MARGE
A Whole-Brain Learning Approach for Students and Teachers

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Preface

MARGE: A Whole-Brain Learning Approach for Students and Teachers began as a conference presentation sponsored by the *Learning and the Brain Foundation*. It then evolved into a series of *Psychology Today* blogs entitled: *Lifelong Learning and Active Brains*. Here, I've compiled the information and geared it specifically for students and teachers.

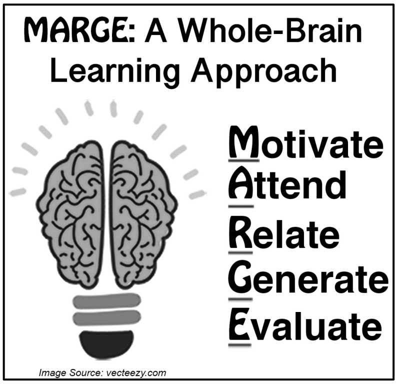
MARGE is an acronym for five principles of efficient learning—**MOTIVATE**, **ATTEND**, **RELATE**, **GENERATE**, and **EVALUATE**. Each principle embodies it own neural circuitry and psychological properties. Most importantly, for each principle I've collected tips and mnemonic techniques that can be used to improve student learning.

As a scientist, I've spent an enjoyable career studying human memory. I began investigating patients with amnesia and later—when the technology became available—I used functional magnetic resonance imaging (fMRI), which allowed me to see the brain in action. As a university professor, I taught memory courses and tried to present research findings in such way that the information could be applied toward everyday situations. **MARGE** is a compilation of these endeavors.

It is my aim that after reading this book you'll come to appreciate how the brain learns and remembers and how basic research can be used to develop learning skills. The text is brief and summarizes an extensive body of biological and psychological science (references and resources are provided for further information). Learning is a *whole-brain* issue—it'll keep you active, should be fun, and best when shared with others!

Chapter 1: Meet MARGE

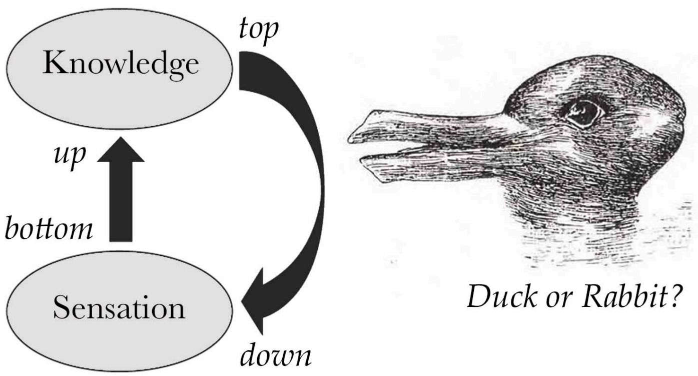
With the luxury of smartphones, binge TV watching, and internet shopping it has become exceedingly easy to live in comfortable laziness. Yet we all realize that both physical and mental activity are essential for healthy brains. We've all heard the saying, *use it or lose it*, but we are rarely given advice on how to use it.[1] Here, I present **MARGE**, a whole-brain approach to learning that applies both biological and psychological science in the service of making student learning more efficient.



MARGE is your mnemonic to help you remember the five principles of efficient learning: **MOTIVATE**, **ATTEND**, **RELATE**, **GENERATE**, and **EVALUATE** (I associate the acronym with Marge Simpson, the caring, gravel-voiced matriarch of *The Simpsons*).

What is learning? An apt question as there are many interpretations and misconceptions about this term. Broadly speaking, learning is our ability to acquire knowledge from sensory experiences. Learning can come in a variety of forms, from perceptual learning (the way a radiologist learns how to read an x-ray scan) to conceptual learning (the way a historian or scientist links new facts and ideas to existing knowledge) to skill learning (the way a musician learns a new piece). Though much of what will be discussed pertains to all forms of learning, I will focus on **conceptual learning** or what is often called *academic* or *student learning*.

A huge obstacle toward efficient learning is failing to **motivate** ourselves to action. In my career as a university professor, one of the most difficult aspects of teaching was keeping students engaged and curious about the subject matter. There is a common misconception about academic learning that I call the *sponge metaphor* of education, which is reinforced by our familiar college lecture format in which the teacher's role is to pour out worthy facts while the student sits and "soaks" up the material. In psychological terms, this kind of learning is strictly a *bottom-up process* (*bottom* refers to sensations, and *top* refers to knowledge), which is highly inefficient and typically leads to failed attempts at rote memorizing a bunch of disparate facts.



Source: Arthur Shimamura/Public Domain

Efficient learning depends on **top-down processing**, which is the active use of existing knowledge to guide and select what sensory information to process. At any given moment we are bombarded by a multitude of sensations and must therefore **attend** to relevant facts and information. Even basic perceptual analyses, such as recognizing the duck or rabbit in the ambiguous figure shown above, depends on using top-down processing to select "duck-relevant" features (e.g., focusing on the duck's "bill") or "rabbit-relevant" features (e.g., focusing on the rabbit's "ears"). Which animal you "see" depends on the way you use your knowledge to guide and select sensory information. *Top-down guidance and selection is the key to focused attention, learning, and retention.*

One way to characterize the conceptual knowledge stored in your brain is to think of it as a vast web of connected information—your personal *Wikipedia*. Just like the web's informational resource, we build knowledge by linking new information to existing knowledge. Exactly how we **relate** new information to our knowledge base is critical for efficient learning and retention. A well-organized memory system is built around an organized framework, which includes links to related information. Psychologists refer to these knowledge structures as **schemas**. For effective conceptual learning, we must work to categorize and organize new information to determine how new facts and concepts fit into existing schemas. *The links that we create between new information and existing knowledge are as important as the new information itself.*

A classic memory study [2] demonstrates the importance of relating information during learning. Individuals were given 52 cards with a random word printed on each and asked to sort the cards into two to seven piles in any way they liked. By working on this task, individuals related the words according to their own categorization system, such as putting *horse* and *tiger* into a pile devoted to *living things*. Later, when asked to recall the words, the greater number of categories used the better the words were remembered. *For efficient learning, categorize new information and relate it to your existing knowledge.*

Initial learning involves attention to relevant facts and relating them to our existing knowledge base. Of course, the learning game is not over. We must work to retain this information so that it can be retrieved at a later time. In the past, memory researchers devoted much effort toward understanding the nature of how new information gets initially learned and stored. In recent years, it has become evident that our ability to *retrieve* memories is as important as the initial learning process itself. The *generation effect* is one of the most efficient ways of improving memory retention. When we **generate** information—such as telling someone about what we've heard or learned recently, we substantially improve our memory for that information. Brain imaging findings reveal broad neural circuits activated when we practice retrieving information.[3]

How do we know that we will remember what we've recently learned? Students often have difficulty determining their success (or failure) in how well they've learned new material. During all phases of learning—from initial presentation to the time of retrieval (e.g., exam time), it is important to **evaluate** one's proficiency in learning. Knowing about what we know is a process that psychologists call **metacognition** (*meta* is Greek for "about" or "beyond"). It involves monitoring learning processes, such as asking whether new material was actually understood, and controlling future processes, such as deciding if more study time is required. The generation effect is both a means of reinforcing learning and a way of monitoring whether you have learned the material. If you cannot say in your own words what you've just learned from reading a textbook chapter, then it would be wise to spend more time on the material. *We must evaluate our conceptual learning from time to time in order to maintain a healthy and proficient knowledge base.*

A central theme of this book is that efficient learning and retention depends on coordinated neural activity in a multitude of brain regions. I will try to convey how different regions contribute to human learning and memory. However, *no brain region works in isolation.* My personal manta is: *it's a whole-brain issue, stupid!* To improve conceptual learning, we must consider how brain regions engage a multitude of psychological processes, such as instilling interest in the learner (*motivate*), selecting relevant information (*attend*), integrating new information with existing knowledge (*relate*), retrieving the information (*generate*), and monitoring success in learning (*evaluate*).

