Memory: How Memories Are Formed, Stored, and Retrieved With Personal Tips for Trainers

Craig E. Geis, M.B.A., Management; M.S. Psychology

1831 Quail Court
Saint Helena, CA 94574
Phone: 707-968-5109
cegeis@aol.com

Abstract

A few months ago a Training Manager at a large Police Academy shared his concerns regarding training and the changes that have taken place over the past 20 years. He said it seems that there is more and more to cover in the same period of time and that the trainees don't seem to be able to remember it all. He said they also lack the motivation previously seen and view Law Enforcement as job with great pay and benefits, not a career they are passionate about. He asked if I could write a simple article about memory and give my thoughts about how training could be improved.

A simple article is difficult because memory is one of the most complex processes of the brain. This article will attempt to describe how memories are formed and retrieved and as trainers or individuals what the implications are to us. The Human Factors: Error & Threat Management Course covers a lot of these points in depth. Please refer to the course text for additional information.

How Information is Received and Transferred

The first step in understanding memory is to understand how the brain receives and transfers information. Neurons are the basic means of information transfer within the nervous system.

A stimulus (information) is detected by a specific type of neuron (sensory neuron). The information then travels throughout the nervous system by communicating with other neurons through an electro-chemical process.

Figure 1 on the following page shows the basic structure of a neuron and will explain how information is detected and moves throughout the nervous system.

NEURON

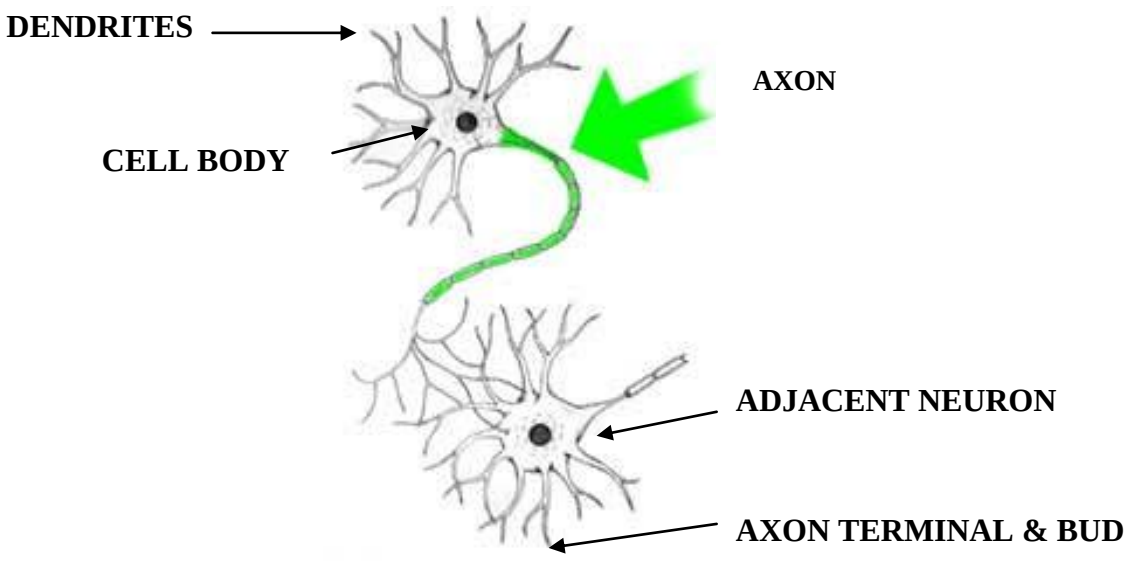

Figure 1

<u>Types of Neurons</u>: There are three types of neurons:

1. Sensory Neurons: These detect the stimulus from each of the senses and communicate the information to the interconnecting neurons.
2. Interconnecting Neurons: These transfer information throughout the nervous system and also connect to the motor neurons.
3. Motor Neurons: These connect to and activate muscle tissue.

