

1

The Brain and Learning

If we teach today's students as we taught yesterday's, we rob them of tomorrow.

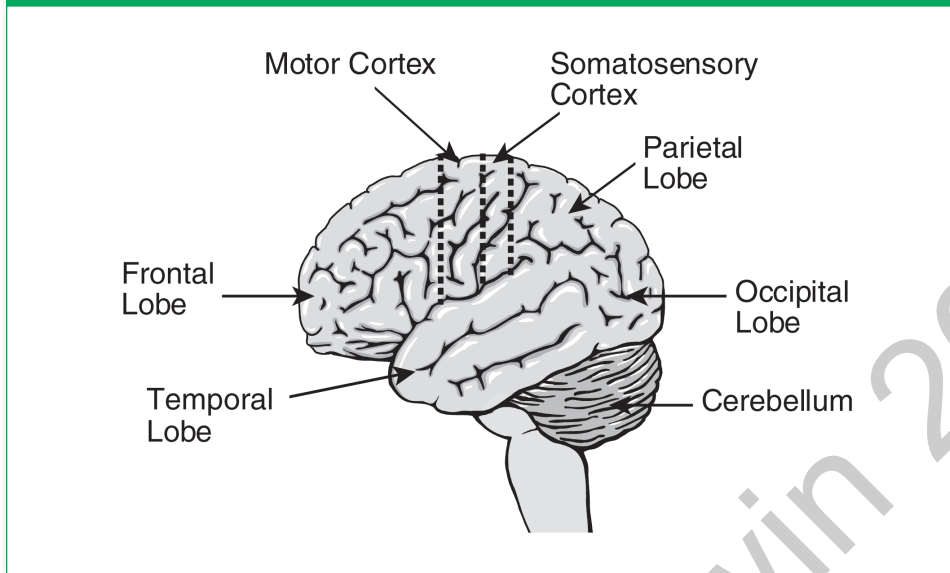
—John Dewey, Philosopher, Educator (1859–1952)

The human brain is an amazing structure. At birth, it is equipped with more than 100 billion nerve cells designed to collect information and learn the skills necessary to keep its owner alive. Although comparatively slow in its growth and development compared to the brains of other mammals, it can learn complex skills, master any of nearly 7,000 languages, store memories for a lifetime, and marvel at the glory of a radiant sunset. Early in life, the brain's cells grow and connect with each other—at the rate of thousands per second—to store information and skills gathered from its environment. The brain's ability to continually reorganize and reconnect its neural pathways because of input from the environment is called **neuroplasticity**. Most of the connections result in the development of neural networks that will help the individual successfully face life's challenges. But sometimes, certain connections go awry, setting the stage instead for problems.

The brain's executive system matures more slowly than the emotional system, so adolescents often resort to high-risk behavior.

To understand the complexity of human brain growth and development, let's review some basic information about its structure. For our purposes, we will first look at major parts of the outside of the brain (Figure 1.1): the frontal, temporal, occipital, and parietal lobes; the motor cortex; and the cerebellum.

Figure 1.1 This diagram shows the four major lobes of the brain (cerebrum), as well as the motor cortex, the somatosensory cortex, and the cerebellum.



SOME EXTERIOR PARTS OF THE BRAIN

Lobes of the Brain

Although the minor wrinkles are unique in each brain, several major wrinkles and folds are common to all brains. These folds form a set of four lobes in each hemisphere. Each lobe tends to specialize for certain functions but can be called on to assist other lobes during complex tasks.

Frontal Lobe. At the front of the brain is the **frontal lobe**, containing almost 50 percent of the volume of the cerebral hemispheres. Lying just behind the forehead is a portion of the frontal lobe called the *prefrontal cortex*. The frontal lobe deals with planning and thinking. It comprises the rational and executive control center of the brain, monitoring higher order thinking, directing problem solving, and regulating the excesses of the emotional system. Because emotions drive attention, the efficiency of this area is linked to the limbic centers.

The frontal lobe also contains our self-will area—what some might call our personality. Trauma to the frontal lobe can cause dramatic—and sometimes permanent—behavior and personality changes. (One wonders why we allow 10-year-olds to play football and soccer, where the risk of trauma to the developing frontal lobe is so high.)