Over the past two decades, brain imaging techniques, such as **functional magnetic resonance imaging (fMRI)**, have revolutionized psychological science by giving scientists a window into brain activity as it unfolds in time.[4] I could put you in a MRI scanner—similar to those used in hospitals today—and observe the brain regions that are active as you try to remember a past event, such as a birthday party, or define a term, such as *what is metacognition*? Imaging the living brain, as we can do with fMRI, would have been considered science fiction only a few decades ago. Now we can isolate brain regions and identify active brain circuits while you are learning or remembering.

In this chapter, a framework or *schema* for **MARGE** was introduced by briefly describing each of the five principles. The following chapters cover the biological foundation, psychological processes, and mnemonic techniques associated with each of the five principles for efficient learning—**MOTIVATE**, **ATTEND**, **RELATE**, **GENERATE**, and **EVALUATE**.

Chapter 1: References and Resources[5]

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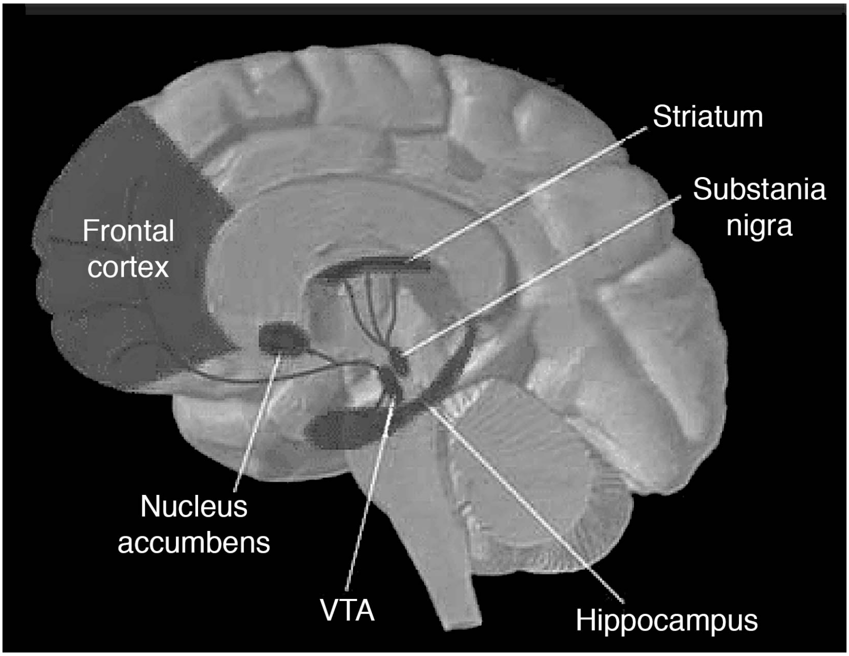
https://www.youtube.com/watch?v=eKcxrB_epTU&t=2970s

Chapter 2: M is for MOTIVATE

Evolutionarily speaking, we are learning machines—geared to sense our environment, register new experiences, and adapt accordingly. In modern times we have co-opted this survival mechanism to enjoy the pleasures of conversation, television, movies, and other forms of entertainment. Unfortunately, our modern pleasures have become much too passive, as we fail to engage ourselves actively with new learning experiences.

How we **motivate** ourselves and others is the first principle of **MARGE** and perhaps the most difficult one to implement. There are times when personal interests make it easy for us to seek new information, such as learning about a favorite topic, activity, or hobby. The trick to motivation is to expand the spectrum of pleasure-seeking experiences and push ourselves into new learning situations. Indeed, just enveloping ourselves in a new setting and breaking away from regular habits—particularly those passive ones in front of a television or computer screen—will fully engage our learning machine. Take a walk around unfamiliar terrain and you will *motivate* yourself to *attend*, *relate*, *generate*, and *evaluate*.

From decades of neuroscience research, we know that pleasurable experiences are driven by a **reward circuit**[1] that includes the *ventral tegmental area (VTA*), *nucleus accumbens*, *substantia nigra*, and *striatum*. This midbrain circuit stimulates the release of *dopamine*, the neurochemical involved in experiencing positive feelings. Highly addictive drugs, such as cocaine and nicotine, stimulate this circuit thus releasing dopamine throughout the brain. In neuroimaging studies, the reward circuit is active when one experiences pleasurable events, such as eating chocolates, listening to music, or looking at attractive faces.[2] Moreover, this circuit is linked directly to the *frontal cortex* and *hippo-*



The *reward circuit* includes the nucleus accumbens, VTA, substantia nigra, and striatum. Source: NIDA.

campus, two brain areas central for efficient learning and memory.

How can we engage the reward circuit in the service of learning? In an elegant neuroimaging study,[3] the influence of **curiosity** on the reward circuit was studied. Individuals were asked to rate how curious they were about various trivia questions (e.g., *What does the term "dinosaur" actually mean?).* Later, when placed in an fMRI scanner, a trivia question appeared and seconds later the answer was provided (e.g., *terrible lizard).* Throughout the reward circuit—specifically the VTA, substantia nigra, and nucleus accumbens—activity was heightened for questions that were rated high in curiosity. Interestingly, this increased activity occurred during the presentation of the question rather than the answer, suggesting that it was the desire to learn about a fact rather than the answer itself that engaged the reward circuit. In a later memory test, individuals remembered answers to questions rated high in curiosity compared to those rated low, a not-too-surprising finding but one that reinforces the importance of curiosity in driving our learning machine.

We live in a culturally rich environment that makes it easy to engage in new learning experiences. Most of us can remember those fun school field trips, which took us out of the classroom and allowed us to explore new environs. We need to encourage that kind of exploration. It is easy with smartphone in hand to walk around town and learn about the history where you live. Museums, historical landmarks, and cultural centers are also wonderful venues for engaging in hands-on learning. Frank Oppenheimer, founder of the *Exploratorium*, the extraordinary science museum in San Francisco, once said, "No one ever flunks a museum."[4] He appreciated the benefits of learning through experience.

Inside the classroom, it is critical at the outset to be engaged and attuned to the topic at hand. Good teachers can spark motivation by offering a personal anecdote, museum-like demonstration, or everyday example of the concepts to be covered. Another way to motivate learning is to frame concepts with **questions that address the big picture**. Curiosity often arrives in the form of a question—I've recently asked myself *"How are magnets made?"* and *"Why do we have two high tides during a 24-hour period?"* It is best to motivate new topics with "big picture" questions—*What is the reward circuit? How do we engage students inside the classroom?* When given thoughtful questions at the beginning of class, students are given a topical framework and should be expected to know answers by the end of class.

During lectures, it is important to be aware of the overarching framework of the concepts at hand. As mentioned earlier, psychologists use the term **schema** to refer to existing knowledge of linked facts and concepts. At the outset, a student's schema of the material may be scant—mere outlines of the concepts at hand. Efficient learning depends on an awareness of whatever basic outline exists. For example, your schema for efficient learning is MARGE, the five principles that form an overarching framework onto which new facts and details can be added. In this chapter, you should be adding facts and concepts to the MOTIVATE section of your MARGE schema. Without a schema, learning is inefficient and comes down to a smattering of facts and concepts without any structure. At the beginning of a lecture or reading a textbook chapter, students need to be aware of what existing schema is available and of how new information is to be added to it. Good teachers (and good textbooks) provide outlines of the topics at hand. Good students will be aware of overarching themes and use this information as a way of linking new concepts to existing knowledge.

A useful means of motivating lectures is **learning through storytelling**. By their very nature stories offer their own schema—they have a beginning, middle, and end—and are typically framed by way of a series of questions and answers *(What will happen next?)*. Think of your favorite movies—good stories introduce interesting characters, predicaments, and quests. They capture our attention and emotions by guiding our thoughts and making us curious about what is to come. There's often a rhythmic pacing or varying of tempo with stops and starts, successes and failures. There may be a hierarchy of small-scale queries woven into the fabric of larger-scale goals. Fables can be construed as tales of learning—*and that's why slow and steady wins the race*. Some of the best examples of learning through storytelling are *TED talks*—those informative 18-min video lectures by engaging speakers. Now if only every class lecture could be structured in this manner.

