How People Learn

Everyone Read This Part:
The field of neuroscience is just beginning to understand some of the psychological and physiological foundations of **how we learn**.

A fundamental idea is that learning is not something that just happens to you; learning is something you do for yourself. You cannot be "given" learning, nor can you be forced to do it. Even the best teacher cannot "cause" you to learn. Only you can do that. **The big rule about learning is that is cannot be achieved passively. It demands an active, focused mind.**

What follows are some details about how people learn, how you can help yourself learn. However, without the desire, nothing will work.*

Each group of students is responsible for becoming the "expert group" on one of the following topics:

- **Topic A: Mindsets**
- **Topic B: Research into Memory and Learning**
- **Topic C: Biology of Learning**
- **Topic D: Importance of Repetition**
- **Topic E: Multitasking While Learning**
- **Topic F: Study Tips and Tricks**
- **Topic G: Sleep to Learn**
- **Topic H: A Common Mistake**

Read the information provided in the text AND graphics provided. Also, follow the links within the reading to gain additional information. Make your own notes to summarize or paraphrase the key information from your group's assigned topic.

Answer the questions on the back of this sheet for your topic.

TOPIC A: Mindsets

1. Choose **one** of the following and explain how you will respond while exemplifying the growth mindset:
   a. You thought you understood the material, but you earned a D on a recent quiz.
   b. Your friend keeps scoring higher than you on labs even though you work together.
   c. Your teacher asks you to "try again" when you are responding to a question with the whole class listening.
2. Take the survey to get a sense of your learning mindset. Comment on the results. http://blog.mindsetworks.com/what-s-my-mindset?view=quiz

TOPIC B: RESEARCH INTO MEMORY AND LEARNING

1. Why are people interested in learning about learning and memory?
2. Explain the benefit of collaboration among scientists studying a common question.
3. Why might competition among scientists be a benefit AND a hindrance to scientific progress?

TOPIC C: BIOLOGY OF LEARNING

1. Describe the structure and function of the cells of the central nervous system.
2. Biologically, what is learning?

TOPIC D: IMPORTANCE OF REPETITION

1. Describe why repetition is the key to learning in terms of the physical changes that occur in the brain when information is learned.
2. Write a caption that could be used to explain the Ebbinghaus Forgetting Curve.
3. How will the percent of material recalled over time change with and without repetitive review of the material?

TOPIC E: MULTITASKING WHILE LEARNING

1. What is memory consolidation?
2. What is the impact of the internet and multitasking on memory consolidation?
3. List the steps YOU will take to ensure strong neural pathways are forged as you learn biology.

TOPIC F: Study Tips and Tricks

1. What are the most effectives ways of studying?

TOPIC G: Sleep to Learn

1. How much sleep does the average adolescent need per night?
2. How does sleep help with learning?

TOPIC H: A Common Mistake

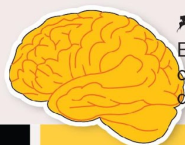
1. Describe the common mistake made by learners.
2. What will you do personally to avoid making the common mistake?

TOPIC A: MINDSETS

One of the most important recent discoveries about learning is the importance of your **MINDSET** about learning. According to Dr. Dweck, your mindset is not set in stone. You weren't born with either a fixed or growth mindset. **You can choose which mindset you will have**! Although, changing your internal dialogue and habit of thinking with a fixed mindset is not easy, it can be done. As you approach learning in IB Biology this year, please think with a growth mindset.

Changing Our Mindset

Carol Dweck, world-renowned Stanford University psychologist, talks about the power of our mindset or our beliefs (especially around challenge). We can either have a Fixed Mindset where we let failure (or even success) define who we are, or a Growth Mindset where we see setbacks as opportunities to grow and improve ourselves. Just like how we learned how to walk… there are many stumbles along the way, but to reach our potential and live the life we desire, it takes practice and perseverance. We always have a choice about which view we adopt for ourselves… and it's never too late to change. What's your view?



It's up to you!	FIXED MINDSET Belief that my intelligence, personality and character are carved in stone; my potential is determined at birth	GROWTH MINDSET Belief that my intelligence, personality and character can be developed! A person's true potential is unknown (and unknowable).
DESIRE	Look smart in every situation and prove myself over and over again. Never fail!!	Stretch myself, take risks and learn. Bring on the challenges!
EVALUATION OF SITUATIONS	Will I succeed or fail? Will I look smart or dumb?	Will this allow me to grow? Will this help me overcome some of my challenges?
DEALING WITH SETBACKS	"I'm a failure" (identity) "I'm an idiot"	"I failed" (action) "I'll try harder next time"
CHALLENGES	Avoid challenges, get defensive or give up easily.	Embrace challenges, persist in the face of setbacks.
EFFORT	Why bother? It's not going to change anything.	Growth and learning require effort.
CRITICISM	Ignore constructive criticism.	Learn from criticism. How can I improve?
SUCCESS OF OTHERS	Feel threatened by the success of others. If you succeed, then I fail.	Finds lessons & inspiration in other people's success.
RESULT…	Plateau early, achieve less than my full potential.	Reach ever-higher levels of achievement.

Read the article by Carol Dweck and make notes about mindset.

FIXED VERSUS GROWTH MINDSETS, BY CAROL DWECK

There are two mindsets that students may have about their intelligence. With the fixed mindset, students believe their intelligence is just a fixed trait; they have a certain amount and that's it. As you will see when students are in this mindset they worry about how clever they are. They don't want to take on challenges or make mistakes; they want to stay in their comfort zone.

But students who have a growth mindset think no, it's not fixed; intelligence is something that you can develop. It's a potential that you can cultivate through educational instruction. Now, in a growth mindset it's not that a student believes anyone can be Einstein, or that everyone is the same. But they understand that even Einstein wasn't Einstein until he spent years and years and years of dedicated passionate labor. So in the growth mindset talent is just a starting point; you jump off from there.

I am often asked "So which mindset is really true?" and what is so exciting now is that more and more research from cognitive psychology and from neuroscience is producing evidence for the growth mindset. Every few weeks it seems now, articles are being published showing that even the most fundamental aspects of intelligence can be trained and improved. And not just in young children, but in older individuals as well. The brain has so much more plasticity [the ability to be easily changed] than we ever dared to imagine. Even as adults we are generating new neurons, and that was never known before. Does a student hold the same mindset in different areas? Not necessarily. A student may believe that their personality can be developed, but that their intelligence is fixed. Or their language abilities can be developed but their mathematical ability, well that's fixed, or vice versa. But whatever mindset they have in a given area will shape their motivation to learn.

Can mindsets be changed? Can they be taught? Yes, and that's what's so interesting. When you leave them alone they are pretty stable, but now that we understand what a mindset is, we can go in and change it. And when we do that we transform student's motivation to learn.

How do mindsets work? They work by creating an entire psychological world for students, where everything has a different meaning, and I'll be going through this in terms of the three rules of the mindsets. In telling you about the mindsets I am going to be focusing a bit on a study we did with hundreds of students who were making the transition to seventh grade, which is a very, very challenging transition in The States. The work gets harder, the grading gets more stringent, the environment becomes less personal, and a lot of students turn off to learning. And we wondered would a growth mindset help students get across that transition? So, at the beginning of seventh grade we measured students' mindsets. We saw who believed their intelligence could be developed-- the growth mindset, and who believed it was fixed amount-- the fixed mindset. We asked them a number of other things, and then we followed them over the next two years looking at their grades.

Mindset Rule Number 1

So, the first thing we found is in a fixed mindset rule number 1 is look clever at all times and at all costs. And if you are not going to look clever, don't do it. But in a growth mindset where you believe your abilities can be developed, the number 1 rule is learn, learn, learn. And in this study we found fixed mindset students told us "The main thing I want when I do my school work is to show how good I am at it". The growth mindset students didn't say things like that. They said "It's much more important for me to learn things in my classes, than it is to get the best grades". They cared about grades, but they cared even more about learning. When we looked at them and we graphed their grades over the next two years we saw this; they had entered with exactly equivalent achievement, but by the end of their first term, their grades had jumped apart pretty dramatically, and their grades continued to diverge over the next two years.

We found the same thing with college students who were in a pre-medical curriculum. Now, nobody cares more about grades than pre-med students; they have lived their lives for this moment; their parents have lived their lives for this moment, and yet the students with a growth mindset said they cared even more about learning. And when we looked, at the end of their term, the students with the growth mindset had actually earned higher grades, even controlling for past achievement. They did this because they took charge of their learning; they studied more deeply; they managed their motivation; they managed their time. And if they got a poor grade on their initial exam, they made sure to pull it up. But when students with a fixed mindset got a poor initial grade they thought "I guess I am not good at this" and they didn't change the way they studied, or the information they gathered, or the resources they used in their environment.

More than any study we have ever done, the study I am about to tell you about shows dramatically how a growth mindset turns you toward learning, but a fixed mindset turns you away from learning.