How Information Is Moved: See Figure 1 & 2

1. All stimulus or nerve messages are picked up by the dendrites protruding from the cell body.
2. When the stimulus is strong enough the cell body fires an electrical impulse.
3. An electrical impulse travels down the axon or "outgoing branch". Then the axon terminals and buds at the end are stimulated to release chemicals called neurotransmitters (tiny molecules that send specific messages). Neurotransmitters are chemicals that are used to relay, amplify and modulate signals between a neuron and another cell.
4. The dendrites or "incoming branches" of other neurons pick up these chemicals as they cross the synapse. The space between the buds of one neuron and dendrites of the adjacent neuron is called a synapse.
5. What it comes down to is brain cells, or neurons, communicating with each other through electo-chemical pathways.

Here is another picture of a neuron showing the transfer of neurotransmitters.

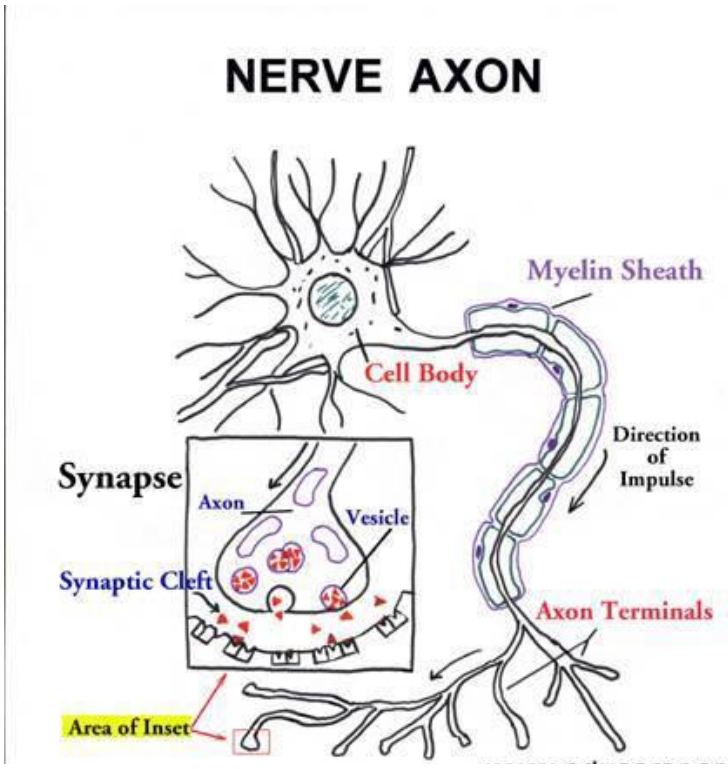

Figure 2