In my personal exploration into the psychology of art,[5] I found it useful to motivate students with what I call the **aesthetic question.** Any time you experience a new item, work of art, novel, movie or even commercial product (clothing, gadget) you can ask yourself, *"Did I like it or not?"* When we ask this aesthetic question and enumerate why or why not, we bring our emotions into the learning experience: *How did you feel about it?* I believe that teachers should ask this question to students as often as possible: *Did you like the novel? Who were your favorite characters? What is good (or not good) about the Electoral College?* By its very nature, the aesthetic question is open-ended as there is no right or wrong answer. The aesthetic question engages emotional brain circuits and forces us to attend to and organize our knowledge.

With the advent of smartphones and tablets, we literally have knowledge at our fingertips. The availability of **web-based resources** such as *Wikipedia* and *YouTube*, makes it exceedingly easy to add new facts and concepts to our knowledge base. Some educators denigrate the use of such resources as they feel the information provided is superficial or may be erroneous. Yet as an entry-level gateway to conceptual information, I find *Wikipedia* and other fact-based applications enormously useful. For further analyses, one can access scholarly articles through electronic databases, such as *Google Scholar*, *PubMed*, or *JSTOR*.

YouTube is an incredible learning resource. One can access many thousands of how-to videos and introductory documentaries. Moreover, many universities, including UC Berkeley and Harvard, have made available course lectures, talks, and symposia presentations, which provide in-depth scholarly analyses. As an educational tool, these web-based resources should be essential "homework" fodder for any course.

Motivating yourself and others to learn is best experienced when pleasurable and engaging. With respect to self-motivation, we must fight inertia—*a body at rest tends to stay at rest*. The best way to encourage active learning is to get moving and explore your surroundings. With respect to motivating student learning, the difficulty is that teachers must find ways to encourage curiosity and interest in the topics at hand. Student engagement can be fostered through "field trips," museum-like demonstrations, presenting the big picture, asking the aesthetic question, storytelling, and assigning fun videos to watch. Students can motivate themselves by keeping in mind how to relate new concepts into their existing schema and thinking about big picture questions.

Motivate Yourself and Others to Learn

- ❖ Explore new environs—take a walk around town or a park.
- ❖ Field Trip! Visit a museum, historic landmark, or other cultural centers.
- ❖ Get thinking—know your schema and ask engaging questions.
- ❖ Get emotional—ask the "aesthetic" question: *Do you like it or not, why?*
- ❖ Learn through storytelling—engage yourself with dramatic tales (e.g., *TED* talks).
- ❖ Use web-based resources (e.g., *Wikipedia, YouTube*).

Chapter 2: References and Resources[6]

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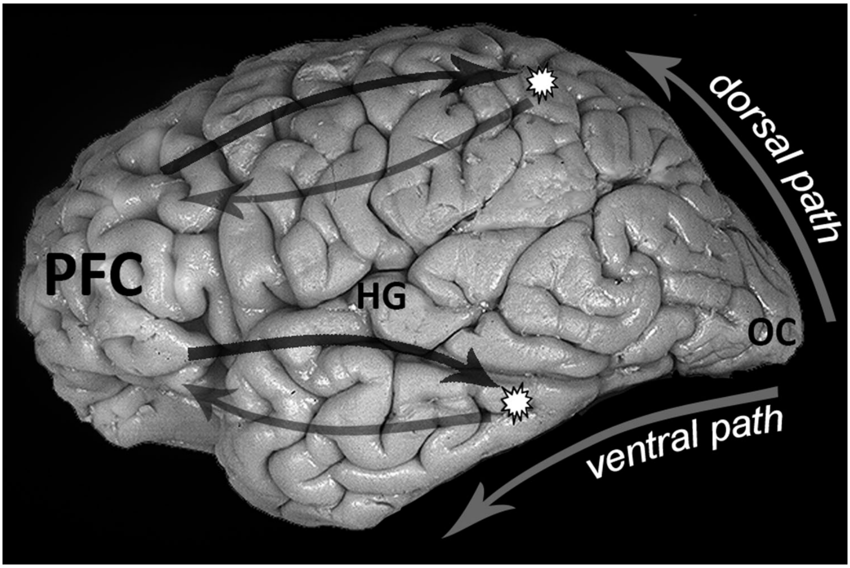
Chapter 3: A is for ATTEND

We spend our waking moments bombarded by a cacophony of sensory signals—sights, sounds, smells, tastes, touches—so much so that it is amazing that we can make any sense of the world around us. Add internal gyrations—feelings and random thoughts—and it becomes evident that our brains require some way of focusing and guiding mental activities. *Information overload* is a major obstacle toward efficient learning, and thus our ability to **attend** to specific thoughts and sensory inputs is essential.

Try this little demonstration—attend to your breathing for a few seconds and make yourself consciously aware of the air moving in and out of your lungs. Now switch your focus and attend to the pressure on your bottom as you sit. Clearly, we have the capability of selecting, maintaining, and switching between mental events (you can now stop thinking about your bottom and focus on the topic at hand). It is your **prefrontal cortex (PFC),** the front 28% of your cerebral cortex that enables you to control mental activity.[1] Consider your brain as a large orchestra with musicians located in various cortical "sections." The PFC acts as your conductor, modulating activity by increasing it in some regions and suppressing it in others. Without a conductor to control volume, timing, and rhythm, the orchestra's performance would appear haphazard and disharmonious.

The figure on the next page shows how **the PFC interacts with the rest of the brain**. The occipital cortex (OC), located at the very back of the brain, is where visual signals first enter the cerebral cortex. From there, visual information is processed along two primary paths—a dorsal ("where") path devoted to spatial processing, and a ventral ("what") path devoted to object processing. Auditory signals emanate from Heschl's gyrus (HG) with surrounding



Attention in the brain—prefrontal-posterior cortex interactions. Brain image reprinted with permission from Digital Anatomist Interactive Atlas, University of Washington, Seattle, WA, copyright 1997.

regions devoted to processing speech, natural sounds, and music. Distributed throughout the cortex are large multisensory regions involved in linking or integrating sensory signals. *At every stage of processing*, there are fibers sending signals directly to the PFC (arrows to PFC) as well as *feedback projections* from the PFC to the same posterior regions (arrows emanating from PFC). These feedback projections enable the PFC a means of modulating (increasing, decreasing, maintaining) activity in posterior cortical regions, a mechanism psychologists call **executive control**.[2]

From this brain perspective, it is clear that the PFC never acts in isolation just as a conductor is nothing without the orchestra. The PFC works by way of selecting, maintaining, and guiding activity in many other cortical regions. Yet it is easy to appreciate how important the PFC is in student learning. If our thoughts are scattered and we are not paying attention to the topic at hand, then our ability to register and remember new information will falter miserably. For efficient learning, we need to focus on relevant information and guide our thoughts toward the integration of new information with existing knowledge. As such, the PFC is essential for **top-down processing**—as it is responsible for determining what mental processes are active at any given moment. In the past, we used the term *short-term memory* to refer to active mental states, but there was confusion over what "short-term" means (seconds?, minutes?). Psychologists now use the term **working memory** to describe the specific features that are active (i.e., working) at any given moment.[3]

The nemesis of efficient student learning is **mind-wandering**. We are all prone to stray thoughts and daydreaming. Moreover, in the classroom the temptation of texting, social media, and web surfing makes it that much harder to attend to the lecturer. Classroom studies[4] have shown that mind wandering is rampant with only 40-46% of students paying attention to the lecturer at any given moment. There is one critical time for focusing attention, which is the **settling-in period**—the first four or five minutes of a lecture. *Student engagement is essential at the start of a lecture.*

In a study of mind wandering during class,[5] chemistry students were instructed to indicate with a clicker each moment during a 50-min lecture when they had been mentally distracted. A consistent lapse in attention occurred during the settling-in period, as if the lecturer was unable to grab the students' attention at the beginning. Thereafter, attention waxed and waned with the number of lapses increasing near the end of the lecture. Students were most attentive during class demonstrations, which reinforces the need to break up a lecture with such engaging methods. Indeed, when you begin a learning session—for yourself or as an instructor—*it is critical to engage attention during the* *settling-in period by considering the big picture, asking goal-oriented questions, or introducing some real-world example or demonstration.*

How can we sustain attention while learning? Top-down engagement is the key. We need to guide our thoughts and focus on relevant bits of information that add to our knowledge base. An important way to sustain attention is to **chunk** information—that is, actively group new information into meaningful units.

