The Brain and How It Works:

Implications for Teaching and Learning

BY MICHAEL ENGLAND

Dubbed the "Decade of the Brain," the past 10 years have been a time of unprecedented research on the function of the human brain and possible applications to teaching and learning. Scientists have learned more about the human brain in the past decade than in the previous hundred years.

In this brief synopsis of recent developments in brain research, we will examine four areas that are relevant to educators in 21st-century classrooms. These include: neural connections, perceptual register, windows of learning opportunity, and enriched environment.

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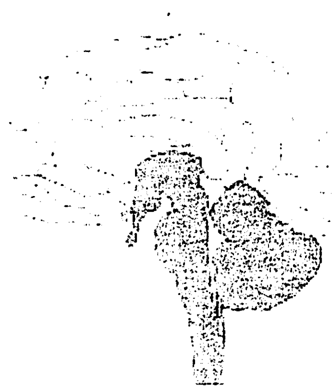

Neural Connections

The brain is made up of 100 billion nerve cells, or neurons. It also houses one trillion supporting cells, the glia, which surround and nourish the neurons. Together, the nerve cells make 1,000 trillion synaptic contact points with each other.[1]

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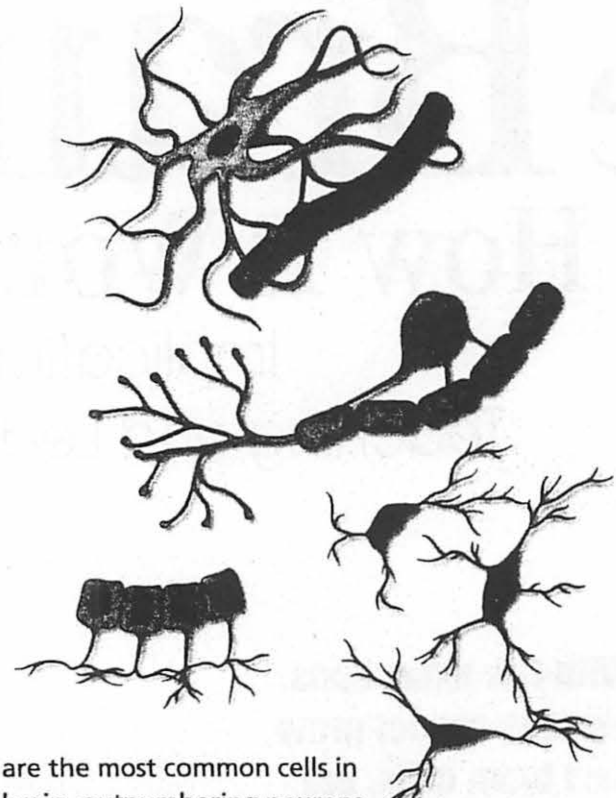
Nerve cells are intricately interconnected and are modified by input from both the internal and external environment. They communicate with one another by acting like relay stations—receiving signals from other cells, processing the signals, and

Common Types of Glial Cells



Glial are the most common cells in your brain, outnumbering neurons by a sizable 10-1 margin.

sending them on to other neurons across tiny gaps called synapses. Nerve cells don't actually touch one another. Instead, they produce chemicals called neurotransmitters in the cell body terminals and store them in little sacks down in the terminals of the axon or nerve fiber.

When a neuron fires, an electrical impulse moves down the axon and stimulates the little sacks of chemicals to move to the surface, break open, and discharge their contents into the gap between the axon terminal and the dendrite of a neighboring cell. Dendrites have receptors, or welcome sites, designed specifically for a particular neurotransmitter such as serotonin, dopamine, or any of the nearly 100 neurotransmitters produced by the brain. The chemicals fit the receptor sites in the same way that a key fits a particular lock. The chemical causes a new reaction in the receiving dendrite, which sends a message down that cell's axon, beginning the whole process again. The brain knows not only what kind of chemical to make but also how much to let out, how long to leave it there, and what to do when it's through.

This electrochemical process is the basis of all human behavior and learning. Every thought we think, every move we make, and every word we say depends on electrical and chemical communication between neurons.[2] Knowing how the brain processes information and learns can help teachers develop instructional strategies that help students understand and remember.

Perceptual Register and Short-Term Memory

Our senses constantly collect bits of information from the environment, even while we are asleep. The brain screens the data to determine its importance to the individual. This is called the perceptual register. The brain also monitors the strength and nature of the sensory impulses. If it regards sensory data as important, or if the perceptual register becomes overloaded, the data are passed on to the first of two temporary memories: (1) the short-term memory, which acts as an extension of the perceptual register; or (2) the working memory, where conscious processing occurs.