Actual Neuron

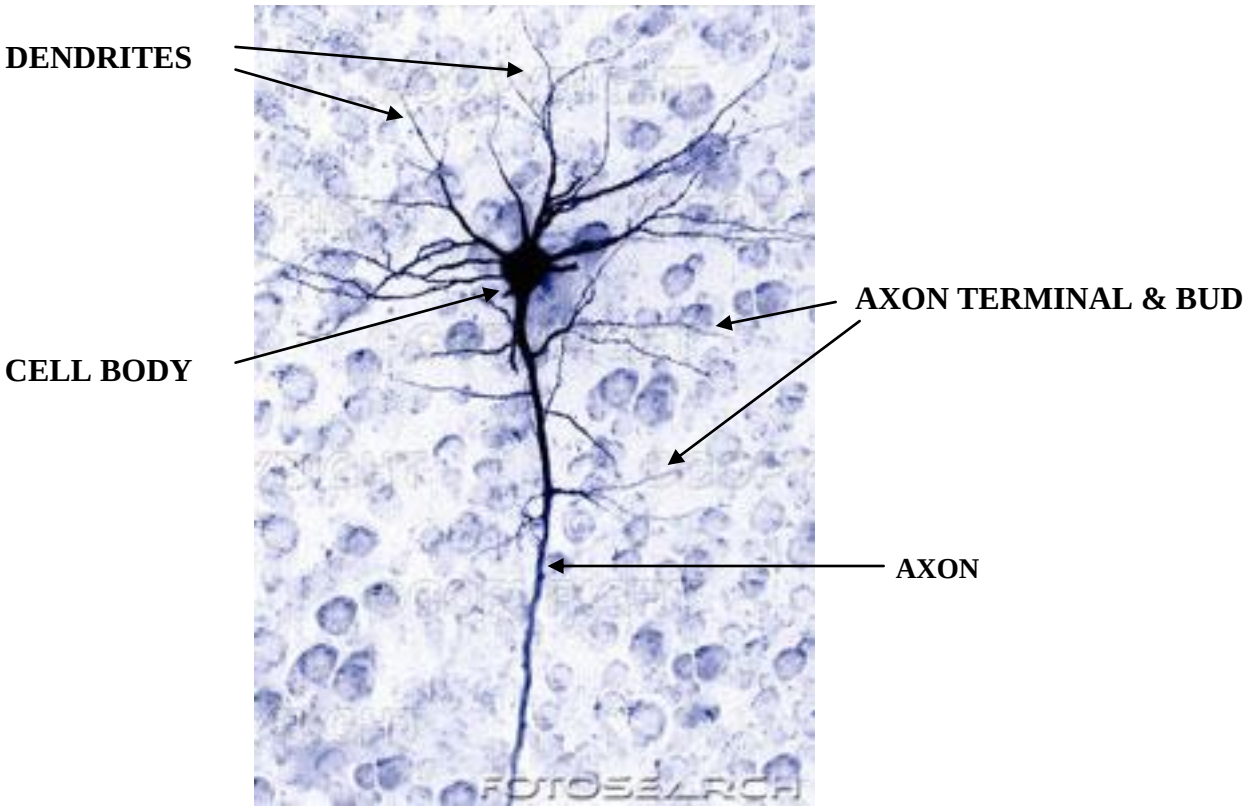

Figure 3

Short-Term (Working) Memory

Neurologists divide memory into sensory storage, short-term memory, or "working" memory, and long-term memory.

Nerve messages from the senses are first routed to the pre-frontal cerebral cortex (frontal lobe of the brain). It is located in the forehead area of the brain and plays a central role in working memory. Experiments using PET and MRI scans point to the fact that "the prefrontal cortex always seems to be "busy" when information is kept "in mind" and when conducting a relevant task. The frontal lobe has neural connections to almost all the areas of the brain that process sensory information.

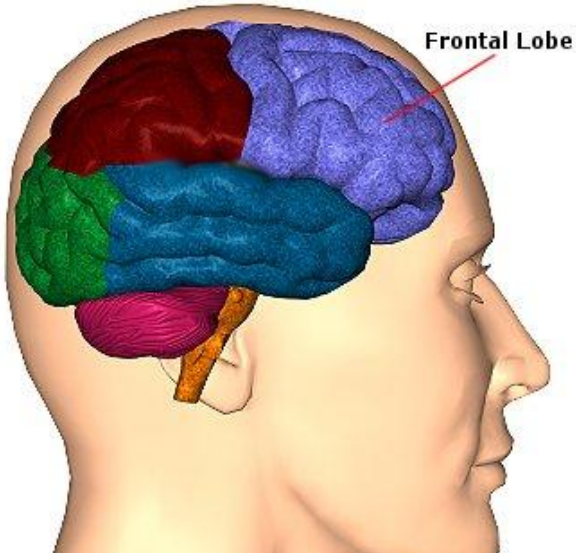

Figure 4

Short-term memory, or STM, is the brain's system for remembering information in use. Most people can only hold five to nine items in their short-term memory at one time. If they try to remember more than that, they will often end up forgetting the middle items.