Try to remember the two sets of letter strings in the box below:

Chunking: Remember These Letter Strings

TVC IAY MCAJ FK

TV CIA YMCA JFK

Which set was easier to remember?

Even though the two letter strings are identical, it is much easier to remember the second set as it is grouped (i.e. chunked) into **meaningful units** rather than an array of 12 seemingly random letters. We already have existing knowledge of TV and the CIA—as these letter strings are meaningful units to us. Efficient learning depends on making information meaningful to us. *Maintain focused attention by asking yourself, how does this new information fit in to what I already know?*

Top-down processing is the key to focusing attention and chunking. Rather than passively listening to the teacher and aimlessly writing down what's being presented, work to be an active participant of your learning experience. Keep in mind the overarching schema of the lecture—

what is today's topic and how does it relate to the material being presented at the moment. For example, while reading this chapter, you should keep in mind the ATTEND principle of MARGE and how the material presented pertains to it.

A fun way of learning is to create for yourself a **guided tour** of new conceptual knowledge. Consider those roadside nature paths that lead you with an assortment of placards describing plants and scenic viewpoints along the way. Exhibitions at art and science museums often include placards that guide you through the halls, perhaps describing a period of art history or geological time. As you stroll through such informational paths, you experience new facts and concepts with a specific learning goal in mind—such as learning about a local ecosystem, art era, or scientific phenomenon.

At home, are you review a lecture or book chapter, consider the information presented as a "path" that you're taking toward new knowledge. Be aware of how the facts picked up along the way are linked and work together to provide a framework (schema) toward understanding the topic at hand. You can facilitate memory for what you've learned by imagining yourself retracing the "path" to learning and the various facts you've picked up along the way. Try to link together adjacent facts by considering how one conceptual point leads to another.

With respect to student learning, there are times when the **instructor acts as the student's PFC** by encouraging top-down processing. A good instructor will engage students by emphasizing the learning goals at the beginning of class, reviewing how new material fits into what has already been taught, and offering real-world examples. Such techniques offer ways of relating new material with existing knowledge and are best provided at the beginning of a class session to prevent attentional lapses during this settling-in period. In the middle of a lecture, instructors can reduce mind wandering by engaging students with a question-answer period, personal anecdote, or demonstration. During the lectures students should be encouraged to think about the new information rather than just passively listen.

At the end of a lecture, it is important to review the "path" taken during class and how it the information presented fits in with previous lectures. ***Attention takes effort***—it is an active process that requires conscious awareness of learning goals. Yet by engaging ourselves toward learning and making experiences meaningful, we can easily encourage ourselves and others to learn new things—inside and outside the classroom!

You Must Attend to Learn Efficiently

- Get settled—start with a question or the big picture; be aware of what you want to learn.
- *Chunk* new information—actively group information as meaningful units.
- *Categorize*, *compare*, *contrast*—the 3 C's for sustaining attention during learning.
- Take a guided tour—view learning as gathering information along a path of knowledge.
- Act as the student's PFC by facilitating executive control and top-down processing.

Chapter 3: References and Resource[6]

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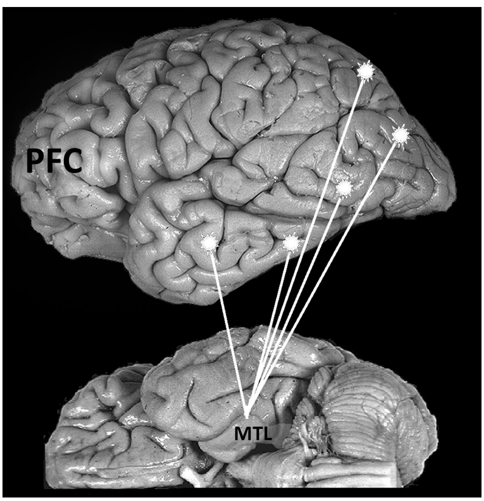
Chapter 4: R is for RELATE

Henry Molaison changed the entire field of memory research. During most of my career, until his death in 2008, we only knew him as H. M., the neurological case who underwent experimental surgery to relieve severe epileptic seizures. The surgery involved bilateral excision of the **medial temporal lobe (MTL)**. His seizures were reduced, yet he was left with a profound amnesia—he was unable to remember events and experiences encountered since his operation. When asked about the lunch he just ate, he could not remember what he ate or even if he had eaten at all. The severity of his amnesia in someone who otherwise seemed normal made the case remarkable. Molaison could converse intelligently, hold thoughts in mind, and even recollect personal and public events that occurred prior to his operation. He experienced some memory loss of very old memories, yet his profound impairment was profound amnesia for events that occurred since his surgery.[1]



The medial temporal lobe (MTL) and relational binding. Brain image reprinted with permission from Digital Anatomist Interactive Atlas, University of Washington, Seattle, WA, copyright 1997.

From studies of Molaison and other amnesic patients, we have come to appreciate the importance of the MTL in storing event (i.e., "episodic") memories. The prefrontal cortex (PFC) activates information in the posterior cortex (white nodes in figure), and the MTL binds this information (lines) as a stored unit. Neuroimaging findings have corroborated the role of the MTL in establishing memory for many kinds of material, including verbal information, scenes, sounds, and faces. Terms such as **relational binding** and **relational memory** have been used to characterize this process, which allows for the rapid linking of activations as a bound set of features—such as binding right now what you're thinking, seeing, hearing, and feeling. It is presumed that this binding process operates continually to provide a stored record of our daily experiences.[2]

Although the MTL is critical for storing episodic memories, *conceptual knowledge must be stored outside of the MTL*, otherwise amnesic patients wouldn't be able to access their existing knowledge or converse normally. Memory theorists suggest that our vast storehouse of knowledge is distributed widely in broad regions of the cerebral cortex as a **network of interconnected information**.[3] So how does conceptual knowledge get stored in this manner? It is argued that facts and concepts through repeated activations become integrated, related, and established as cortical networks through a process called **memory consolidation.**[4] By this view, conceptual learning requires 1) PFC activation of pertinent information in working memory, 2) MTL binding of that information, and 3) memory consolidation—that is, reactivating and relating new information into existing knowledge networks stored in the cerebral cortex.

This biological framework reinforces the third principle of **MARGE**—the need to **RELATE** new information to what we already know. Throughout the learning process it is critical to establish meaningful **chunks** of new information and relate them to existing knowledge. Yet sometimes we need to learn seemingly arbitrary associations that have no inherent meaningfulness, such as remembering a group of terms or names of places. In such cases, it is often useful to create your own verbal or visual mnemonic. **Acronyms**, such as *MARGE* or *HOMES*, serve as useful verbal mediators to remember sets of terms or names (*HOMES can be used to remember the five Great Lakes—Huron, Ontario, Michigan, Erie, Superior*). **Visual imagery** can help link names—for example to remember that *the capital of Arkansas is Little Rock* you could create an image of an ark stuck on a little rock. It is best to generate interactive images when creating visual mediators.

Verbal and visual mediators are effective for arbitrary associations that don't have intrinsic meaning. More important is the need to develop techniques that *integrate* meaningful facts and concepts into existing knowledge frameworks. An effective way to do this is to apply what I call the **3 C's—categorize**, **compare**, and **contrast**. While learning new material, say a new term or fact, bring to mind related information that will help you categorize (i.e., catalog) the new information into your existing knowledge base. Learning is facilitated by finding similarities (comparing) and differences (contrasting) between new material and what you already know. While reading this chapter, you might ask, *Who is Henry Molaison and why is he important for memory research? Contrast the roles of the PFC and MTL in learning and memory?* When you apply the 3 C's, you actively attend to relevant features, reactivate the information, and relate it to your existing knowledge base.