Because most of the working memory is located here, it is the area where focus occurs. The frontal lobe matures slowly. Brain imaging studies of adolescents and postadolescents reveal that the frontal lobe continues to mature into early adulthood. During this time, used neural pathways are being strengthened while unused neurons are being pruned.

In Figure 1.2, the lighter areas on the brain images show the increasing maturation of the frontal lobe over the span of 15 years between the ages of 5 and 20 (Giedd, 2015). Thus the capability of the frontal lobe to

control the excesses of the emotional system is not fully operational during adolescence and is not likely to be fully mature until about the age of 24 (Dennis et al., 2013; Giedd, 2015). Full maturation occurs about a year earlier in females than in males. In other words, the last part of the brain to grow up is the part capable of making rational decisions, understanding the consequences of one's actions, and putting the brakes on emotional impulses. Consequently, this slow development of the frontal lobe is one important reason why adolescents are more likely than mature adults to submit to their emotions and resort to high-risk behavior.

Temporal Lobe. Above the ears rests the *temporal lobe*, which deals with sound, music, face and object recognition, and some parts of long-term memory. It also houses the speech centers, although this is usually on the left side only.

Occipital Lobe. At the back of the brain is the *occipital lobe*, which is used almost exclusively for visual processing.

Parietal Lobe. Near the top is the *parietal lobe*, which deals mainly with spatial orientation, calculation, and certain types of recognition.

Motor Cortex and Somatosensory Cortex

Between the parietal and frontal lobes are two bands across the top of the brain from ear to ear. The band closer to the front is the **motor cortex**. This strip controls body movement and, as we will learn later, works with the cerebellum to coordinate the learning of motor skills. Just behind the

Figure 1.2 The lighter areas on these brain images show the increasing maturation of the frontal lobe over 15 years (adapted from Giedd, 2015; Giedd et al., 1999).



motor cortex, at the beginning of the parietal lobe, is the *somatosensory cortex*, which processes touch signals received from various parts of the body.

Cerebellum

The *cerebellum* (Latin for “little brain”) is a two-hemisphere structure located just below the rear part of the cerebrum, right behind the brainstem. Representing about 11 percent of the brain’s weight, it is a deeply folded and highly organized structure containing more neurons than all the rest of the brain put together. The surface area of the entire cerebellum is about the same as that of one of the cerebral hemispheres.

This area coordinates movement. Because the cerebellum monitors impulses from nerve endings in the muscles, it is important in the performance and timing of complex motor tasks, such as playing the piano or basketball. It modifies and coordinates commands to swing a golf club, smooth a dancer’s footsteps, and allow a hand to bring a cup to the lips without spilling its contents. The cerebellum may also store the memory of automated movements, such as touch-typing, hitting a baseball, and tying a shoelace. Through such automation, performance can be improved as the sequences of movements can be made with greater speed, greater accuracy, and less effort. The cerebellum also is known to be involved in the mental rehearsal of motor tasks, which also can improve performance and make it more skilled. A person whose cerebellum is damaged slows down and simplifies movement and would have difficulty with finely tuned motion, such as catching a ball or completing a handshake.

Recent studies indicate that the role of the cerebellum has been underestimated. Researchers now believe that it also acts as a support structure in cognitive processing by coordinating and fine-tuning our thoughts, emotions, senses (especially touch), and memories. Because the cerebellum is connected to regions of the brain that perform mental and sensory tasks, it can perform these skills automatically, without conscious attention to detail. This allows the conscious part of the brain the freedom to attend to other mental activities, thus enlarging its cognitive scope. Such enlargement of human capabilities is attributable in no small part to the cerebellum and its contribution to the automation of numerous mental activities.

SOME INTERIOR PARTS OF THE BRAIN

Brainstem

The **brainstem** is the oldest and deepest area of the brain. It is often referred to as the reptilian brain because it resembles the entire brain of a reptile. Of the 12 body nerves that go to the brain, 11 end in the brainstem (the olfactory nerve—for smell—goes directly to the limbic system, an evolutionary artifact). Here is where vital body functions, such as heart-beat, respiration, swallowing, sleep and wakefulness, body temperature, and digestion, are monitored and controlled. The brainstem also houses the **reticular activating system (RAS)**, responsible for the brain’s alertness.