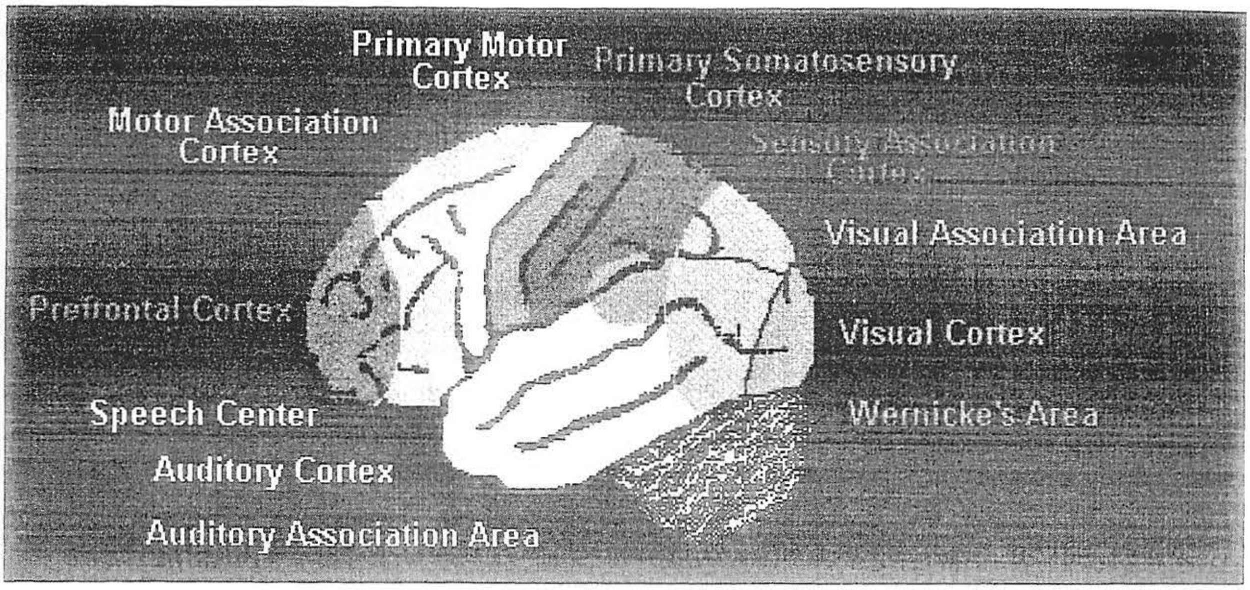
Short-term memory operates subconsciously, holding data for up to 30 seconds. The individual's experiences determine the importance given to the data. When an item is in working memory, it generally demands attention. The brain's criteria for keeping an item is that it makes sense and has meaning to the individual. If a learner cannot recall new learning after 24 hours, there is a high probability that it was not stored in long-term memory, and thus can never be recalled.

The sensory input that finds a place in the brain's long-term storage areas forms the basis for how we view life. Worldview combines a cognitive belief system (how we see the world) with self-concept (how we view ourselves in that world). Our self-concept is shaped by our experiences, many of which produce strong emotional reactions.

Worldview and self-concept interact in the classroom. Worldview helps the brain sort out which concepts fit into an acceptable framework, accepting those that match and rejecting or further examining those that do not. Self-concept affects the learner's willingness to attempt new learning and to persevere. This takes us back to the perceptual register, where the learner consciously recognizes whether he or she has experienced success with this information and decides whether to focus on it for further work.

How Does Memory Work?

The popular concept of memory as the brain's videotape of life is inaccurate. Memory is a process, not a fixed thing or a singular skill. Information is not stored in a specific location in the brain. Rather, it is stored as changes in neurons along specific pathways[3] that are joined in circuits or networks of neurons in the visual, auditory, and motor cortices. Each time we recall an event or experience, we literally reconstruct it by using the same circuit or circuits we used to store it.[4] It is the retrieval process that activates dormant neurons to trigger memory. When enough of the right type of neurons, firing in the right way, are stimulated, memory retrieval is successful. Our best learning involves multiple memory locations and systems.