One technique that draws on the 3 C's is the ***elaborative-interrogation* mnemonic**,[5] in which new learning is accompanied by asking "why" or "how" questions and generating reasonable answers. For example, here are some facts about blue whales abstracted from *Wikipedia*:

> *Blue whales, the largest animal known to have ever existed, gorge on krill (small shrimp-like creatures) in*

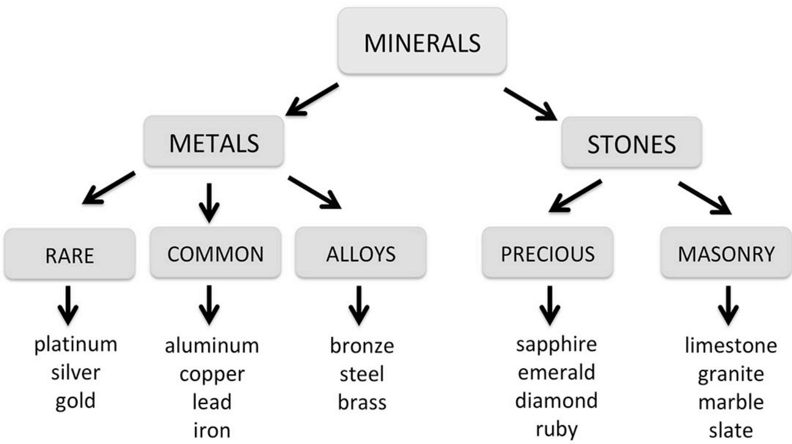
the rich waters of the Antarctic Ocean before migrating to their breeding grounds in the warmer, less-rich waters nearer the equator.

To elaborate on this information consider such questions as, *Why do blue whales spend time in the Antarctic Ocean? Why do they migrate to warmer waters near the equator?* The simple act of generating questions and providing answers helps to integrate new facts into your knowledge database. The *elaborative-interrogation mnemonic* forces you to categorize, compare, and contrast.

Another way to reactivate and integrate facts is to develop a **mental image** or better yet a **mental movie**, such as imagining a huge blue whale feeding on krill amongst glaciers then swimming toward the equator to breed. You can narrate your movie and create your own documentary of the information. By actively working on your visual production you are mentally organizing concepts as a meaningful cluster that can be integrated into what you already know.

A useful way to introduce new concepts is to consider **metaphors** and **analogies** that connect new schemas to familiar ones. For example, by relating conceptual knowledge to the web-based *Wikipedia* application, one gains a sense of how human memory can be viewed as a network of organized facts and how new information can be added by linking new information to existing knowledge. Metaphors and analogies work because a new conceptual framework is described with respect to a familiar concept. Another example is the use of a camera to describe the optics of the human eye. There are useful analogies to their parts, such as the cornea as lens, pupil as aperture, and retina as light sensor. There are of course differences between an eye and camera, just as there will be differences between any two concepts. As such, when applying metaphors and analogies as educational tools, it is useful to describe both commonalities and inconsistencies between a new concept and the metaphor/analogy used.

New information must be appropriately organized into existing knowledge for it to be well established and easily retrieved in the future. In a classic memory study,[6] individuals were given two ways to learn a list of 18 minerals. One group was simply shown the words in a random display and asked to remember them. Another group was shown the words diagrammed as a **conceptual hierarchy** in which the minerals were grouped into meaningful subcategories, such as METALS and STONES (see figure).



Source: Bower et al. (1969)

When shown the hierarchical diagram, individuals recalled 65% of the words compared to recalling only 18% of the words in the random display condition. The power of hierarchical organizations is that they provide a schematic framework that allows one to access any specific item via a few associative links. In this case, every mineral is only three links away from the main topic. For example, *bronze* is accessed via *MINERALS*→ *METALS*→ *ALLOYS*→*bronze*.

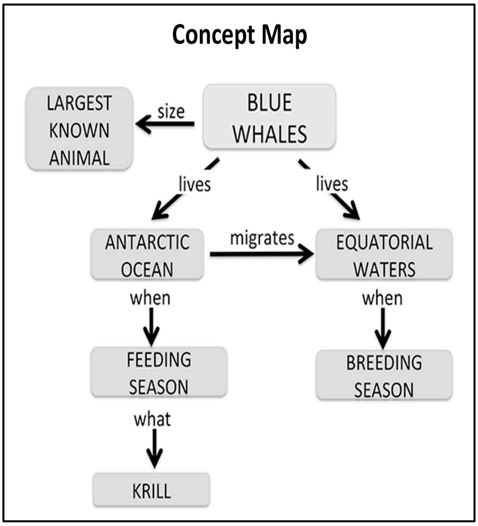
We are familiar with the standard method of formatting **hierarchical outlines**, with Roman numerals indicating the main topic, then capital letters, numbers, and lower case letters referring to subsequent sublevel categories. A partial outline format of the stimulus set of minerals is shown in the figure. Outlines provide an essential means of organizing conceptual knowledge—not unlike how conceptual knowledge should be stored as mental schemas. *Keep in mind the hierarchical organizations of your own knowledge and how new information fits into these frameworks.*

Outline Format

I. MINERALS
A. METALS
1. RARE
a. platinum
b. silver
c. gold
2. COMMON
a. aluminum
b. copper
c. lead
d. iron

Class lectures should be written as hierarchical outlines either during class or soon thereafter. When in class, note-taking has its advantages and disadvantages. It requires multitasking as the student must both listen to key points and write them down. The good outweighs the bad as efficient note-taking, such as constructing hierarchical outlines, requires active participation in learning. It is helpful for instructors to provide outlines at the beginning of lectures.[7] In my courses, I provide partial outlines of lectures, which includes main headings and subheadings of topics. I require students to add to this outline by "filling in" detailed facts (e.g., the lower case letter sublevel information). *Research has shown that the very act of note-taking improves memory for course material.*[8]

Concept maps[9] are **schematic representations**, that can be useful as study material. They provide a visual schema in which terms are represented as boxed items (*nodes*), which are linked by arrows (*propositions*) that define relationships. The figure on the right depicts a concept map of the facts about blue whales presented earlier. The proposition that blue whales live in the Antarctic Ocean is represented by the boxed node, [BLUE WHALES}, linked to [ANTARCTIC OCEAN] with an arrow labeled "lives." Concept maps can be used to reformulate lectures or textbook chapters into student-generated representations. When constructing concept maps (and hierarchical outline formats) it is best to limit the numbers of outgoing links (arrows or subcategories) to not more than five (three or four outgoing links per item is optimal).



Source: Arthur Shimamura

When we use **relational memory** techniques, such as forming verbal/visual mediators, applying the 3 C's, forming metaphors/analogies, and constructing schematic organizations (outlines, concept maps), we are facilitating memory consolidation and long-term retention through elaboration and reactivation. These methods engage the learner by relating and integrating new information as meaningful links to existing knowledge. Thus, **relate it** to make it stick!

Make it Stick: Relate New Information With Existing Knowledge

- ❖ Chunk it: Group information as meaningful units.
- ❖ Associative it: Consider using acronyms, verbal mediators, and visual imagery.
- ❖ Use it: Think about the 3 C's—*categorize*, *compare*, and *contrast*.
- ❖ Integrate it: Apply *elaborate-interrogation* mnemonic, and mental movies.
- ❖ Relate it: Use metaphors and analogies to link new concepts to prior knowledge.
- ❖ Organize it: Construct schematic representations (hierarchical outlines, concept maps).

