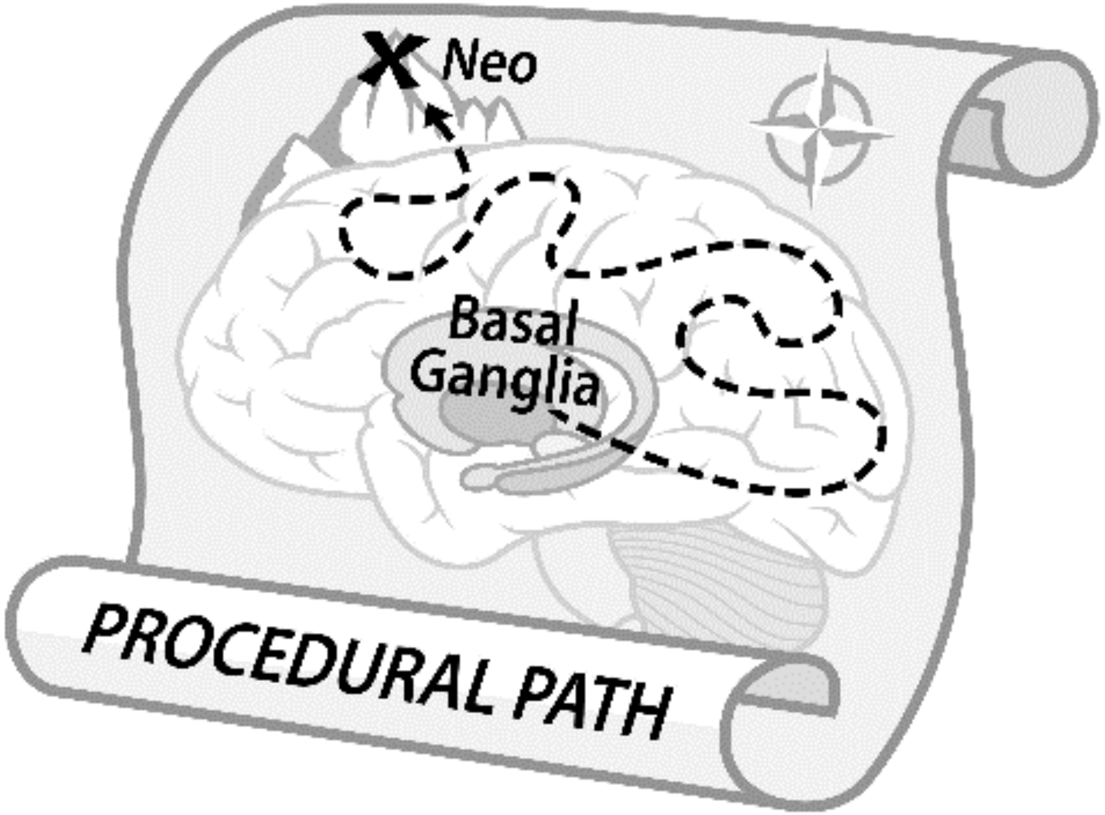
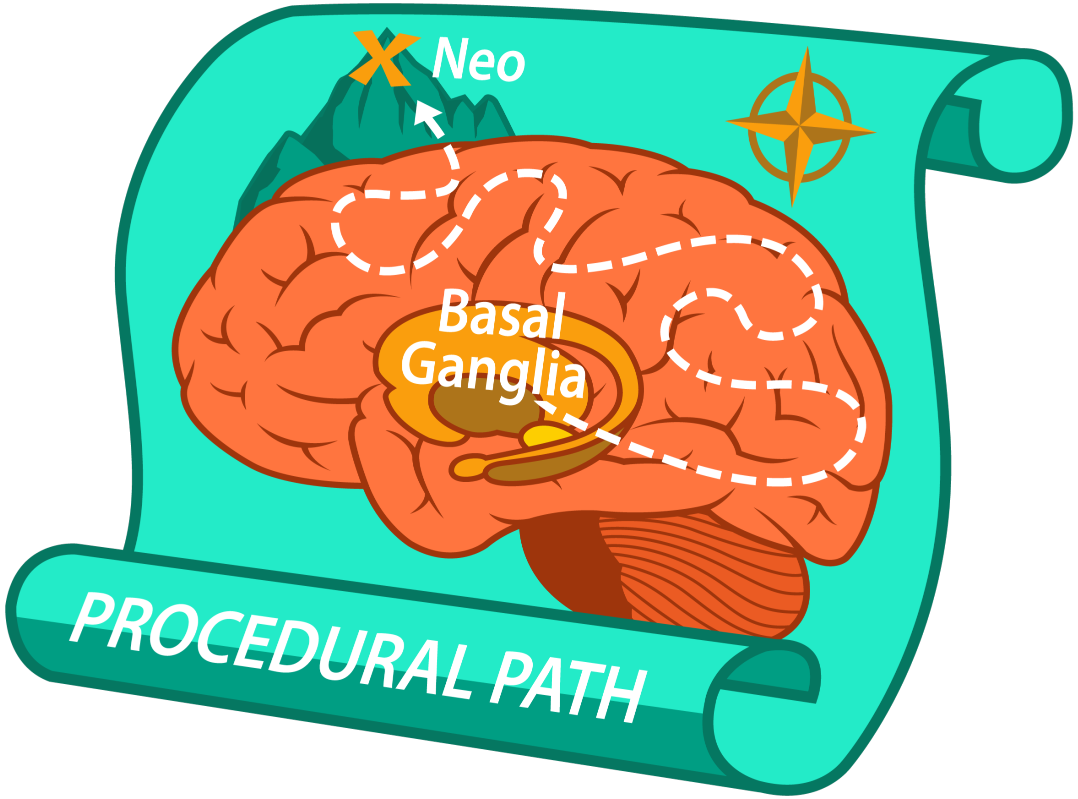