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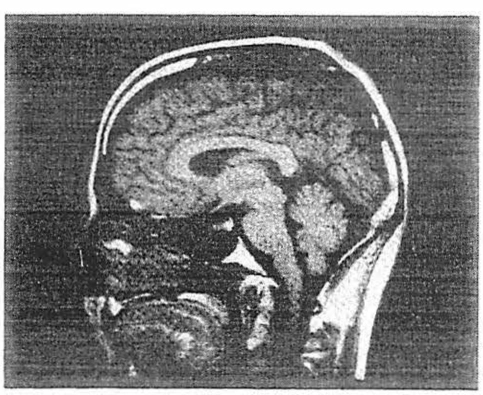
The number-one way to trigger recall is by association and elaboration. Because synaptic connections are often temporary, we need elaboration to strengthen the original contacts. Elaboration is the sorting, sifting, analyzing, testing, and deepening of learning that gives students genuine feedback on how well they understand. It ensures that students not only "own" the information, but also that the information is correct. The best feedback is specific and timely. Using multiple sources and approaches ensures that students can use their various intelligences to learn and to construct memories.

Encoding should be combined with elaboration to ensure permanent storage and efficient retrieval of important information. Ways to do this include involving emotion to help encode long-term memory; providing "rehearsals" before examinations; helping students learn about ideas in a

Current Technologies



Neuroscientists are using a number of tools to study the brain's mysteries:

- NMRI (Nuclear Magnetic Resonance Imagery) captures an image every 50 milliseconds that allows researchers to measure the sequence of thinking across very narrow areas of the brain.
- EEG (Electroencephalogram) measures the electrical output of the brain.
- MEG (Magnetoencephalograpy) uses high-tech sensors that are supercooled, and super-conductive liquid helium to locate faint magnetic fields that are generated by the brain's neural networks. This tool has enabled researchers to measure the amount of brain activity that occurs during problem solving.
- PET (Positron Emission Tomography). After the subject drinks radioactive glucose, the PET measures the amount of radioactive substances released when certain areas of the brain consume glucose.
- SPECT (Single Photon Emission Computed Tomography). These nuclear medicine studies measure blood flow and activity levels in the brain, and have been used to diagnose patients with dementia, depression, and schizophrenia.
- Autopsies. Weight, stage of development, and amount of decay or lesions can be observed and measured by a neurological pathologist.

The above technologies allow us to get a much broader picture of what is going on inside our heads. Scientists can actually see information being stored and retrieved. They can also see which region of the brain is used for different functions.

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variety of ways and from different sources; and involving activity, movement, emotion, drama, repetition, and games in reinforcing learning.[5]

Retrieving Memories

Retrieval is highly dependent upon state, time, and context. Semantic memory is activated by association, similarities, or contrasts. The stronger the associations, the more likely that the memory can be retrieved. We remember such items best in chunks—single thoughts, ideas, or groups of related ideas—but only after considerable repetition and review.

Memory may also be triggered by location or circumstance. *What* happened may be remembered mainly in terms of *where* it occurred. (This is why you remember where you were when you heard about the death of Princess Diana.) Contamination is a problem with this type of memory in classroom learning. Although a student may have listened to a great deal of information while sitting in a particular location in the classroom, other facts compete for his or her attention. The student cannot retrieve the information because he or she lacks the "hooks" or "file names" to organize it. Moving to another location in the classroom or having a different teacher on the day of the test will only make recall more difficult. For this reason, multiple-choice tests are popular with students, because they provide the prompts that the brain needs. In many cases, unfortunately, cues are not present when recall is needed.[6]

Students learn best when material is varied, structured, and meaningful. Information that is stored in more than one part of the brain through different approaches to learning and many related themes is likely to be easier to retrieve than single, isolated facts.

Here are some tips for ensuring that concepts are stored in memory and can be recalled:

- Teach what is most important first or last, and organize learning from global to specific. Use a logical, sequential method to introduce ideas.
- Schedule frequent reviews, using different approaches. Have students act out concepts, create posters or PowerPoint presentations, summarize in their own words, or work in small groups.
- Use rhymes, mnemonics, pegwords, movement, music, metaphors, and discussion to create connections that enhance retrieval.
- Engage emotion by using music, games, drama, debates, and storytelling, as well as classroom celebrations and rituals.
- Allow time for reflection and processing after periods of intense concentration and introduction of complex concepts.
- Reorganize learning and present it from different angles. For example, a thematic, interdisciplinary study of weather will make the concepts more meaningful and memorable.
- Use a variety of approaches to teaching and learning, such as props, music, costumes, discussion, journal writing, field trips, guest speakers, peer tutoring, and hands-on projects.
- Connect new learning to previous knowledge, and help students see the relevance of what they are learning to their personal lives.
- Test in the same room where the students learned the material, using similar approaches to the subject as you employed during instruction.[7]

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Windows of Opportunity

Some abilities are acquired more easily during certain sensitive periods, or "windows of opportunity." At birth, a child's cerebral cortex has as many neurons as it will ever have. In fact, in utero, the brain produces nearly twice as many neurons as it will need. Beginning at about the 28th week of prenatal development, a massive pruning begins, resulting in the loss of one-third to one-half of the neurons. (So we lose up to half our brain cells before we're born!) While the brain prunes excess neurons, a tremendous increase in dendrites occurs, adding substantially to the surface area available for synapses, the functional connections between cells. Connections are built at the incredible speed of up to three billion a second. During the period from birth to age 10, the number of synaptic connections increases rapidly, then begins a slow decline during adulthood.