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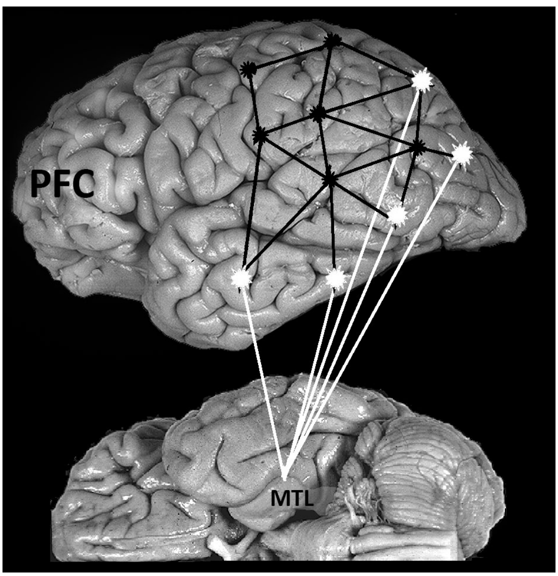
Chapter 5: G is for GENERATE

Think it, say it, teach it! These are the simplest things to do to improve your memory. Have you read an interesting news item lately? Listened to a fascinating podcast? Tell someone what you've just learned. Not only will you be engaging in healthy social interchange, you'll remember the information better yourself! Do you want to remember the name of someone you just met? Say the name aloud—"*It's a pleasure to meet you Jim*"—and it will stick better in your memory. This is the **GENERATE** principle of **MARGE,** and it can improve your memory by 30-50%!

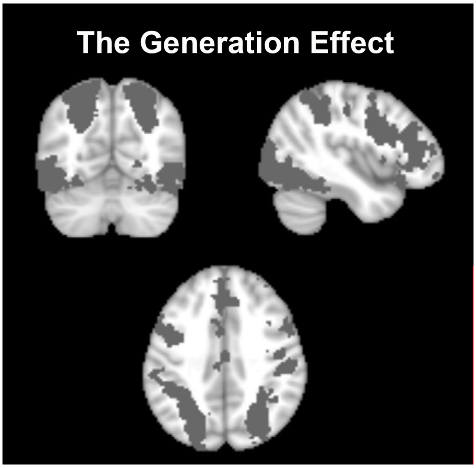
When we generate information, learned material is reactivated, thus enabling *memory consolidation*, the brain process that establishes long-lasting conceptual memories. Brain scientists have described memory consolidation in terms of PFC activation and MTL bindings[1]. Specifically, initial learning requires 1) PFC activation of pertinent information in the posterior cortex (white dots in figure), and 2) MTL bindings that link the information as a stored connected unit (white lines). Through repeated usage and reactivation of learned information, long-lasting neural con-



Memory consolidation creates long-lasting cortical connections. Brain image reprinted with permission from Digital Anatomist Interactive Atlas, University of Washington, Seattle, WA, copyright 1997.

nections distributed widely in the cerebral cortex are established (black nodes and links). *The key to long-lasting memories is the reactivation and elaboration of pertinent information after initial learning.*[2]

Neuroimaging findings show that self-generating information activates broad cortical networks. In one study,[3] individuals were presented cued word fragments (e.g. GARBAGE - W_ST_) and asked to generate the second word (e.g., WASTE). On other trials, individuals simply read word pairs (e.g. QUARREL - FIGHT). Even for this simple fragment completion task, there was greater brain activation for word pairs that had to be generated compared to intact word pairs. The brain areas activated via fragment generation included the prefrontal cortex, medial temporal lobe, and regions in the back of the brain known to be involved in thinking and imagining (grey areas in figure above). Importantly, this activation led to better performance later when memory was tested.



Source: Rosner et al. (2013)

Other terms, such as **retrieval practice**[4] and **production effect**[5] have been used to characterize the generate principle. The essential factor is the active self-generation of information. It's not as good to simply restate or repeat what you've learned. The key is to **say it in your own words**. Many students spend hours re-reading textbook material and dousing pages with highlighter ink. Such practices have extremely low utility as they prevent the active self-generation of information. Closing the textbook and retrieving the information from memory can more than double your retention compared to rereading or highlighting material.

The more often you self-generate material the better it will be established as a long-lasting memory. Find as many friends as you can who will listen to you and tell them about what you've learned! Students should space their retrieval practice across days. A rule of thumb is to divide your total study time into fifths and test yourself at each time point. For example, if you have 10 days until exam time, try to practice retrieval at an interval of every two days. If you need to retain the information longer (e.g., until a final exam), work to increase the interval between retrieval practice sessions. Useful ways to self-generate information is to apply the 3 C's (categorize, compare, contrast), ask yourself elaborative-interrogation questions ("why" and "how" questions), and write/review schematic organizations of lecture and textbook material (hierarchical outlines, concept maps).

Whenever we describe what we've learned to others, we are essentially teaching, and as the noted science fiction author Robert A. Heinlein once said, "*when one teaches, two learn.*" Indeed, teaching is one of the best ways to retain conceptual knowledge as you must reactivate learned information and organize it in your head before you relate it to others. Whether formally to a group or just casually chatting with others, you should be encouraged to teach and tell others what you know. If you feel ambitious, you can even set up a blog and write about a favorite topic. In this way, you are encouraged (as I've been) to regularly disseminate your knowledge—and regardless of whether you garner any followers of your writings, you've improved your own memory for the information! Students should be encouraged to participate in study groups and teach each other the material. In this way, students work together to practice generating course information.

The best way to study material is to generate it and say in your own words. Re-reading textbook chapters should only be done to determine what parts of the material were not learned well. Avoid highlighting multiple sentences or worse yet full paragraphs. If you like to highlight text, simply mark important terms and thematic phrases (as I have done for you by putting terms and phrases in bold or italics). For the most part, "study" time should mostly be "test" (i.e., retrieval practice) time.

Outside the classroom, we basically generate information whenever we encounter it again. That is why the conceptual knowledge we encounter frequently, such as things we need to know in the workplace, are well established. During my career as a memory researcher, I'm sure I've encountered the terms *memory consolidation* and *prefrontal cortex* many thousands of times. Such concepts are well integrated in my cortex. So, to retain your conceptual knowledge well past the end of the academic year, you must work to re-activate it—*use it or lose it*.

Generate: Say it, Test it, Teach it

- Tell other about what you've learned (or just tell yourself).
- No need to re-read or highlight facts. Practice retrieving information *in your own words*.
- Test yourself using 3 C's, elaborative interrogation, and schematic organizations.
- Space your retrieval practice (test yourself at regular intervals).
- Teach material to others—work on organizing material (draw outline, concept maps).

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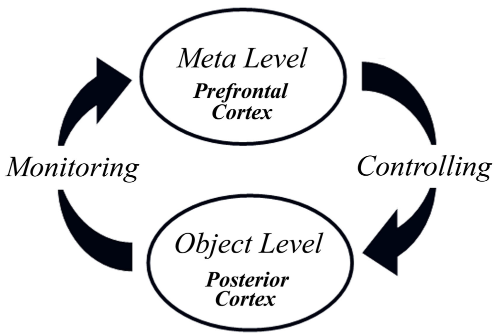
Chapter 6: E is for EVALUATE

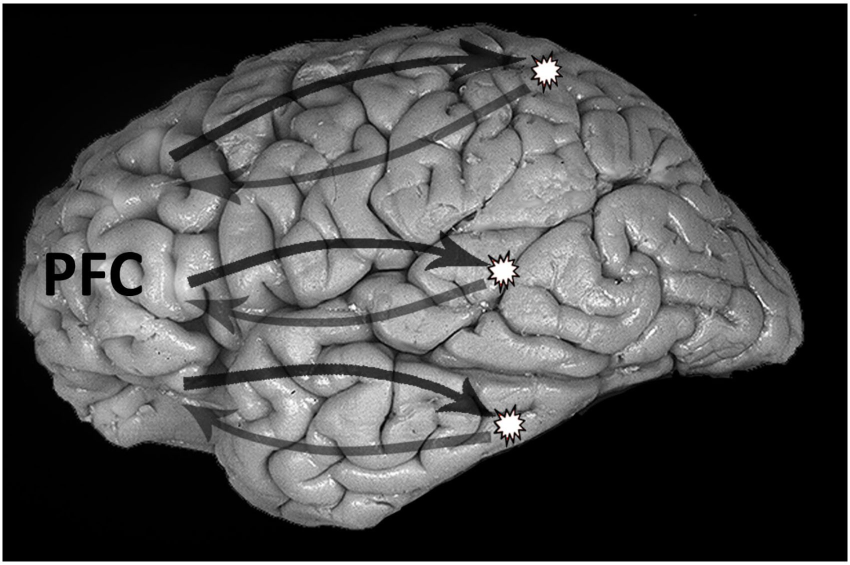
How do you know what you know? Psychologists use the term, **metacognition**,[1] to describe the ability to evaluate our own mental processes. If a student comes up after an exam and says, "*I don't know why I did so poorly, I thought I really knew the material*"—it clearly suggests poor metacognition. Such "*illusions of knowing*" can stall learning proficiency, because a student would not feel the need to study further if he/she felt that the material was already well learned.