Learners and Non-Learners in Action - How do Mindsets Control our Attention?
In this study we brought students one at a time into our brainwave lab. We outfitted them with a cap full of electrodes, that you see here, that measured the electrical activity from different parts of their brain. We were especially interested in measuring the activity ... from a part of the brain that shows that they are harnessing their attention to learn something; to receive information. After they were fitted with the cap of electrodes they were seated in front of a computer, which asked them a long series of very difficult questions; here is 'Who was the union general at the battle of Gettysburg?' The answer is 'Meade'. 'What's the capital of Australia?' which most Americans don't know 'Canberra'. Anyway, the student typed in an answer. A second-and-a-half later they found out whether their answer was right or wrong. And a second-and-a-half later they found out what the correct answer really was. When we looked at students who had endorsed a fixed mindset, they entered a strong state of attention to find out if they were right or wrong. But that was it; their job was done. They didn't care about what the right answer really was. But when we looked at students with a growth mindset, they entered a strong state of attention to find out if they are right or wrong, that's part of learning. But then they entered another very strong state of attention to find out what the correct answer really was. And they did this even when they had been correct. They wanted to elaborate upon their knowledge and learn more. Now, being psychologists, we didn't stop there. We gave them a surprise retest on the items they got wrong, and now we found that the students with the growth mindset got significantly higher scores, because they cared about learning.
And if you extrapolate that to real life you can think about it like this; people with a fixed mindset are going around saying "Am I right?" "Am I clever?" "Tell me how bright I am?" But people with a growth mindset are saying "Tell me when I am wrong, because I want to learn."

I'd like you now to take one or two minutes; turn to your neighbor and think about a time you were in a fixed mindset and chose to be a non-learner. Maybe you had had some setbacks and you were not feeling you had the courage to learn. Maybe you had just been promoted into a new position and thought you had to have all the answers. Maybe you were in the presence of people who were judgmental and you were afraid to stretch. So think of a time you were in a fixed mindset and chose to be a non-learner, and then think about, what could you do differently next time?

Mindset Rule Number 2
Let's move now to rule number 2. And this rule is crucial; it's about effort. In a fixed mindset, effort is a bad thing. Students in a fixed mindset believe if you really have ability then things should just come naturally. They believe that ... they say "To tell the truth, when I work hard at my school work it makes me feel like I am not very smart. So, what they are saying is, whenever they have to apply effort they feel stupid. They think if they were really clever it should just all come to them. But students in a growth mindset believe that working hard is the key. They say "The harder you work at something, the better you will be at it". They think that even geniuses have to work hard for their great discoveries. So, who's right? Do geniuses really work hard, or does it come naturally? Some of

the most exciting work in all of psychology now is showing that there is one thing that distinguishes geniuses from their other talented peers, and that's how hard they have worked, how much practice they have put in to developing their skills. And not just building on their strengths, but addressing their weaknesses. Yes, they may be talented, but so were many other people and they are the ones that took their talent to the finish line.

The fixed mindset belief that effort is only for people who aren't clever is one of the worst beliefs students can have. It means that every time they meet a challenge and have to apply themselves, they are going to feel inadequate. They are going to do something only when it is coming easily. I believe this is why many of our brightest students stop working in school at some point. They have coasted along; everybody has told them how brilliant they are, and they come to equate low effort with being bright. At some point the low effort doesn't work any more; school becomes difficult, and they become anxious. They have a choice; should they work hard and feel stupid? Or should they retire while they are still a genius? Many of them choose to retire, and not push themselves; not feel the anxiety, so everyone will still think they are extremely clever but lazy. And they prefer that to testing out whether they are bright or not. Students in a growth mindset expect effort and enjoy effort.

Mindset Rule Number 3 - In the Face of Setbacks
In the face of setbacks, hide your mistakes; conceal your deficiencies, because mistakes and deficiencies are permanent.

In a fixed mindset a failure means you just don't have it. And if you don't have it, you will never have it. But in a growth mindset mistakes are part of learning; deficiencies are part of being human, and so what you do there is you work harder; you find out what you can do to learn. And so, in our study of students making the transition to seventh grade, those with a fixed mindset after a disappointing score on an early exam in a course said "I'd spend less time on this subject from now on. I'd try not to take this subject ever again, and I would try to cheat on the next test". Look, if they did poorly and it reflects on their ability; they don't like effort, they don't believe in it. They are now tempted to take these circuitous routes to success. But in a growth mindset they say "I'd work harder in this class from now on. I'd spend more time studying for the tests, because continued effort is the way to grow that ability." In study after study, after study we have seen over and over that the fixed mindset gives students no recipe for recovering from failures. They give up and retreat to their comfort zone. They blame others for their failures, or they try to feel superior to someone else. I can't resist telling you about a recent study we did at my school, Stanford University, where the students are highly selected and you would think they would be learners, but not all of them are. We brought them into our lab one at a time; we gave them a very, very, very difficult test on which they did poorly. And then we said, we have some tests of other students that you can look at before you perform again, and would you like to look at students who did much worse than you, or students who did much better than you? And what we found was that students in a fixed mindset overwhelmingly said they wanted to look at the exams of students who did worse than they did. And afterwards they said "I really feel good about my abilities. I really feel I am on top of this material". But, mark my words; we made sure there was no useful information in those exams. Whereas the students with a growth mindset overwhelmingly chose to look at the exams of those who had done substantially better than they had, so they could learn.

Originally from www.nais.org/publications/ismagazinearticle.cfm?Itemnumber=150509&sn.ItemNumber=145956

TOPIC B: RESEARCH INTO MEMORY AND LEARNING

People have been interested in learning and memory for a long time. Click here to read a summary of our study of human memory over time. You do NOT need to know names or dates. As you read, think big picture; such as:

- Why are people interested in learning about learning and memory?
- How has our understanding of learning and memory changed over time?
- Why has understanding of learning and memory changed over time?

As you make your notes on this topic, think about:

- Why does research into learning and memory often require collaboration amongst teams of scientists with different specialties?

THE STUDY OF HUMAN MEMORY

The study of human memory stretches back at least 2,000 years to Aristotle's early attempts to understand memory in his treatise *"On the Soul"*. In this, he compared the human mind to a blank slate and theorized that all humans are born free of any knowledge and are merely the sum of their experiences. Aristotle compared memory to making impressions in wax, sometimes referred to as the "storehouse metaphor", a theory of memory which held sway for many centuries. In antiquity, it was generally assumed that there were two sorts of memory: the "natural memory" (the inborn one that everyone uses every day) and the "artificial memory" (trained through learning and practice of a variety of mnemonic techniques, resulting in feats of memory that are quite extraordinary or impossible to carry out using the natural memory alone). Roman rhetoricians such as Cicero and Quintillian expanded on the art of memory or the method of loci (a method often first attributed to Simonides of Creos or the Pythagoreans), and their ideas were passed down to the medieval Scholastics and later scholars of the Renaissance like Matteo Ricci and Giordano Bruno.

??? Did You Know ???

Proponents of the "tabula rasa" (blank slate) thesis favour the nurture side of the nature versus nurture debate, when it comes to aspects of personality, intelligence and social and emotional behaviour.
The idea first surfaced in a treatise of Aristotle, but then lay dormant for over a thousand years until developed by the 11th Century Persian philosopher Avicenna, and then John Locke's classic statement of the theory in the 17th Century.
Sigmund Freud revived the idea in the 20th Century, depicting personality traits as being formed by family dynamics.

The 18th Century English philosopher David Hartley was the first to hypothesize that memories were encoded through hidden motions in the nervous system, although his physical theory for the process was rudimentary at best. William James in America and Wilhelm Wundt in Germany, both considered among the founding fathers of modern psychology, both carried out some early basic research into how the human memory functions in the 1870s and 1880s (James hypothesized the idea of neural plasticity many years before it was demonstrated). In 1881, Théodule-Armand Ribot proposed what became known as Ribot's Law, which states that amnesia has a time-gradient in that recent memories are more likely to be lost than the more remote memories (although in practice this is actually not always the case).

However, it was not until the mid-1880s that the young German philosopher Herman Ebbinghaus developed the first scientific approach to studying memory. He did experiments using lists of nonsense syllables, and then associating them with meaningful words, and some of his findings from this work (such as the concepts of the learning curve and forgetting curve, and his classification of the three distinct types of memory: sensory, short-term and long-term) remain relevant to this day.

The German evolutionary biologist Richard Semon first proposed in 1904 the idea that experience leaves a physical trace, which he called an engram, on specific webs of neurons in the brain. The British psychologist Sir Frederick Bartlett is considered one of the founding fathers of cognitive psychology, and his research in the 1930s into the recall of stories greatly influenced later ideas on how the brain stores memories.