This sensory stimulus is held for a fraction of a second in the sensory memory. Unless an individual pays attention to encode the stimulus into short-term memory, it will be lost. The memory then is stored on something akin to an electronic tape loop. Once a complete loop is made, three things can happen:

- The information can be "rehearsed" (repeated) silently or aloud, which will provide auditory cues and the tape loop continues. This will keep the information in short-term memory.
- The information can be transferred into long-term memory.
- The information can be lost.

Research has shown that short-term memory involves chemical modifications that strengthen existing connections, called synapses, between neurons.

Long-Term Memory

Long-term memory, or LTM, is that part of our memory storage system that has unlimited capacity to retain information over an extended time. At least three different types of memory are included in LTM.

- Unconsciousness memory (procedural memory) represents motor or skill learning which is memory without a record. It includes learning how to drive a car or tie your shoelace, etc. Such memories are slow to acquire but more resistant to change or loss. This memory is recalled directly through performance without conscious awareness.
- Conscious memory (declarative memory) is memory for facts, such as names and dates. It is fast changing, quick to acquire but quick to be lost. Much of the loss is by design. This is because considerable information activates the receptors but is not retained. We attend to meaningful or relevant stimuli and ignore unchanging or uninformative information. Constant repetition can transform conscious memory into unconsciousness memory (use of familiar names, procedures. etc.). Mental exercise can form new connections in the neurons and is not as easily lost.
- Remote memory simply refers to memories that were acquired early. They represent the foundation memories upon which more recent memories are built. Since early acquired information is the foundation for new memories and may be linked to many more new memories, such memory is less subject to change and/or loss.

The Location of Memory

In the past, it was thought that all memory was stored in the cerebral cortex of the brain. We have now learned that long-term memories are stored in multiple regions throughout the nervous system. (In other words, they are not localized but stored through circuitry).

The cerebral cortex is the primary area of storage in the brain. The cerebral cortex is often referred to as gray matter and covers the outer portion (1.5mm to 5mm) of the brain.

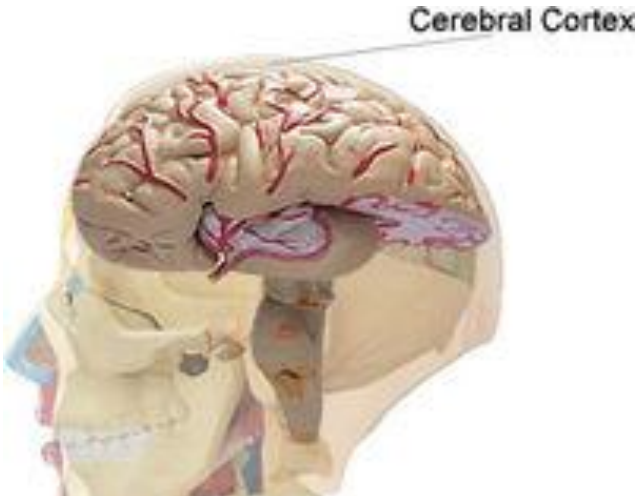

Figure 5

Research has now shown that some memory is stored throughout the body. So every thought you have is “felt” throughout your entire body because the receptors for the chemicals in your brain are found on the surfaces of cells throughout your body. Thus when the chemicals are activated across synapses in the brain, the message is communicated to every part of your body by chemotaxis, a process that allows cells to communicate by “neurotransmitters” or remote travel using blood and cerebrospinal fluid.

Recent research has shown that some memory may even be stored in muscle tissue. This became evident with organ transplants. People who have received donor organs have reported experiencing cravings or emotional reactions to certain incidents that they never had before.