Limbic System

Located above the brainstem and below the cerebrum lies a collection of structures commonly referred to as the *limbic* (Greek for “border”) system and sometimes called the old mammalian brain. Most of the structures in the limbic system are duplicated in each hemisphere of the brain. These structures carry out a number of different functions, including the generation of emotions and processing emotional memories. Its placement between the cerebrum and the brainstem permits the interplay of emotion and reason.

Four parts of the limbic system are important to learning and memory. They are:

The Thalamus. All incoming sensory information (except smell) goes first to the *thalamus* (Greek for “inner chamber”). From here information is directed to other parts of the brain for additional processing. The cerebrum and cerebellum also send signals to the thalamus, thus involving it in many cognitive activities.

The Hypothalamus. Nestled just below the thalamus is a pearl-sized structure called the hypothalamus. While the thalamus monitors information coming in from the outside, the hypothalamus monitors the internal systems to maintain the normal state of the body (called *homeostasis*). By controlling the release of a variety of hormones, it moderates numerous body functions, including sleep, food intake, and liquid intake. If body systems slip out of balance, it is difficult for the individual to concentrate on cognitive processing of curriculum material.

The Hippocampus. Located near the base of the **limbic area** is the *hippocampus* (the Greek word for “seahorse,” because of its shape). It plays a major role in consolidating learning and in converting information from working memory via electrical signals to the long-term storage regions, a process that may take days to months. It constantly checks information relayed to working memory and compares it to stored experiences. This process is essential for the creation of meaning.

Its role was first revealed by patients whose hippocampus was damaged by lesions or removed because of disease. These patients could remember everything that happened before the surgery but not afterward. If they were introduced to you today, you would be a stranger to them tomorrow. Because they can remember information for only a few minutes, they can read the same article repeatedly and believe on each occasion that it is the first time they have read it. Brain scans have confirmed the role of the hippocampus in permanent memory storage. Alzheimer’s disease progressively destroys neurons in the hippocampus, resulting in memory loss.

The Amygdala. Close to the tip of the hippocampus is the *amygdala* (Greek for “almond”). This structure plays an important role in emotions, especially fear and anxiety. It regulates the individual’s interactions with the environment that can affect survival, such as whether to attack, escape, mate, or eat.

Because of its proximity to the hippocampus and its activity on brain scans, researchers believe that the amygdala encodes an emotional message, if one is present, whenever the hippocampus tags a memory for long-term storage. It seems that only the emotional component of a memory is stored in the amygdala while other cognitive components of that

memory (names and dates) are stored elsewhere. The emotional component is recalled whenever the memory is recalled. This explains why people recalling a strong emotional memory will often experience those emotions again. The interactions between the amygdala and the hippocampus ensure that we remember for a long time those events that are important and emotional.

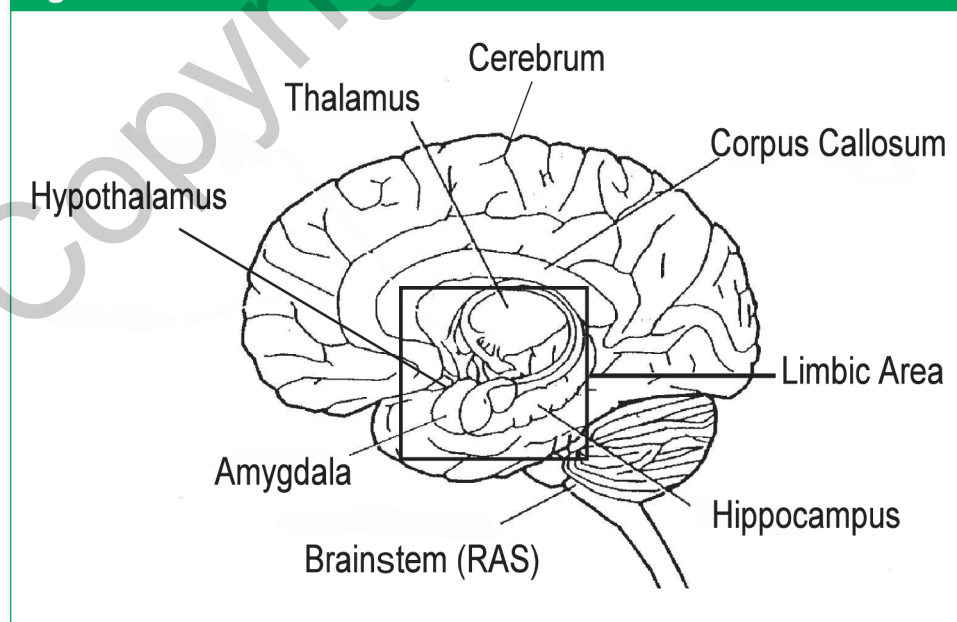
Teachers plan and present their lessons with the intention that their students will permanently remember what was taught. Thus it is worth noting that the two structures in the brain mainly responsible for long-term remembering are located in the *emotional* area of the brain. Tying emotions to new learning can be a powerful memory device.