With advances in technology in the 1940s, the field of neuropsychology emerged and with it a biological basis for theories of encoding. Karl Lashley devoted 25 years of his life to research on rats in mazes, in a systematic attempt to pinpoint where memory traces or engrams are formed in the brain, only to conclude in 1950 that memories are not localized to one part of the brain at all, but are widely distributed throughout the cortex, and that, if certain parts of the brain are damaged, other parts of the brain may take on the role of the damaged portion.

??? Did You Know ???

Flashbacks are involuntary (and often recurring) memories, in which an individual has a sudden powerful re-experiencing of a past memory, sometimes so intense that the person "re-lives" the experience, unable to fully recognize it as a memory and not something that is really happening.
Such involuntary memories are often of traumatic events or highly-charged emotional happenings, and often occur at times of high stress or food deprivation, although the exact causes and mechanisms are not clear.

The Canadian neurosurgeon Wilder Penfield's work on the stimulation of the brain with electrical probes in the 1940s and 1950s, initially in search of the causes of epilepsy, allowed him to create maps of the sensory and motor cortices of the brain that are still used today, practically unaltered. He was also able to summon up memories or flashbacks (some of which the patients had no conscious recollection of) by probing parts of the temporal lobe of the brain.

As early as 1949, another Canadian, Donald Hebb, intuited that "neurons that fire together, wire together", implying that the encoding of memories occurred as connections between neurons were established through repeated use. This theoretical idea, sometimes referred to as Hebb's Rule, was supported by the discovery of the mechanics of memory consolidation, long-term potentiation and neural plasticity in the 1970s, and remains the reigning theory today. Eric Kandel's work on sea-slugs (whose brains are relatively simple and contain relatively large, and easily-observed, individual neural cells) was particularly important in experimentally demonstrating Hebb's Rule and identifying the molecular changes during learning, and the neurotransmitters involved.
As computer technology developed in the 1950s and 1960s, parallels between computer and brain processes became apparent, leading to advances in the understanding of the encoding, storage and retrieval processes of memory. The computer metaphor is, however, essentially just a more sophisticated version of the earlier storehouse view of memory, based on the rather simplistic and misleading assumption that a memory is just a simple copy of the original experience.

??? Did You Know ???

The brain in general, and memory in particular, has a distinct **negativity bias**. It pays more attention to, and highlights, **unpleasant experiences**. The brain typically detects negative information faster than positive information, and the **hippocampus** specifically flags negative events to make doubly sure that such events are stored in memory. Negative experiences leave an indelible trace in the memory, even when efforts are made to "unlearn" them.
This is probably an evolutionary adaptation, given that it is better to err on the side of **caution** and ignore a few pleasant experiences than to overlook a negative, and possibly dangerous, event.

The change in the overall study of memory during the 1950s and 1960s has come to be known as the **"cognitive revolution"**, and led to several new theories on how to view memory, and yielded influential books by **George Miller**, **Eugene Galanter**, **Karl Pribram**, **George Sperling** and **Ulric Neisser**. In 1956, George Miller produced his influential paper on short-term memory and his assessment that our short-term memory is limited to what he called "the magical number seven, plus or minus two".
In 1968, **Richard Atkinson** and **Richard Shiffrin** first described their **modal**, or **multi-store**, model of memory - consisting of a sensory memory, a short-term memory and a long-term memory - which became the most popular model for studying memory for many years. **Fergus Craik** and **Robert Lockhart** offered an alternative model, known as the **levels-of-processing** model, in 1972. In 1974, **Alan Baddeley** and **Graham Hitch** proposed their model of working memory, which consists of the central executive, visuo-spatial sketchpad and phonological loop as a method of encoding.

The 1970s also saw the early work of **Elizabeth Loftus**, who carried out her influential research on the **misinformation effect**, **memory biases** and the nature of **false memories**. The pioneering research on human memory by **Endel Tulving** from the 1970s onwards has likewise been highly influential. He was the first to propose two distinct kinds of long-term memory, episodic and semantic, in 1972 and he also devised the **encoding specificity principle** in 1983.

During the 1980s and 1990s, several formal models of memory were developed that can be run as computer simulations, including the **Search of Associative Memory (SAM) model** proposed by Jerome Raaijmaker and Richard Shiffrin in 1981, the **Parallel Distributed Processing (PDP) model** of James McClelland, David Rumelhart and Geoffrey Hinton's in 1986, and various versions of the **Adaptive Control of Thought (ACT) model** developed by John Anderson in 1993.

Nowadays, the study of human memory is considered part of the disciplines of **cognitive psychology** and **neuroscience**, and the interdisciplinary link between the two which is known as **cognitive neuroscience**. You can visit advancedwriters.com/custom-research-paper/ if you need research paper help from experts.

Research into the brain, memory and learning is a rapidly expanding area of scientific study which perfectly illustrates the cooperation and collaboration between groups of scientists. Psychologists, molecular biologists, biochemists, physicians, pharmacists, mathematicians and computer scientists all work together to understand the functioning of the brain. For example, the newly formed Science of Learning Institute at Johns Hopkins University (scienceoflearning.jhu.edu) illustrates the collaborative nature of brain research. The institute has the people with the following areas of expertise on the team:

- Neuroscience
- Electrical engineering
- Computer engineering
- Psychology
- Pediatric medicine
- Cognitive science
- Surgery
- Education
- Philosophy
- Mechanical engineering
- Biomedical engineering
- Genetics
- Radiology

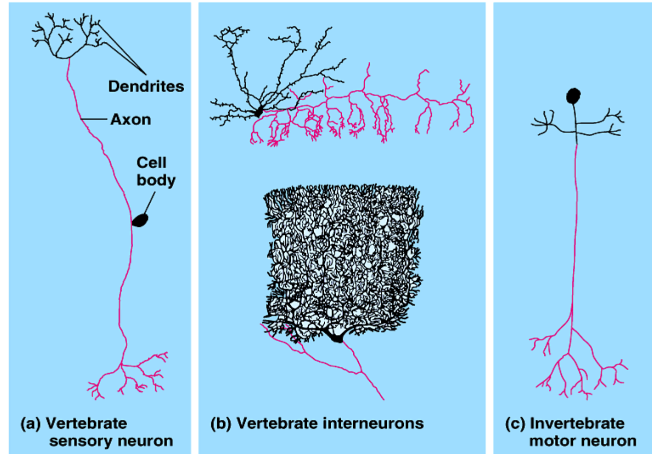
There are research institutions and universities around the world investigating learning and the brain. Although there is sometimes competition among scientists to be the first to make a discovery, there is also cooperation and assistance between scientists.

TOPIC C: BIOLOGY OF LEARNING

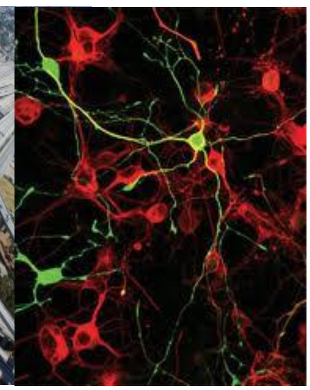
The following is a basic breakdown of our current understanding of learning.

As you make your notes on this topic, think about:

- What are the basic cellular structures involved in learning and memory?
- What are "neural pathways" and how are they formed?
- Explain how the phrase, "use it or lose it" is relevant to learning.



1. Learning is the process by which new knowledge or skills sticks to our brains. Its *functional "sticky" unit* is the **neuron**. Neurons are cells specially adapted to communicate with each other. Neurons have a **cell body** and fibers which extend from them called **dendrites** and **axons**. These fibers are the key to learning because they are the connectors between cells.
2. Everything we experience is reflected in the brain by neurons which communicate to form what are called **neural pathways**. These networks can be pictured as overlapping 3-D road maps which span brain regions responsible for processing everything from the bitter-sweet taste of dark chocolate to why your neighbor is such a grump. As we learn, these neural "road maps" interact and shift while also fading or strengthening in relation to our experiences.
3. Whether it be recognizing a friend or changing a flat tire, learning entails the formation and strengthening of *connections* or **synapses** between neurons. Brief experiences typically leave connections tracing as short-lived neural network. This might be envisioned as crisscrossing deer paths which, if left unused, fade quickly.
4. After repeated exposure to a learning experience, like the second time we change that flat tire, the associated neuronal connections are reinforced, resembling more a network of single lane country roads than deer paths. And when it comes to daily



practice and *expertise* in a skill, one can imagine that the guy at the local tire shop would have the neuronal equivalent of intersecting superhighways. This strengthening of neural network connections is thought to be the physiological basis of learning.

5. **To summarize**: The neural pathway becomes "entrenched" through repetition of the stimulus. The more times the neural pathway is used the more dendrite connections. The more dendrite connections, the faster the message can be sent. Think of singing the song "twinkle twinkle little star." The very first time you sing the song, you don't know the words because no neural pathway exists. The next time you sing it, it is easier to remember the words because you have started to create a neural pathway. Eventually, all you need to hear is "twinkle twinkle…" and the rest just comes into your brain. This happens because you have forged a strong neural pathway through the repetition of singing the song.
6. The path → country road → city street → freeway analogy is really good – but what is happening at cellular or molecular level when learning occurs? The answer is that we still have a lot to learn about learning!