Figure 46: The procedural pathway climbs to the top of the mountain (long-term memory in the neocortex) through the basal ganglia.

Figure 46



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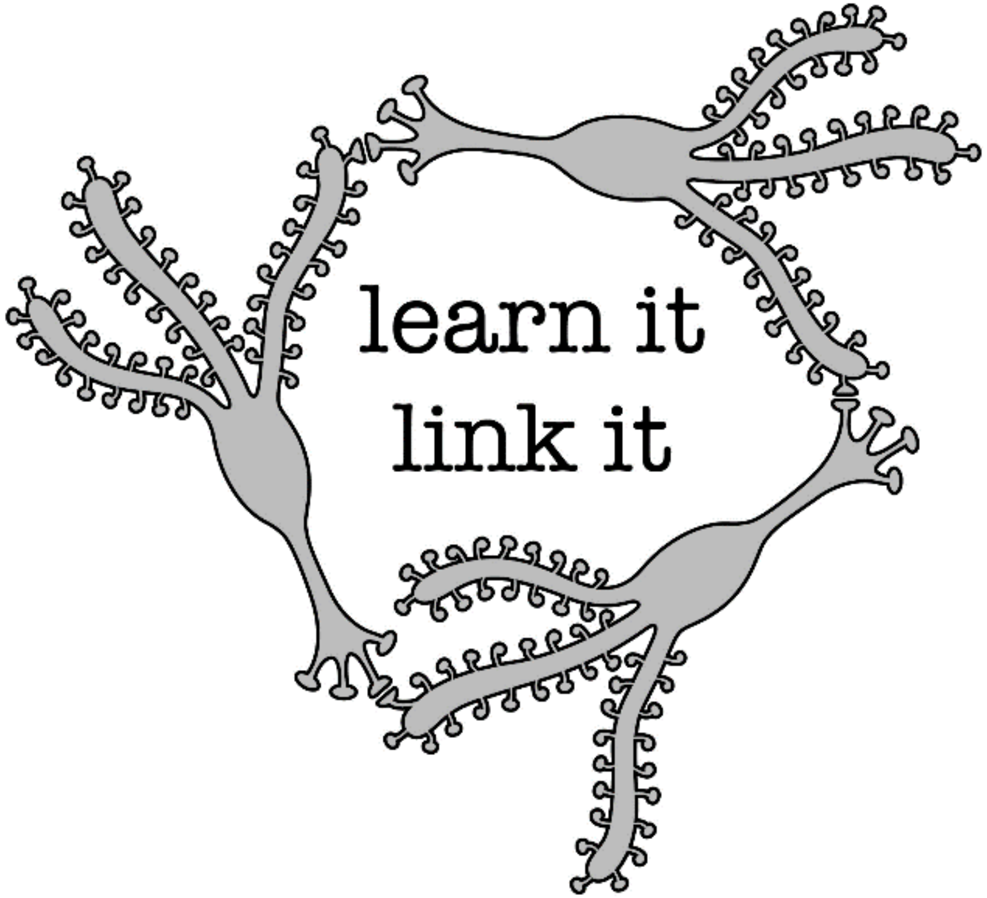
Farewell and Hello!



Appendix A: How to Manage Yourself on a Collaborative Team

Appendix B: Master Teacher Checklist