Solidifying the Synapse

For learning to “stick”, the synapses need time to “gel” (create new connections and synapses). If the synapse doesn’t “gel” then recreating the event, i.e. recalling the memory is difficult, if not impossible. A research team reported the discovery of a new protein – transforming growth factor-B (TGF-B) that acts to solidify the new synapses (Science, March 1997). However, if there is too much protein it can build up and “clog” the synapse,

thus reducing memory recall. Usually the neurotransmitter calpain, found in calcium, keeps the buildup of protein down. So, inadequate dietary calcium means that too much protein can build up because there is not enough calpain to keep the synapses clean. Unfortunately, an excess of calcium in the diet also creates a problem because the calpain starts to interfere with proper neural transmissions.

> Implications: Vitamins, minerals, and supplements are helpful if needed. Too much or too little of anything is not good. If you eat well balanced meals you probably dot need to take them. If you do take them, take them in moderation.

New Connections after Learning

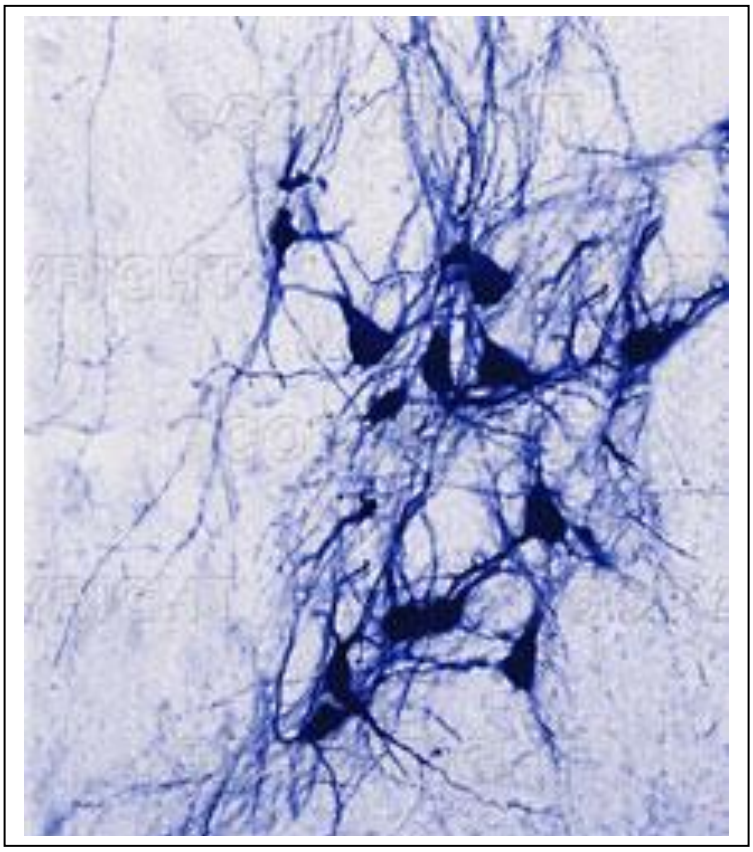

Figure 6

Simply put, memories are stored in subgroups of neurons that are activated in response to various sensory experiences. The interconnections which are

formed are subject to continual change. If you look at Figure 6 you will see a group of neurons. This is what takes place as learning occurs. You can see the neurons start to line up and new connections are formed. The storage of information in LTM is a function of new interconnections and synapses and the production of new protein molecules.

Implications:

1. It has been demonstrated that an enriched environment leads to denser dendrite growth in rats. This is important because we now know that areas of the brain continue to produce new neurons.
2. Recent studies have found patterns of neural activity during sleep that is identical to those seen when learning a new task. It is believed that this aids in the consolidation and storage of memory. Adequate sleep is important to memory.
3. Excessive stress and obesity produce an over-production of a complex set of stress hormones called glucocorticoids (cortisol being one example). Over exposure to glucocorticoids damages and destroys neurons in the brain's hippocampus – a region critical to learning and memory. One really good way to burn off excess cortisol is through exercise. So for those experiencing particularly high stress levels exercise is not only beneficial, it is necessary.

Why Do We Forget?

This is a difficult and complicated area for researchers. I will try to point out the different theories and give you some personal thoughts.