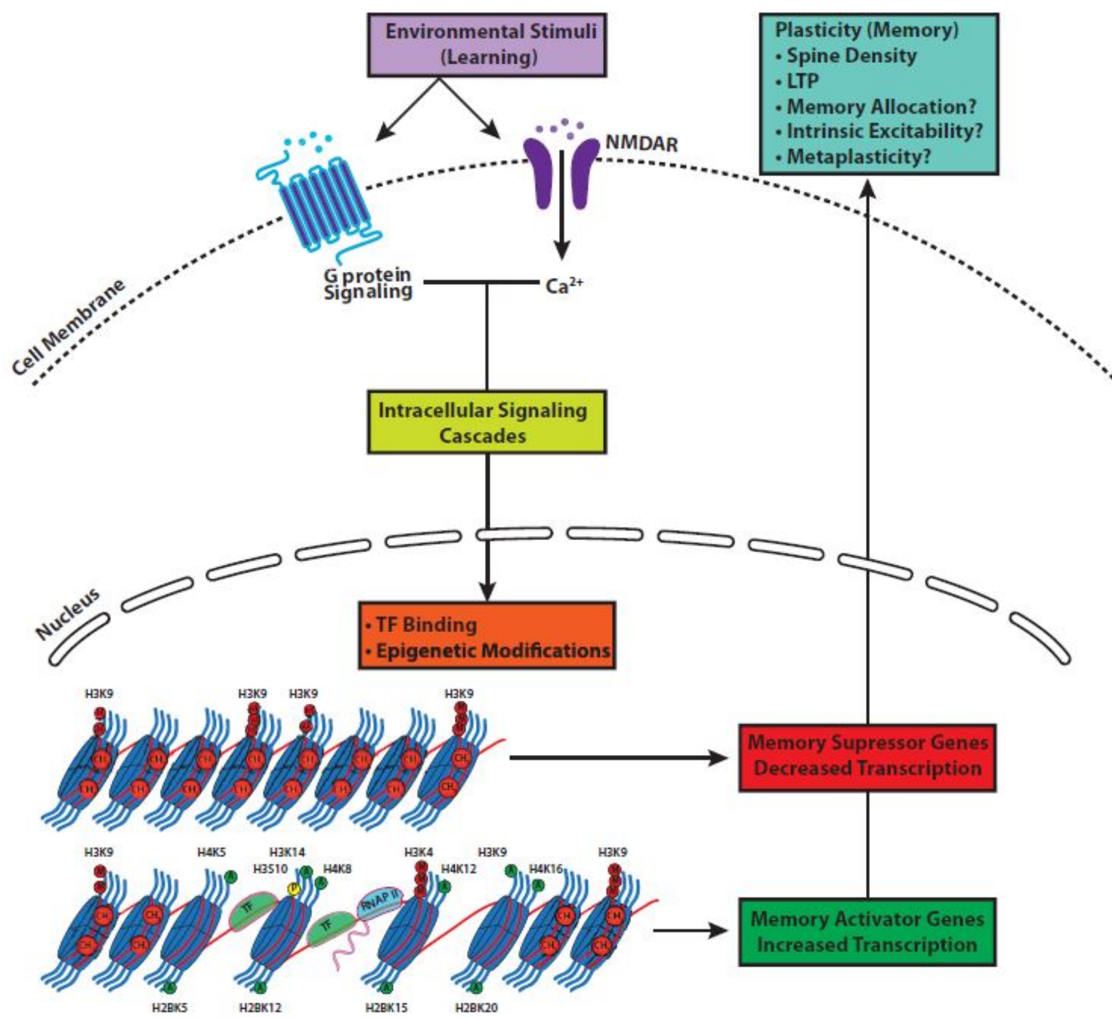


Figure 2. A model depicting the role of epigenetic mechanisms in memory formation and maintenance. Environmental stimuli, which consist primarily of associative learning tasks in animal models, initiate cellular communication by activating specific post-synaptic receptors. Receptor activation stimulates specific intracellular signaling cascades that lead to particular patterns of epigenetic modifications, which in turn regulate the access of transcription factors (TF) and RNA polymerase II (RNA P II) to gene promoters. These regulatory processes result in an increased transcription of memory activator genes and decreased transcription of memory-suppressor genes, which ultimately promote memory formation and maintenance through effects on long-term potentiation (LTP), spine density, memory allocation, cell excitability, and metaplasticity.

TOPIC D: IMPORTANCE OF REPETITION

Each time you are exposed to a learning stimulus the neural connection becomes stronger and stronger. Therefore, **REPETITION IS THE KEY TO LEARNING**. We've actually known this for a long time!

Science 16 September 1966:
Vol. 153 no. 3742 pp. 1351-1358
DOI: 10.1126/science.153.3742.1351

ARTICLES

Time-Dependent Processes in Memory Storage

James L. McGaugh[1]

± Author Affiliations

ABSTRACT

These observations indicate that the long-lasting trace of an experience is not completely fixed, consolidated, or coded at the time of the experience. Consolidation requires time, and under at least some circumstances the processes of consolidation appear to be susceptible to a variety of influences— both facilitating and impairing— several hours after the experience. There must be, it seems, more than one kind of memory trace process (31). If permanent memory traces consolidate slowly over time, then other processes must provide a temporary basis for memory while consolidation is occurring. The evidence clearly indicates that trial-to-trial improvement, or learning, in animals cannot be based completely on permanent memory storage. Amnesia can be produced by electroshock and drugs even if the animals are given the treatment long after they have demonstrated "learning" of the task.

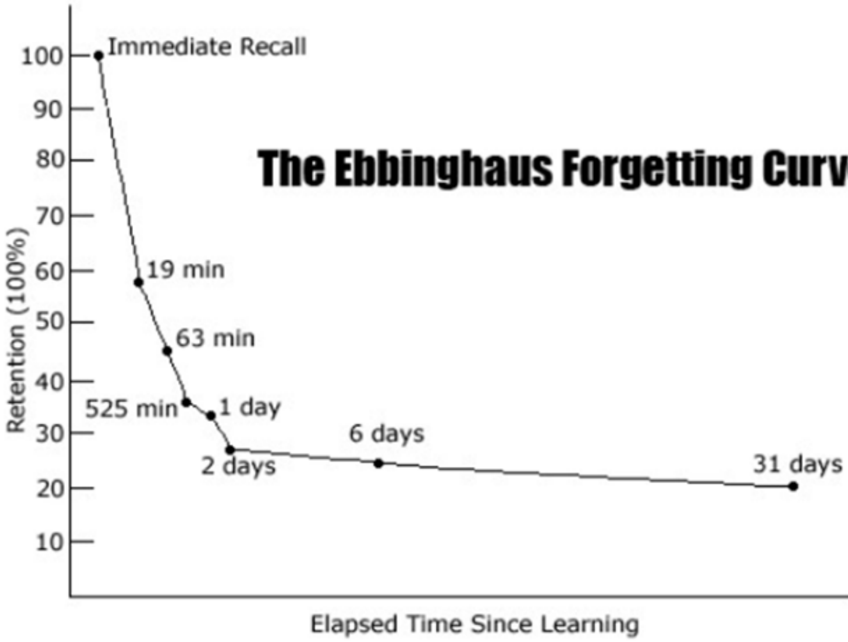
CITATION

Effects of repetition and spaced review upon retention of a complex learning task. Database: PsycARTICLES
Reynolds, James H.; Glaser, Robert [Journal Article]
Journal of Educational Psychology, Vol 55(5), Oct 1964, 297-308. doi: 10.1037/h0040734

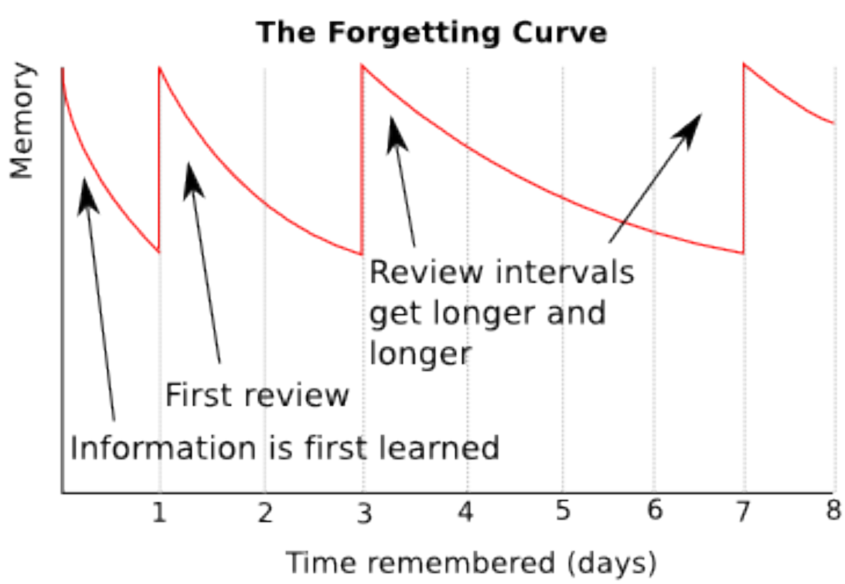
ABSTRACT

2 experiments were conducted to evaluate the effects of (a) amount of S-R repetition and (b) the spacing of periodic review sequences upon retention of academic materials taught to junior-high-school Ss by programed instruction methods. Repetition was varied by constructing programed sequences which contained 3 different levels of stimulus and response repetitions for each of a number of scientific terms being taught. Spaced review consisted of presenting review frames of previously learned materials after Ss had received other interpolated learning tasks. Results indicated that variations in repetition had only transitory effects upon retention, but that spaced review produced a significant facilitation in retention of the reviewed material. (PsycINFO Database Record (c) 2012 APA, all rights reserved)

Without repetition, what the brain is able to recall after initially learning something diminishes with time. The "forgetting curve" shows the percentage of recall over time, and more importantly, the percentage of information forgotten.