The need to **evaluate** what we know is the fifth principle of **MARGE**. Thomas Nelson—one of my graduate school mentors—and his colleagues developed a model of metacognition that helps us understand its importance in evaluating our memory abilities.[2] As shown in the figure at left, a *meta level* monitors and controls *object level* processes, which are cognitive processes that go on at every conscious moment, including your ability to recognize these words and garner their meaning. Like an orchestral conductor overseeing the musicians and modulating their performance, the meta level oversees cognitive processes and controls future actions.



Metacognitive monitoring and control.
Source: Arthur Shimamura

With respect to **brain mechanisms**, there are parallels between metacognition and the role the prefrontal cortex (PFC) plays in supervising activity in the posterior cortex.[3] Object-level processes can be viewed as neural activity in



Brain view of metacognitive monitoring and control. Brain image reprinted with permission from Digital Anatomist Interactive Atlas, University of Washington, Seattle, WA, copyright 1997.

the posterior cortex associated with cognition (seeing, recognizing, understanding), and the PFC acts as your meta level by monitoring activity via projections to the PFC and controlling them via projections back to the same posterior regions (arrows in figure). Thus, we can connect metacognition with the PFC—both are important for *focused attention* and *executive control*.

Why do we sometimes fall prey to an illusion of knowing? Memory researchers make a distinction between two kinds of metacognitive "knowing." There's hard-core knowing, which involves **recollection**, our ability to state explicitly why we know something, and **familiarity**, that more diffuse "warmth" feeling of knowing that occurs when something is recognizable but you can't really place your finger on why you know it. The illusion of knowing often occurs because we have familiarity without recollection.[4] The information feels fresh and recognizable at the moment (i.e., familiar), but that feeling prevents us from a valid judgment of its actual memory strength (i.e., recollection). This helps explain a student's illusion of knowing just after an exam—the general information feels very familiar, but the ability to recollect specific details (answering exam questions) was apparently not available.

To give another example of familiarity without recollection, I was sitting at a coffee place near campus, and a young woman came up to me and said "Hi, how are you?" I recognized the woman (there was familiarity), but was struggling to place her as I fervently searched through my mental file of former students. The woman noticed my struggles and said, "I'm your next-door neighbor, Aubrey." Of course, my problem was that I was searching in the wrong mental file cabinet (also Aubrey had just moved in a few months ago—my other excuse). There's actually a name psychologists use for this experience of familiarity without recollection—*the butcher in the bus* phenomenon—in which we see the butcher on the bus but can't place him because he's out of his usual context.[5]

Illusions of knowing can occur when learning new material. In one study,[6] individuals were given word pairs to study (e.g., OCEAN-TREE). For some pairs, they were asked immediately after learning to rate how well they would be able to come up with the second word when cued with the first (e.g., OCEAN- ?). For other pairs, this evaluation wasn't requested until several minutes after learning. When assessed right after seeing the pairs, individuals grossly overestimated their learning ability—they thought they would do well when tested later. This illusion of knowing occurred because the pairs—having just been presented—was still fresh in their working (i.e., short-term) memory and thus seemed available at the time. When the evaluation was delayed, that freshness/familiarity was gone and the evaluation reflected better how well they could recall the second word from long-term memory. *Thus, one way to prevent illusions of knowing is to wait some time (minutes, hours, days) before testing your memory.*

Teachers can encourage the **EVALUATE** principle by having students practice retrieving information during class time. Rather than lecturing the whole time, question/answer "retrieval practice" periods should be sprinkled throughout the presentation. The best way to engage students is to offer open-ended questions and call on students to provide answers. Fact-based questions can also be useful to determine if students are paying attention (*Can someone tell me the difference between recollection and familiarity?*). For large classes, another method is to present multiple-choice questions and have students elicit answers with clickers. Research has shown that the use clickers in class instills active learning and better memory for class material.[7] For best results, instructors should keep questions to 4-5 per session and allow 30 seconds for students to answer each question.

Between initial learning and exam time, students must engage in **multiple retrieval practice sessions** that involve a combination of generating and evaluating course material. The easiest way to do this is to **test yourself** by writing down in your own words what you remember from a lecture or homework assignment. As you monitor your output you will soon realize forgotten points or weakly remembered concepts. You can then go back to sources, relearn material (apply 3 C's, elaborative-interrogation mnemonic, concept maps), and then test yourself again say a day or two later. When you evaluate your learning through this kind of retrieval practice you have accomplish two things—you've re-activated the information thus strengthening your memory for the material itself, and you've determined missing points or weakly remembered concepts which you can go back, relearn, and test again. *By testing yourself repeatedly you strengthen memory as you establish multiple pathways to the knowledge.*

Learning, particularly in classroom settings, often depends on remembering cued or pairwise associations, such as new terms, definitions, or foreign vocabulary words (e.g., CAT-GATO). A good way to study course material is to generate your own set of key terms (4-6 per section or book chapter) and write in your own words their definitions. Such cued associates can be tested using flash cards (virtual versions are available online), in which you only see the cue and must generate the associate (e.g., CAT-?). To prevent illusions of knowing, be sure to delay the time (minutes, hours, or days) between learning and flash card testing.

Just for fun, let's apply visual mediators and learn six state capital. Later we'll evaluate our learning proficiency. Spend several seconds visualizing the images suggested in parentheses: Arizona-Phoenix (a phoenix ARIZing), Nebraska-Lincoln (Abraham Lincoln ASKing you to vote for him), Connecticut-Hartford (a CONman selling hearts on a Ford), Florida-Tallahassee (the tail of Florida on a tall hussy), Kentucky-Frankfort (a Kentucky Derby horse eating a frankfurter), Michigan-Lansing (the two parts of Michigan being lanced together).

Another student learning tip is to **interleave** your evaluate sessions across subject topics. You may have to learn material across several topics (e.g., book chapters) within a course or even simultaneously have to study material from several courses. Interleave (i.e., mix up) the order of retrieval practice session. For example, on one day it would be better to test yourself on material from two different courses than from two lectures of the same course. If you need to study for multiple lectures/homework for the same course, try to interleave the material so that you are integrating the entire body of information together. The main thing is to avoid "blocking" or "massing" your learning sessions with just one issue—try to mix it up.[8]

Now test yourself on the state capitals: Connecticut-?; Michigan-?; Arizona-?; Florida-?; Kentucky-?; Nebraska-? If you can remember the state capital of each, congratulations! If you cannot remember, evaluate your metacognition by rating how well you think you'd get the answer if I showed you some choices. Then, for those you've forgotten, go back and try to relearn them. Don't say I never taught you anything!

Evaluate What You've Learned

- Avoid illusions of knowing by delayed evaluations—test minutes/hours after learning.
- Test through generation—tell someone what you've learned, monitor forgotten points.
- Construct your own key terms and test them using flash cards.
- Interleave topics by mixing up the order of testing.
- Test yourself repeatedly—develop multiple paths to retrieval; relearn then test aging.