Much credit for these insights into the developing brain goes to Harry Chugani and Michael Phelps at the University of California-Los Angeles School of Medicine.[8] Phelps co-invented the imaging technique called Positron Emission Tomography (PET), which visually depicts the brain's use of energy. Using PET scans, Chugani has averaged the energy use of brains at various ages. His findings suggest that a child's peak learning years occur just as all those synapses are forming. Chugani states that not only does the child's brain overdevelop during the early years, but it also has a remarkable ability to adapt and reorganize.

It appears some skills are more readily acquired at this time than in the years after puberty. These stages, once called "critical periods," are more accurately described as "sensitive periods" or "windows of opportunity."

The window seems to be open from birth until about age 10 for optimal language learning. Many researchers believe that this is the time to teach foreign languages because neurons are available for different sounds. If a child does not hear the sound by age 10, those neurons may not be available again. Therefore, adults who learn a second language will usually speak it with an accent.

After age 10, the brain begins pruning unused synapses.[9] This does not imply that the brain has difficulty learning after this point. It continues to learn rapidly and to retain information, and can do so throughout adulthood. The pruning process is basically the brain's way of disposing of what it perceives as unnecessary, and of abandoning connections. This makes it easier for the brain to care for the important connections already made.[10]

Lifelong Learning

Researchers agree that at birth, humans do not yet possess a fully operational brain. The adult brain results from interaction between the individual's genetic inheritance and his or her experiences. Ronald Kotulak uses the metaphor of a banquet to explain the relationship between genes and the environment: "The brain gobbles up the external environment through its sensory system and then reassembles the digested world in the form of trillions of connections which are constantly growing or dying, becoming stronger or weaker depending on the richness of the banquet."[11]

Until recently, most scientists thought brain capacity was fixed at birth. Unlike tissue in most other organs, neurons do not regenerate, so researchers assumed that whatever brain capacity one had at birth was what he or she would have for life.

Further study has revealed that the environment affects how genes operate, and genes determine how the environment is interpreted. Marian Diamond[12] found that dendrites, the connections between brain cells, can grow at any age. A healthy older person does not necessarily suffer from progressive nerve loss or reduced memory and cognitive abilities.

The human brain is designed for learning, and it does this quite well. Learning changes the brain, making it rewire itself with each new stimulation, experience, and behavior. The way to become more intelligent is to grow more synaptic connections between brain cells and not to lose one's existing connections. It is these connections that allow humans to solve problems and to reason.

It is estimated that we use less than 1 percent of 1 percent of our brain's projected processing capacity.[13] Each of our 100 billion neurons ordinarily connects with 1,000 to 10,000 other neurons. Since each neuron has several thousand synapses, our entire brain has trillions of them. The human brain is capable of processing as much as 1,027 bits of data per second.[14] Paul Churchland[15] estimates that the total configuration is 10 to the 100 trillionth power.

The brain's ability to grow new synapses in response to new experiences is what makes lifelong learning possible. The ability of the mature brain to change and reorganize, although seldom mentioned in the education literature, is a new and exciting finding of brain science.[16]

Sylwester postulates that teachers have a marvelous brain laboratory in the classroom. "They've got 20-30 brains floating around, four or five feet off the ground, 100 pounds of brain tissue that they can study all day long. They can look at these brains and engage them in activities. They can try to find out how students feel, how long they were able to stay attentive, and what they learned."[17] As Seventh-day Adventist educators, we must do our best to maximize the talents of our youth. Brain-compatible learning is a step in the right direction.

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NOTES AND REFERENCES

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3. Memories of sound are stored in the auditory cortex; spatial memories, such as those involved in speaking, reading, and recall about an emotional event, are stored in the hippocampus. The cerebellum is critical for associative memory formation. Memories of names, nouns, and pronouns are traced to the temporal lobe. Learned skills involve the ganglia structures. The cerebellum is critical for associative memory formation, such as in learning motor skills. Peptide molecules, which circulate throughout the body, also store and transfer information.

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