Without review, the further out the test is from learning the material, the lower you can expect to score. **Duh.** To be efficient, you as a learner need to expose the brain to the information you wish to learn at key times. These are 24 hours, 48 hours, one week and once a month for as long as you wish to remember the details of the subject. Through repetition, knowledge can be kept at an optimal level. This isn't made up, real science supports this.

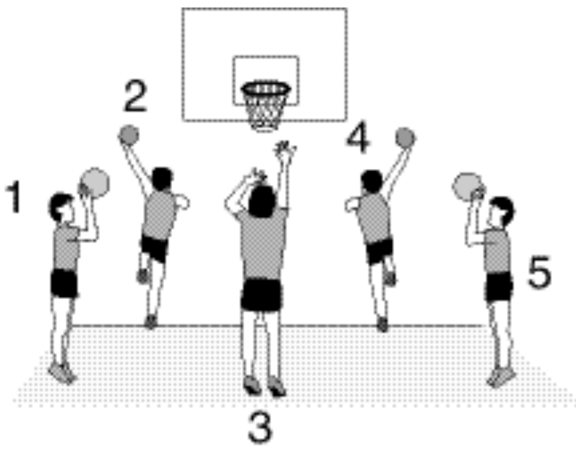


For fun in remembering:

youtube.com/watch?v=0ahnDEXOagw

youtube.com/watch?v=5MgBikgcWnY

Read the article below about distributed versus blocked practice. Make notes on how you can apply this technique to academic study.



Distributed Versus Blocked Practice
Distributed Drills Produce Better Performance in Games
The traditional way to schedule skill drills within a team-sport practice is to repeat the skill a number of times with no interruption by other activities. A basketball example might be practicing five consecutive jump shots from the same spot. This type of training is called **"block practice."**

Block Practice
Block practice seems to be the fastest way to develop a nervous system pattern for optimal technique-and it does make it easier for the athlete to concentrate on the skill. And in fact, most athletes do show faster progress during practice when using block practice. However, recent motor skill studies have shown that while block practice produces the best practice results, a system called **"distributed practice"** produces better results during actual team sport competitions.

Distributed Practice
In distributed practice, a skill is never practiced twice in a row. Instead, a repetition of a skill is followed by a variation of the skill or a repetition of a different technique entirely. For example, to vary the skill, instead of taking five jump shots from the high post position, the player might take a jump shot from the high post, then from the baseline, then from the low post, then the opposite baseline, then the top of the key. Or to intersperse different skills, the player might first take a jump shot, then a right-handed layup, then a hook shot, then a left-handed layup, then another jump shot.

Why Distributed Practice is More Effective
There are several reasons why distributed practice produces better competition results:

1. **Better Reaction to Different Situations** In reacting to a competitive situation, an athlete must subconsciously decide which skill to use, then recall it from his/her memory, then send that message to the appropriate muscles. Distributed practices are more like game situations because every repetition requires a decision and recall. In block practice, no decision has to be made after the first repetition.
2. **Better Learning** Skills practiced using distributed methods are learned better and remembered longer. Why? Because athletes performing different skills in a sequence are able to compare techniques (i.e. OK, this is like shooting a foul shot, except). This comparison produces a better understanding of the skill, which improves its performance.
3. **Attention** Repeating the same skill over and over can become boring. Constantly changing the task requires greater concentration and makes practice more challenging.
4. **Application Y**ou can use distributed drills once your students can perform a rough approximation of the skill. You can change the entire skills used in your practice sequence or you can use variations of the skill: for example, changes in speed, distance, direction, sequence, or opposition, through the complete range of variations that might occur in a game.

Conclusion
Distributed practice (see Basketball Scoring example below) will be more effective in team sports, where skills must be selected and performed according to rapidly changing situations. And the ability to compare with other related skills may also make it an effective option when learning individual sports skills. However, block practice does seem to produce better in-practice results.

http://test.scoilnet.ie/Res/tonyweir230100205032_2.htm?utm_campaign=elearningindustry.com&utm_source=%2Fbeating-the-forgetting-curve-with-distributed-practice&utm_medium=link

TOPIC E: MULTITASKING WHILE LEARNING

Do you have your phone near you? Put it away.

Do you have multiple internet browser tabs open? Close all but this one.

Are you texting? Stop.

Are you sending an instant message? Type *brb* or *g2g*.

The fact of the matter is, we cannot learn well while the brain is multitasking. According to BrainFacts.org…

More than one task splits the brain

Whenever you need to pay attention, an area toward the front of the brain called the prefrontal cortex springs to action. This area, which spans the left and right sides of the brain, is part of the brain's motivational system. It helps to focus your attention on a goal and coordinates messages with other brain systems to carry out the task.

While the right and left sides of the prefrontal cortex work together when focused on a single task, the sides work independently when people attempt to perform two tasks at once. Scientists at the Institut National de la Santé et de la Recherche Médicale (INSERM) in Paris discovered this when they asked study participants to complete two tasks at the same time while undergoing functional magnetic resonance imaging (fMRI). When the scientists told the group they would receive a larger reward for accurately completing one of the two tasks, they found that nerve cell activity increased in only one side of the prefrontal cortex. However, when the greater reward was associated with the other task, the other side became more active. The findings suggest that when there are two concurrent goals, the brain divides in half, says INSERM neuroscientist Etienne Koechlin, who led the study.

When the scientists asked the study participants to attempt yet another task, they found that the participants regularly forgot one of the three tasks they were asked to perform. The participants also made three times as many errors as they had made when attempting only two tasks. Koechlin says the study demonstrates that while we can readily switch between two tasks, we "might be in great trouble when we try to juggle more than two tasks, simply because we have only two frontal lobes."

To put it simply, when we are multitasking, the brain is not able to "consolidate" information. Watch this YouTube video to learn more (youtube.com/watch?v=cKaWJ72x1rI). *Note: the biologist in me must point out that humans and dinosaurs did not live on the planet at the same time.*

TOPIC F: Study Tips and Tricks

In schools, we use the word "study" frequently and incorrectly assuming that it means the same thing to everyone. But, it doesn't. For way too many students, studying doesn't happen until just before a test. Many students see no reason to study if there is no test on the horizon. So, there it is- one of the most serious misunderstandings between teachers and students. For teachers, the purpose of study is to understand and remember the course content; for students the purpose of study is to pass the test. In an ideal world, these would amount to the same thing.

Brain research is able to provide guidance around the best ways to study. Watch this YouTube clip (youtube.com/watch?v=p60rN9JEapg&amp=&feature=youtu.be) and then read the article below to learn more.

Getty Ingfei Chen

How Does the Brain Learn Best? Smart Studying Strategies

In his new book, "How We Learn: The Surprising Truth about When, Where, and Why It Happens," author Benedict Carey informs us that "most of our instincts about learning are misplaced, incomplete, or flat wrong" and "rooted more in superstition than in science."

That's a disconcerting message, and hard to believe at first. But it's also unexpectedly liberating, because Carey further explains that many things we think of as detractors from learning — like forgetting, distractions, interruptions or sleeping rather than hitting the books — aren't necessarily bad after all. They can actually work in your favor, according to a body of research that offers surprising insights and simple, doable strategies for learning more effectively.

Society has ingrained in us "a monkish conception of what learning is, of you sitting with your books in your cell," Carey told MindShift. It's a ritual of self-discipline, isolation and blocks of repetitive practice, whether in math, vocabulary, piano or tennis. But that traditional ideal has psychological downsides. Often, "you feel like you haven't done it right or you haven't done enough of it," he said. "It causes a lot of anxiety because of what we think we should be doing." For many students, learning has become a high-stress burden.