1. Retrieval Failure

Have you ever felt like a piece of information has just vanished from memory? Or maybe you know that it's there, you just can't seem to find it. Memories fade away rapidly when not reviewed or used. The curve of forgetting is like a playground slide; we forget most immediately after we learn--in the first 24 hours; then it proceeds slowly. Motor learning seems to be better retained than verbal learning because a motor act as to be completely done to be done at all and so requires a higher degree of organization and competency which involves over learning.

One common cause of forgetting is simply an inability to retrieve a memory. One explanation for why retrieval fails is known as **decay theory.** According to this theory, a memory trace is created every time a new memory is formed. Decay theory suggests that over time, these memory traces begin to fade and disappear. If information is not retrieved and rehearsed, it will eventually be lost. One problem with this theory, however, is that research has demonstrated that some memories which have not been rehearsed or remembered are remarkably stable in long-term memory.

Personal Thoughts:

- When we don't use a connection or recall a memory the memory trace (connection) is weak. With some memories the initial memory trace (connection) was extremely strong for some reason. This could be due to motivation, association, importance, fun, emotion, etc. The initial strong trace makes it easier to remember even if we don't use it.
- Another reason is that under high stress (cortisol production) cortisol interferes with the retrieval of information from long-term memory. The synapses are blocked by the cortisol and make it difficult to find the right connections. This can delay our response or make it impossible to find until the stress declines.

2. Interference

Another theory known as **interference theory** suggests that some memories compete and interfere with other memories. When information is very similar to other information that was previously stored in memory, interference is more likely to occur. There are two basic types of interference:

- **Proactive interference** is when an old memory makes it more difficult or impossible to remember a new memory.

  Personal Thoughts:

  - The initial connections are so strong because we use them all the time while the new memory trace is weak. It makes it harder to remember the new information. Habit capture (reverting to old established patterns) is an example of proactive interference.

- **Retroactive interference** occurs when new information interferes with your ability to remember previously learned information.

  Personal Thoughts:

  - There is more interference between two similar subjects or ideas than between two unlike subjects or ideas. (Follow study of history with chemistry rather than English history or literature.)

3. Failure to Store

- We also forget information because it never actually made it into long-term memory. *Encoding failures* sometimes prevent information from entering long-term memory.

  Personal Thoughts:

  - Very often only information that is important is encoded. We don't encode a lot of the details and they are not stored in memory. Another reason is that under high stress (cortisol production) cortisol interferes with the transfer of information from short-term memory to long-term memory. The synapses are blocked by the cortisol and make it difficult to transfer the information.

  Try this test: Draw both sides of a penny from memory, and then compare your results to an actual penny.

  How well did you do? Chances are that you were able to remember the shape and color, but you probably forgot other minor details. The reason for this is that only details necessary for distinguishing pennies from other coins were encoded into your long-term memory.

4. Motivated Forgetting

Sometimes, we may actively work to forget memories, especially those of traumatic or disturbing events or experiences. The two basic forms of motivated forgetting are: suppression, a conscious form of forgetting, and repression, an unconscious form of forgetting.

However, the concept of repressed memories is not universally accepted by all psychologists. One of the problems with repressed memories is that it is difficult, if not impossible, to scientifically study whether or not a memory has been repressed. Also note that mental activities such as rehearsal and remembering are important ways of strengthening a memory, and memories of painful or traumatic life events are far less likely to be remembered, discussed or rehearsed.

Why Do We Remember Negative Events?

Whenever emotions are activated, especially strong emotions, the information or experience is entrenched into memory. Often times we tend to dwell on it, thereby rehearsing it and entrenching it even further. It is also easier to recall negative memories when we are in a bad mood. Why? Because we remember things in the state that we learned them so whenever you are feeling angry you will more easily recall other situations in which you were angry.