Chapter 6: References and Resource[9]

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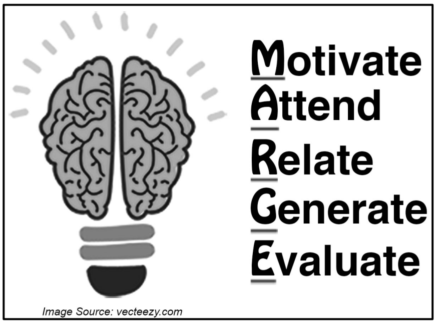
Chapter 7: Putting it all Together



With **MARGE** in hand, you now have tools for efficient learning. The five principles should be applied at all stages of learning—during class sessions, reading textbook material, and studying for exams. If you need reminding of tips and techniques, *refer to the table at the end of each chapter.* Remember that conceptual learning is an ongoing process that takes effort and focused attention. The tips provided should make your learning experience less arduous (and perhaps even enjoyable at times!).

As is obvious now, it has been my intention to instill knowledge about brain mechanisms. As someone who has had the pleasure and privilege of studying how the brain learns and remembers, there is no doubt in my mind that an understanding of the biology of memory has important implications for educational practices. I've also included important findings from basic psychological science, which I also strongly believe can be applied to everyday learning. The techniques presented here have all been driven by these advances in memory research.

There are, however, pitfalls associated with brain-based educational approaches. Over-indulgent practitioners often fall prey to a modern day form of phrenology in which there is exaggerated focus on specific brain regions, such as the prefrontal cortex or medial temporal lobe. There is a sentiment that if we could only boost activity in these brain regions, we can solve the problems of poor student learning. Even worse are practitioners who use brain regions as markers for "styles" of learning—are you a left-brain (verbal), a right-brain (spatial), a back-brain (perceiving), or a front-brain (thinking) learner? Although there may be subtle differences in the way individuals process information, there is no evidence to suggest that educational practices should be geared differently for so-called different learning styles.[1] *MARGE will benefit all students by fostering broad-based active learning skills.* Indeed, I hope I've reinforced throughout this book, that **learning is a whole-brain issue** that involves a multitude of distributed neural circuits—all of which are essential for establishing long-lasting conceptual knowledge.

Given the principles presented here, educators have the tools to foster more efficient student learning. Simple aids during class include 1) displaying on screen or providing handouts of main points (schema) in outline form, 2) spending several minutes at the beginning of class engaging motivation with the big picture using key questions, real-world analogies, demonstrations, or personal anecdotes, and 3) encouraging retrieval practice with question/answer periods.

A more radical change from the standard 50-min lecture (and passive listening) mode of teaching would be to split class time into two 16-min lectures not unlike a TEDtalk video (fostering a more storytelling mode). Each shorter lecture should be followed by an 8-min question/answer period. Of course, less material would be presented for each class session but given findings of pervasive mind wandering during class, particularly near the end of a 50-min lecture, students may learn and retain more from two 16-min lectures with question/answer periods than a 50-min lecture without retrieval practice. Students could be assigned as homework web-based videos (e.g., *YouTube* assignments) to supplement lecture material.

Learning requires effort from both teacher and student. Indeed, student participation is key and *without the engagement of top-down active processing, learning is futile*. During class, students must be aware of the big picture (schema) and be able to identify key points along the way. Note-taking is paramount and best written in hierarchical outline format. Even at this time it is beneficial for students to apply the 3 C's—*categorize, compare, contrast* and consider how new information fits into what is already known about the topic.

At home, course material should be reviewed with multiple sessions involving retrieval practice. Generate information by saying aloud or writing down *in your own words* material presented in lectures or homework assignments. Evaluate your retrieval and monitor missing information or weakly remembered key points. Go back to sources, relearn material (re-apply 3 C's, elaborative-interrogation mnemonic, concept maps), and test again a day or two later. Join study groups that encourage retrieval practice—*think it, say it, teach it.*

There is a decades-old, yet excellent approach to reading textbook material called the *SQ3R method,*[2] which I've presented on the first day of every course I've taught at the University of California, Berkeley. The acronym stands for SURVEY, QUESTION, READ, RECITE, REVIEW, and interestingly, these steps map very well with MARGE (see table below). The method encourages schema building, top-down processing, retrieval practice, and metacognitive evaluation. Too often students jump right into a textbook chapter and begin reading without any expectation or guidance as to what will be presented. The SQ3R method prevents this mistake by requiring two important steps prior to reading—SURVEY and QUESTION—each taking only 3-6 minutes to accomplish.

The first step, SURVEY, provides an overview (i.e., schema) of the material by first reading headings, subheadings, figure/table captions, and summary paragraphs. The next step, QUESTION, prepares the reader for active, top-down processing by creating key questions to think about. At this time, the student is prepared to READ with schema and questions in mind. The RECITE phase involves retrieval practice of the material followed by a REVIEW phase in which the student evaluates progress in learning and re-

SQ3R Method for Reding Textbook Chapters & Its Relation to MARGE

SURVEY: MOTIVATE & get the big picture (schema) (3-6 min).
- Read title, heading, subheadings
- Read introductory and concluding paragraphs
- Read captions for figures, tables, charts

QUESTION: ATTEND & engage top-down processing (3-6 min).
- Note any key questions provided by author.
- Write down 5-6 key questions ("*What?*"; "*Why?*"; "*How?*")
- Ask: *What am I supposed to learn from this chapter?*

READ; RELATE text material to existing knowledge.
- Keep in mind big picture and key questions.
- Note terms/key points marked by bold or italics.
- Be active not passive: read for meaning/understanding.

RECITE: GENERATE via retrieval practice (8-10 min).
- Close book and describe what you learned in own words.
- Address key questions/provide answers from memory.
- Summarize big picture: *What was the aim of the chapter?*

REVIEW: EVALUTE--*What did I learn from chapter?* (8-10 min).
- Note weakly remembered points and relearn.
- Make sure you can answer key questions from memory.
- Make sure you can define terms and concepts.
- Practice retrieval frequently (separated by hours, days).

turns to the material to address any deficiencies. *The SQ3R method should always be applied when reading textbook material.*

It is my hope that you will engage in lifelong learning well past your time as a student. Keep MARGE in mind whenever curiosity arises and the desire to learn comes upon you. Visit museums, relate to others what you've learned, explore your environs. Create your own guided tour: **MOTIVATE** yourself and take a walk around your home town. **ATTEND** to your environs and learn about places, shops, and other sites. **RELATE** facts to sites using your smartphone for information or gather information from your walk (talk to store owners about the store's history!). When you return, **GENERATE** a story about your town, organize it around the path you walked, and tell someone about your adventures. **EVALUATE** your knowledge by reminding yourself of the information each time you are in town. Better yet, actually take someone on your guided tour! Keep in mind that learning is a whole-brain issue—it'll keep you active, should be fun, and best when shared with others!

Chapter 6: References and Resource[3]

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[1] Pashler, H., McDaniel, M., Rohrer, D. & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9,* 106-119. Riener, C. & Willingham, D. (2010). The myth of learning styles, *Change: The Magazine of Higher Learning*, *42*, 32-35.

[2] Robinson, F. P. (1978). *Effective Study* (6th ed.). New York: Harper & Row.

[3] Video: Willingham, D. *Learning Styles Don't Exist*, YouTube video.

https://www.youtube.com/watch?time_continue=311&v=sIv9rz2NTUk

About the Author

ARTHUR SHIMAMURA is a Professor Emeritus of Psychology from the University of California, Berkeley and a world-renowned expert on human learning and memory. He co-founded the *Cognitive Neuroscience Society*, received a Distinguish Teaching Award at UC Berkeley, and served as a science advisor for the *San Francisco Exploratorium Science Museum*. Awarded a John Simon Guggenheim Fellowship to explore links between art, mind, and brain, Shimamura integrated his scholarly interests with his passion of the arts and photography. His broad interests and background led him to develop *Get SMART! Five Steps Toward a Healthy Brain*.