"How We Learn" presents a new view that takes some of the pressure off. As a veteran science reporter for the New York Times and previously the Los Angeles Times, Carey has covered cognitive science, psychology and psychiatry for 20 years. (Disclosure: I've known Carey since we both worked at Time Inc. Health in the '90s.) Combing through decades of cognitive science investigations of memory and learning, he has pulled together its best lessons into a practical and engaging guide.

He lays out a variety of counterintuitive techniques that can aid and deepen learning, sprinkles in some illustrative memory exercises and puzzles, and weaves in his own painful experiences as a restless and anxious — yet dutiful and hardworking — student who initially failed to get into college. All in all, Carey vividly shows readers how learning can be less of a chore and more a way of living that lets new information and skills "seep under our skin."

Getting to Know Your Brain's Memory Processes. In an interview, he highlighted three take-home messages from his book:

Forgetting isn't always bad. Most of the time, it's natural and essential to remembering and learning. According to a theory championed by Robert Bjork and Elizabeth Ligon Bjork at UCLA, forgetting serves as a powerful spam filter: Whenever you're trying to recall a word or fact, your brain has to actively suppress, or forget, competing information. What's more, the way memories tend to fade over time actually aids subsequent learning. Under a principle the Bjorks call desirable difficulty, when the brain has to work hard to retrieve a half-forgotten memory (such as when reviewing new vocabulary words you learned the day before), it re-doubles the strength of that memory.

If you sit down to study a load of material, “of course you’re not going to remember most of it the next day,” Carey said. You do have to go back and build your knowledge. “But it’s not that you don’t remember well, or you’re not a good learner. It’s that forgetting is a critical part of learning.”

The brain is a foraging learner. For our ancient hominid ancestors, remembering how and where to hunt prey or find shelter was crucial to survival. The human brain evolved to pick up valuable pieces of information here and there, on the fly, all the time, and put it all together, he said. It still does that — absorbing cues from daily life, overheard conversations, its own internal musings. It keeps things in mind that are important to you (an unfinished project, for instance) and adds to your thoughts about them by subconsciously tuning in to any relevant information you see or hear around you. By foraging in this way, the brain is “building knowledge continually, and it’s not only during study or practice,” Carey said. And we’re not even completely aware of that.

We can be tactical in our schooling. The traditional advice on learning has been to “study hard,” in a quiet place and with the same routine, yet that doesn’t say much about what to specifically do. But pupils today can change the way they study to exploit the brain’s quirky learning processes, using the strategies revealed by memory and learning research. While that science is still maturing, “it’s at a place now where it can give you a specific tactical plan,” Carey said. Students can tailor their preparation with techniques targeting different kinds of content or skills, and manage their schedule to optimize their time. “That’s a powerful thing, because we go through our whole lives never knowing that,” he said.

For example:

— Breaking up and spacing out study time over days or weeks can substantially boost how much of the material students retain, and for longer, compared to lumping everything into a single, nose-to-the-grindstone session.

— Varying the studying environment — by hitting the books in, say, a cafe or garden rather than only hunkering down in the library, or even by listening to different background music — can help reinforce and sharpen the memory of what you learn.

— A 15-minute break to go for a walk or trawl on social media isn’t necessarily wasteful procrastination. Distractions and interruptions can allow for mental “incubation” and flashes of insight — but only if you’ve been working at a problem for a while and get stuck, according to a 2009 research meta-analysis.

— Quizzing oneself on new material, such as by reciting it aloud from memory or trying to tell a friend about it, is a far more powerful way to master information than just re-reading it, according to work by researchers including Henry Roediger III and Jeffrey Karpicke. (Roediger has co-authored his own book, “Make It Stick: The Science of Successful Learning.”)

Experimenting With Learning Tactics. Anybody can try these methods to see what works best, Carey said. For instance, to prepare for a Spanish test that’s one week away, students could plan to study an hour today, an hour tomorrow — and then self-test themselves next week right before the exam, he said. The book also explores the benefits of sleep (which improves retention and comprehension of what you learn), perceptual learning modules and mixing up different kinds of related problems or skills in practice sessions instead of repetitively rehearsing just one skill at a time.

Carey thinks the science-based learning strategies should explicitly be taught to all students early on, as part of the school curriculum. But kids shouldn’t use them “as an excuse to do nothing,” he added. The message isn’t that they can spend every second glued to their cellphones and still be learning. “You have to be motivated and pay attention and so on.”

Unfortunately, most people, educators included, are unaware of the lessons from the science of learning, Carey said. Education and cognitive science are largely separate worlds that have begun communicating only in the last decade, partly because “teachers see all sorts of reforms come and go, and they’re skeptical — and rightly so — of anyone who comes in and says, “Well, I’m going to tell you how to make the kids learn better,” he said. But some individual teachers who have followed the research may be applying certain strategies in the classroom, he said, such as assigning mixed-up math problem sets.

Knowing the basics of how the brain actually learns can offer breathing room from societal expectations about “good” academic habits. A fidgety teenager who has trouble concentrating and forgets her physics formulas might think, “I’m no good at this” or “I’m not so smart, and maybe it’s not worthwhile for me to pursue this,” Carey said. But that’s not necessarily true, according to the cognitive research. Students need to understand that learning happens not only during reading and studying, but in all sorts of ways, so that they can examine their own habits to know which ones may be helping or not, and make adjustments, he said. Only then can they evaluate whether they’re good at something.

Surviving the Modern Jungle. Ultimately, the value of these learning strategies isn’t just about earning better grades, Carey said. In the modern jungle of society, learning is still about surviving: For young people, it’s about sussing out what they’re good at, what rings their bell, and what they want to do with their lives. “It’s informing you of: Who am I? Where do I place my bets? Do I major in physics or do I major in architecture or design, or do I major in English? Do I belong here at all?” Carey said. Those are important decisions. “Being self-aware about what’s effective learning and how it happens, I think, gives you a real edge in making those choices.”

Carey has fully incorporated the learning techniques into his own life — whether in practicing guitar or getting up to speed on the latest neuroscience research to write a newspaper story. For example, when reading a difficult scientific journal article, “I realize I’m not going to understand a bunch of the stuff right away, no matter how hard I try or concentrate. I don’t let that slow me down.” He runs through it a few times, puts it aside and, spacing out his learning, tries again later, when the material almost always begins to gel.

Deadline pressure often forces him to start writing his article before he even has all the pieces, which is an “extremely valuable way to efficiently pick up the knowledge,” he said. “In effect, you’re testing yourself on how much you know… and you’re trying to write it clearly so you’re sort of teaching it, too. Those are two very effective study techniques.” He wishes he’d known these learning secrets years ago, when he was in school. “I know for sure it would’ve taken so much of the anxiety and dread out of preparation and study and learning,” Carey said.

Study groups are a great way to study, IF you use the time efficiently to talk about the course content, review notes and compare assigned work. Schedule firm times and places to talk about the content, write summary paragraphs or descriptions, and/or make labeled diagrams.

TOPIC G: Sleep to Learn

A person is not able to retain information when they are sleep deprived. Rapid-eye-movement sleep (REM sleep) is essential for a good memory. A student's performance in school and the amount of sleep they receive are in direct correlation with each other. It has been shown that adolescents who receive a good amount of sleep receive better grades than those who receive less sleep. Researchers at the University of Minnesota reported the results of a study of more than 7,000 high-school students whose school district had switched from a 7:15 am start time to an 8:40 am start time. Compared with students whose schools maintained earlier start times, students with later starts reported getting more sleep on school nights, being less sleepy during the day, getting slightly higher grades and experiencing fewer depressive feelings and behaviors.

This chart shows the correlation between the amount of hours students sleep per day and their grade point averages. Radwin reports that, on average, the GPA of students who usually sleep at least seven hours per weeknight is 0.10 points (a tenth of a letter grade) higher than students who sleep five to six hours. And it's 0.29 points higher (about the difference between a B+ and a B) than students who slept less than five hours. The study clearly shows that as the hours of sleep the students receive per day increases, their grade point averages also increase.

Watch this video clip (youtube.com/watch?v=SVQlcxiQlzI) to see how much sleep you need and then read the article below to learn more about the importance of sleep on learning and memory.

Sleep, Learning, and Memory
At a Glance
Research suggests that sleep plays an important role in memory, both before and after learning a new task.
Lack of adequate sleep affects mood, motivation, judgment, and our perception of events.
Although there are some open questions about the specific role of sleep in forming and storing memories, the general consensus is that consolidated sleep throughout a whole night is optimal for learning and memory.

The Learning Process and Sleep
Sleep, learning, and memory are complex phenomena that are not entirely understood. However, animal and human studies suggest that the quantity and quality of sleep have a profound impact on learning and memory. Research suggests that sleep helps learning and memory in two distinct ways. First, a sleep-deprived person cannot focus attention optimally and therefore cannot learn efficiently. Second, sleep itself has a role in the consolidation of memory, which is essential for learning new information.