The Subconscious Remembers Everything

If we were to compare the conscious mind with the subconscious, the conscious would measure about one foot long and the subconscious would be the length of a football field. The potential is enormous. So everything we experience can be stored. However, the conscious mind would get overloaded trying to process all the incoming bits of data on a daily basis. Instead, all the information goes into the subconscious for storage and we may never deal with it, except if the mind chooses to process it later.

How Effective Trainers Can Help Students Remember

Personal Tips for Trainers

- Sensory – We remember things that involve more than one sense. So, the more senses that get activated, the easier it will be to recall. Let the student hear it, let them see it on a slide, let them feel it through a story or example. The more the better.
- Intensity – When something is more intensely funny, sexual, absurd, etc. it tends to stand out in our memories. Use pictures, video clips, comedy, personal stories, etc.

- Outstanding – Things that are dull and unoriginal are more difficult to remember because there is nothing to distinguish them from all the other memories. Make your verbal and visual presentation stand out.
- Emotional – The amygdala – a round, pea-sized part in the middle of the brain - acts as a gate keeper, so when something happens that has high emotional content – positive or negative – the amygdale says, "This is important!" and we tend to remember it more easily. Put your emotions into teaching. Love your subject and get the students to love it.
- Survival – The brain is wired for survival. This means that anything we perceive as important to survival we will remember more easily. It's not just physical survival. Survival can include emotional survival, psychological survival, and financial survival. Show the students how the material is not only interesting but necessary for survival (personal, job, family, financial, etc.)
- Personal Importance – We naturally remember things that interest us and that have some personal importance. Follow the adult learning model. Have them explain how this material fits into their personal experience.
- Repetition – The more often we recall information, the better we get at recalling on demand. Constantly refer to pervious material and link it together. Summarize the key points and start new lectures with a summary of previous points. In training we say: "Tell them what you are going to tell them, tell them, and tell them what you told them." It works
- First and Last – The brain most easily recalls things from the beginning and the end of any session or lecture. Structure your sessions that key points come early and later.
- Paying Attention – Often times the biggest problem is that people's minds are not focused in the moment. Instead, they are thinking about something in the past of future. Get them to attend to the material intensely and wholly. Nothing else should enter their mind. Keep the class focused on the learning objectives.
- Recitation: Ask questions after every paragraph or natural break. Have them recite in their own words. Recitation not only serves memory but tests and promotes understanding.

- Review: Best time to review is immediately after initial learning has taken place. Review key points at the end of a lesson. We forget most in the first 24-48 hours.

- Background: Build background. The more background they have on a subject, the more interest they will have and the better they can form associations and discern relationships between the new and the old.

- Organization: A good memory is like a well-organized and well-maintained filing system. When a new fact is presented associate it with something previously learned. This will help the student file it with its natural or logical group. Bunch or associate ideas, facts or details consistent with the organization of the material.

- Visualization – Create a visual in the student's mind because the brain thinks in pictures and concepts, not paragraphs. Use stories, analogies, examples. Keep it organized.
- Association – The more associations you can elicit for an idea, the more meaning it will have; the more meaningful the learning, the better one is able to remember it. People with good memories usually think over their experiences--real and vicarious--and systematically relate or associate them with previous learning. Find something to connect the information to…similar to word association. Ask, "What does this remind me of? Where have you seen this happen before?" Follow the adult learning model.

- Notes: Have them take notes in their own words and arrange them in some meaningful order. Ask them to review them immediately after concluding the material and a week or so later.

- Spaced Review: Periodically review so that forgetting has less of a chance to take place. If the intervals between reviews are too widely spaced, more forgetting will occur.

- Over Learn: When you are sure they know it, then hit it one more time or two. If they can recall it instantly, you have helped them over learn it. The more important and difficult the learning, the more you should over learn it and reinforce it with frequent reviews.

- Sleep: Freshly learned material is better remembered by most people after a period of sleep or mental activity than after a period of daytime

activity when interference takes place. Don’t put them to sleep but remind them of the importance of sleep after learning.