Although the exact mechanisms are not known, learning and memory are often described in terms of three functions. Acquisition refers to the introduction of new information into the brain. Consolidation represents the processes by which a memory becomes stable. Recall refers to the ability to access the information (whether consciously or unconsciously) after it has been stored.

Each of these steps is necessary for proper memory function. Acquisition and recall occur only during wakefulness, but research suggests that memory consolidation takes place during sleep through the strengthening of the neural connections that form our memories. Although there is no consensus about how sleep makes this process possible, many researchers think that specific characteristics of brainwaves during different stages of sleep are associated with the formation of particular types of memory.

Sleep researchers study the role of sleep in learning and memory formation in two ways. The first approach looks at the different stages of sleep (and changes in their duration) in response to learning a variety of new tasks. The second approach examines how sleep deprivation affects learning. Sleep deprivation can be total (no sleep allowed), partial (either early or late sleep is deprived), or selective (specific stages of sleep are deprived).

Sleep Stages and Types of Memory

Different types of memories are formed in new learning situations. Scientists are exploring whether there is a relationship between the consolidation of different types of memories and the various stages of sleep.
The earliest sleep and memory research focused on declarative memory, which is the knowledge of fact-based information, or "what" we know (for example, the capital of France, or what you had for dinner last night). In one research study, individuals engaged in an intensive language course were observed to have an increase in *rapid-eye-movement* sleep, or REM sleep. This is a stage of sleep in which dreaming occurs most frequently. Scientists hypothesized that REM sleep played an essential role in the acquisition of learned material. Further studies have suggested that REM sleep seems to be involved in declarative memory processes if the information is complex and emotionally charged, but probably not if the information is simple and emotionally neutral.

Researchers now hypothesize that slow-wave sleep (SWS), which is deep, restorative sleep, also plays a significant role in declarative memory by processing and consolidating newly acquired information. Studies of the connection between sleep and declarative memory have had mixed results, and this is an area of continued research.

Research has also focused on sleep and its role in procedural memory—the remembering "how" to do something (for example, riding a bicycle or playing the piano). REM sleep seems to plays a critical role in the consolidation of procedural memory. Other aspects of sleep also play a role: motor learning seems to depend on the amount of lighter stages of sleep, while certain types of visual learning seem to depend on the amount and timing of both deep, slow-wave sleep (SWS) and REM sleep.

The Impact of Sleep Deprivation on Learning and Performance

Another area that researchers study is the impact that a lack of adequate sleep has on learning and memory. When we are sleep deprived, our focus, attention, and vigilance drift, making it more difficult to receive information. Without adequate sleep and rest, over-worked neurons can no longer function to coordinate information properly, and we lose our ability to access previously learned information.

In addition, our interpretation of events may be affected. We lose our ability to make sound decisions because we can no longer accurately assess the situation, plan accordingly, and choose the correct behavior. Judgment becomes impaired.

Being chronically tired to the point of fatigue or exhaustion means that we are less likely to perform well. Neurons do not fire optimally, muscles are not rested, and the body's organ systems are not synchronized. Lapses in focus from sleep deprivation can even result in accidents or injury.

Low-quality sleep and sleep deprivation also negatively impact mood, which has consequences for learning. Alterations in mood affect our ability to acquire new information and subsequently to remember that information. Although chronic sleep deprivation affects different individuals in a variety of ways (and the effects are not entirely known), it is clear that a good night's rest has a strong impact on learning and memory.

Open Questions

Although current research suggests that sleep is essential for proper memory function, there are unanswered questions, as in any area of active scientific inquiry. For example, certain medications will significantly, if not entirely, suppress REM sleep. However, patients taking these medications do not report any memory impairment. Similarly, injuries or disease causing lesions to the brainstem (and subsequently eliminating a person's REM sleep) have not resulted in any obvious loss of the ability to form new memories. Exploration and debate continue.

Not all researchers are convinced that sleep plays as prominent a role in memory consolidation as others believe. In experiments in which animals completed a course through a complicated maze, the animals' amount of REM sleep increased after performing the task. Some researchers believe that the increase in REM sleep reflects an increased demand on the brain processes that are involved in learning a new task. Other researchers, however, have suggested that any changes in the amount of REM sleep are due to the stress of the task itself, rather than a functional relationship to learning.

Researchers are likewise split with regard to the impact of sleep deprivation on learning and memory. For example, rats often perform much worse on learning tasks after being selectively deprived of REM sleep. This suggests that REM sleep is necessary for the animals' ability to consolidate the memory of how to perform the task. Some scientists have argued that the observed differences in learning are not actually due to the lack of REM sleep, but may be due to the animals not being as well rested because they were deprived a portion of their sleep.

Summary

In the view of many researchers, evidence suggests that various sleep stages are involved in the consolidation of different types of memories and that being sleep deprived reduces one's ability to learn. Although open questions (and debate) remain, the overall evidence suggests that adequate sleep each day is very important for learning and memory.

Harvard University
A resource from the Division of Sleep Medicine at
Harvard Medical School
Produced in partnership with WGBH Educational Foundation

TOPIC H: A Common Mistake:

A common mistake is when a student "thinks they know" something when they really don't. Unfortunately, it's not often until a quiz or test that students realize they "don't actually know." Oops.

This effect is called the **CURSE OF FAMILIARITY** and it's primary cause is the (bad) study technique of re-reading notes over and over. Read all about it below (note, the article is designed for a teacher audience, but students can figure it out…)

Ask the Cognitive Scientist

Why Students Think They Understand—When They Don't By Daniel T. Willingham

Question: Very often, students will think they understand a body of material. Believing that they know it, they stop trying to learn more. But, come test time, it turns out they really don't know the material. Can cognitive science tell us anything about why students are commonly mistaken about what they know and don't know? Are there any strategies teachers can use to help students better estimate what they know?

Answer: There are multiple cues by which each of us assess what we know and don't know. But these cues are fallible, which explains why students sometimes think that they know material better than their classroom performance indicates.

How do we know that we know something? If I said to you, "Could you name the first President of the United States?" you would say, "Yes, I could tell you that." On the other hand, if I said, "Could you tell me the names of the two series of novels written by Anthony Trollope?" you might say, "No." What processes go into your judgment of what you know? The answer may at first seem obvious: You look in your memory and see what's there. For the first question, you determine that your memory contains the fact that George Washington was the first U.S. President, so you answer "yes." For the second question, if you determine that your memory contains little information about Trollope (and doesn't include the novel series named Barchester and Palliser), you would answer "no."

But, if the mechanism were really so simple, we would seldom—if ever —make mistakes about what we know. In fact, we do make such mistakes. For example, we have all confidently thought that we knew how to get to a destination, but then when put to the test by actually having to drive there, we realize that we don't know. The route may seem familiar, but that's a far cry from recalling every turn and street name.

The feeling of knowing has an important role in school settings because it is a key determinant of student studying (e.g., Mazzoni & Cornoldi, 1993). Suppose a third-grader has been studying the Vikings with the goal of understanding where they were from and what they did. At what point does the third-grader say to him or herself: "I understand this. If the teacher asks me, 'Who were the Vikings?' I could give a good answer."

Every teacher has seen that students' assessments of their own knowledge are not always accurate. Indeed, this inaccuracy can be a source of significant frustration for students on examinations. The student is certain that he or she has mastered some material, yet performs poorly on a test, and may, therefore, conclude that the test was not fair. The student has assessed his or her knowledge and concluded that it is solid, yet the examination indicates that it is not. What happened? What cues do students use to decide that they know something?

Cognitive science research has shown that two cues are especially important in guiding our judgments of what we know: (1) our "familiarity" with a given body of information and (2) our "partial access" to that information. In this column, I'll discuss how these two cues can lead students to believe that they know material when they don't.

And, in the box on page 41 (//www.aft.org/newspubs/periodicals/ae/winter0304/willinghamsb.cfm), I suggest ways that teachers can help students develop more realistic self-assessments of their knowledge.

"Familiarity" Fools Our Mind into Thinking We Know More Than We Do
The idea of familiarity is, well, familiar to all of us. We have all had the experience of seeing someone and sensing that her face is familiar but being unable to remember who that person is or how we know her.

Psychologists distinguish between familiarity and recollection. Familiarity is the knowledge of having seen or otherwise experienced some stimulus before, but having little information associated with it in your memory. Recollection, on the other hand, is characterized by richer associations. For example, a young student might be familiar with George Washington (he knows he was a President and maybe that there's a holiday named after him), whereas an older student could probably recollect a substantial narrative about him. (See Yonelinas, 2002, for an extended review of the differences between recollection and familiarity.)

Although familiarity and recollection are different, an insidious effect of familiarity is that it can give you the feeling that you know something when you really don't. For example, it has been shown that if some key words of a question are familiar, you are more likely to think that you know the answer to the question. In one experiment demonstrating this effect (Reder, 1987), subjects were exposed to a variety of word pairs (e.g. "golf" and "par") and then asked to complete a short task that required them to think at least for a moment about the words. Next, subjects saw a set of trivia questions, some of which used words that the subjects had just been exposed to in the previous task. Subjects were asked to make a rapid judgment as to whether or not they knew the answer to the question—and then they were to provide the answer.

If the trivia question contained key words from the previous task (e.g., "What term in golf refers to a score of one under par on a particular hole?"), those words should have seemed familiar, and may have led to a feeling of knowing. Indeed, Reder found that subjects were likely to say that they knew the answer to a question containing familiar words, irrespective of whether they could actually answer the question. For questions in which words had not been rendered familiar, subjects were fairly accurate in rapidly assessing their knowledge.

A similar effect was observed in an experiment using arithmetic problems (Reder & Ritter, 1992). On each trial of this experiment, subjects saw an addition or multiplication problem (e.g., 81 + 35) and they had to rapidly decide whether they would calculate the answer or answer from memory. If they chose to calculate, they had 20 seconds to do so; if they chose to answer from memory, they had just 1.4 seconds. Sometimes problems repeated, so subjects might have had the answer to a complex problem in memory. Subjects were paid depending on their speed and accuracy, so the decision about whether or not to calculate was important. As in the trivia question experiment, subjects were accurate in knowing when they could retrieve an answer from memory and when they needed to calculate it—except in one situation, when the experimenters repeated a two-digit problem but changed the operation (e.g., addition to multiplication). In that case, subjects were just as likely to try to retrieve an answer from memory for a problem they had actually just seen (e.g., 81 + 35) as they were for a problem they had not just seen but which used familiar operands (e.g., 81 – 35). The experimenters argued that subjects made their judgment about whether to calculate based on the familiarity of the problem components, not on the whether the answer was in memory.

"Partial Access": Our Mind Is Fooled When We Know Part of the Material or Related Material
A second basis for the feeling of knowing is "partial access," which refers to the knowledge that an individual has of either a component of the target material or information closely related to the target material. Suppose I ask you a question and the answer doesn't immediately come to mind, but some related information does. For example, when I ask for the names of the two series of Trollope novels, you readily recall Barchester and you know I mentioned the other series earlier; you even remember that it started with the letter P, and you believe it had two or three syllables. Your quick retrieval of this partial information will lead to a feeling of knowing the

relevant information —even if Palliser is not actually in your memory.

The effect of partial access was demonstrated in an experiment (Koriat & Levy-Sadot, 2001) in which subjects were asked difficult trivia questions. If subjects couldn't answer a particular question, they were asked to judge whether they would recognize the answer if they saw it (i.e., to make a feeling-of-knowing judgment). The interesting twist: Some of the questions used categories for which lots of examples came to mind for their subjects (e.g., composers) and matching questions used categories for which few examples came to mind (e.g., choreographers)—that is, these subjects could easily think of at least a few famous composers, but couldn't think of more than one or two choreographers, if any.

The results showed that whether or not they could actually recognize the right answer, people gave higher feeling-of-knowing judgments to questions using many-example categories (e.g., "Who composed the music for the ballet Swan Lake?") than to questions using few-example categories (e.g., "Who choreographed the ballet Swan Lake?"). The experimenters argued that when people see the composer question, the answer doesn't come to mind, but the names of several composers do. This related information leads to a feeling of knowing. Informally, we could say that subjects conclude (consciously or unconsciously), "I can't retrieve the Swan Lake composer right now, but I certainly seem to know a lot about composers. With a little more time, the answer to the question could probably be found." On the other hand, the choreographer question brings little information to mind and, therefore, no feeling of knowing.*

These studies, and dozens of others like them, confirm two general principles of how people gauge their memories. First, people do not assess their knowledge directly by inspecting the contents of memory. Rather, they use cues such as familiarity and partial access. Second, most of the time these cues provide a reasonable assessment of knowledge, but they are fallible.

How Students End Up with "Familiarity" and "Partial Access" to Material

If a student believes that he knows material, he will likely divert attention elsewhere; he will stop listening, reading, working, or participating. Mentally "checking out" is never a good choice for students, but all the more so when they disengage because they think they know material that, in fact, they do not know. The feeling of knowing becomes a problem if you have the feeling without the knowing. There are some very obvious ways in which students can reach this unfortunate situation in a school setting. Here are several common ones:

1. Rereading. To prepare for an examination, a student rereads her classnotes and textbook. Along the way, she encounters familiar terms ("familiar" as in she knows she's heard these terms before), and indeed they become even more familiar to her as she rereads. She thinks, "Yes, I've seen this, I know this, I understand this." But feeling that you understand material as it is presented to you is not the same as being able to recount it yourself.

As teachers know, this gap between feeling that you know and genuine recollection can cause great frustration. I have frequently had exchanges in which one of my students protests that despite a low test grade, he or she really knew the material. When I ask a general question or two, the student struggles to answer and ends up sputtering, "I can't exactly explain it, but I know it!" Invariably, a student with this problem has spent a great deal of time reading over the course material, yielding a lot of familiarity, but not the necessary and richer recollective knowledge.

2. Shallow Processing. A teacher may prepare an excellent lesson containing a good deal of deep meaning. But this deep meaning will only reside in a student's memory if the student has actively thought about that deep meaning (see "Students Remember ... What They Think About," in the Summer 2003 issue of American Educator). Let's say, for example, that a teacher has prepared a lesson on the European settlement of Australia and on the meaningful issue of whether that settlement should be viewed as a colonization or invasion. But, let's say that a given student did not process and retain the deep meaning intended by the lesson. He did absorb key terms like

"Captain Cook" and "Aborigines." His familiarity with these key terms could mislead him into believing he was ready for a test on the subject.

3. Recollecting Related Information. Sometimes students know a lot of information related to the target topic, and that makes them feel as though they know the target information. (This is analogous to the subjects in the experiment who knew the names of many composers and so felt that they knew who composed Swan Lake.) Suppose that a fifth-grade class spent three weeks studying weather systems, including studying weather maps, collecting local data, keeping a weather journal, learning about catastrophic weather events like hurricanes, and so on. In preparation for a test, the teacher says that there will be a question on how meteorologists use weather maps to predict hurricanes. When the student hears "weather map," she might recall such superficial information as that they are color coded, that they include temperature information, and so on; she feels she knows about weather maps and doesn't study further. In fact, she hasn't yet come to understand the core issue—how weather maps are used to predict weather. But her general familiarity with the maps has tricked her into believing she had the necessary knowledge when she didn't. (Ironically, the problem of recollecting related information is most likely to occur when a student has mastered a good deal of material on the general topic; that is, he's mastered related material, but not the target material. It's the knowledge of the related material that creates the feeling of knowing.)

Cognitive science research confirms teachers' impressions that students do not always know what they think they know. It also shows where this false sense of knowledge comes from and helps us imagine the kinds of teaching and learning activities that could minimize this problem. In particular, teachers can help students test their own knowledge in ways that provide more accurate assessments of what they really know—which enables students to better judge when they have mastered material and when (and where) more work is required.

Daniel T. Willingham is associate professor of cognitive psychology and neuroscience at the University of Virginia and author of Cognition: The Thinking Animal. His research focuses on the role of consciousness in learning.

Readers can pose specific questions to "Ask the Cognitive Scientist," American Educator, 555 New Jersey Ave. N.W., Washington, DC 20001 or to amered@aft.org (mailto:amered@aft.org? subject=article%20request). Future columns will try to address readers' questions.

*Another important aspect of this phenomenon is that the accuracy of partially retrieved information is irrelevant to the feeling of knowing. In an experiment illustrating this phenomenon, Asher Koriat (1993) asked subjects to learn strings of letters. Later, subjects were asked to recall as many letters as possible and then judge whether they would successfully recognize the entire string from among several choices. Subjects' confidence that they would recognize the letter string increased with the number of letters that they had recalled, regardless of whether or not those letters were correct. The more they thought they were pulling out of memory, the more confident they were that they really knew the whole string and would recognize it when they saw it.

References

Koriat, A. (1993). How do we know that we know? Psychological Review, 100, 600–639.

Koriat, A. & Levy-Sadot, R. (2001). The combined contribution of the cue-familiarity and accessibility heuristics to feelings of knowing. Journal of Experimental Psychology: Learning, Memory, and Cognition, 27, 34–53.

Mazzoni, G. & Cornoldi, C. (1993). Strategies in study time allocation: Why is study time sometimes not effective? Journal of Experimental Psychology: General, 122, 47–60.

Reder, L. M. (1987). Strategy selection in question answering. Cognitive Psychology, 19, 90–138.

Reder, L. M. & Ritter, F. (1992). What determines initial feeling of knowing? Familiarity with question terms, not with the answer. Journal of Experimental Psychology: Learning, Memory, and Cognition, 18, 435– 451.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. Journal of Memory and Language, 46, 441–517.