Cerebrum

A soft jellylike mass resembling a huge walnut, the **cerebrum** is the largest area, representing nearly 80 percent of the brain by weight. Its surface is pale gray, wrinkled, and marked by furrows called fissures. One large fissure runs from front to back and divides the cerebrum into two halves, called the *cerebral hemispheres*. For some still unexplained reason, the nerves from the left side of the body cross over to the right hemisphere, and those from the right side of the body cross to the left hemisphere. The two hemispheres are connected by a thick cable of more than 250 million nerve fibers called the **corpus callosum** (Latin for “large body”). The hemispheres use this bridge to communicate with each other and coordinate activities.

The hemispheres are covered by a thin but tough laminated **cortex** (meaning “tree bark”), rich in cells, that is about one-tenth of an inch (2.5 mm) thick and, because of its folds, has a surface area of about two square feet (0.19 m²). That is about the size of a large dinner napkin. The cortex is composed of six layers of cells meshed in about 10,000 miles (16,100 km)

Figure 1.3 A cross section of the human brain.



of connecting fibers per cubic inch (16.4 cm³)! Here is where most of the action takes place. Thinking, memory, speech, and muscular movement are controlled by areas in the cerebrum. The cortex layer is often referred to as the brain's **gray matter**.

The neurons in the thin cortex form columns whose branches extend down through the cortical layer into a dense web below known as the **white matter**. Here, neurons connect with each other to form vast arrays of neural networks that carry out specific functions.

Brain Cells

The control functions and other activities of the brain are carried out by signals traveling along brain cells. The brain is composed of a trillion cells of at least two known types: nerve cells and their support cells. Nerve cells are called **neurons** and represent about one-tenth of the total number of cells—roughly 100 billion in the mature brain. Most of the cells are support cells, called **glial** (Greek for “glue”) **cells**, that hold the neurons together and act as filters to keep harmful substances out of the neurons.

Neurons are the functioning core for the brain and the entire nervous system. They come in different sizes, but it takes about 30,000 brain neurons to fit on the head of a pin. Unlike other cells, the neuron (Figure 1.4)

can have tens of thousands of branches or **dendrites** (from the Greek word for “tree”) emerging from its center. The dendrites receive electrical impulses from other neurons and transmit them along a long fiber, called the **axon** (Greek for “axis”). Each neuron has only one axon. A layer called the **myelin** (related to the Greek word for “marrow”) **sheath** surrounds each axon. The sheath insulates the axon from the other cells and increases the speed of impulse transmission. The impulse travels

along the neurons through an electrochemical process and can move the entire length of a six-foot (183 cm) adult in two-tenths of a second. A neuron can transmit between 250 and 2,500 impulses per second.

Neurons have no direct contact with each other. Between each dendrite and axon is a small gap of about a millionth of an inch called a **synapse** (from the Greek meaning “to join together”). A typical neuron collects signals from others through the dendrites. The neuron sends out spikes of electrical activity (impulses) through the axon to the synapse, where the activity releases chemicals stored in sacs (called **synaptic vesicles**) at the end of the axon.

The chemicals, called **neurotransmitters**, either excite or inhibit the neighboring neuron. More than 100 neurotransmitters have been discovered so far, but only about 10 or so do most of the work. Some of the more common neurotransmitters are acetylcholine, epinephrine, serotonin, and **dopamine**.

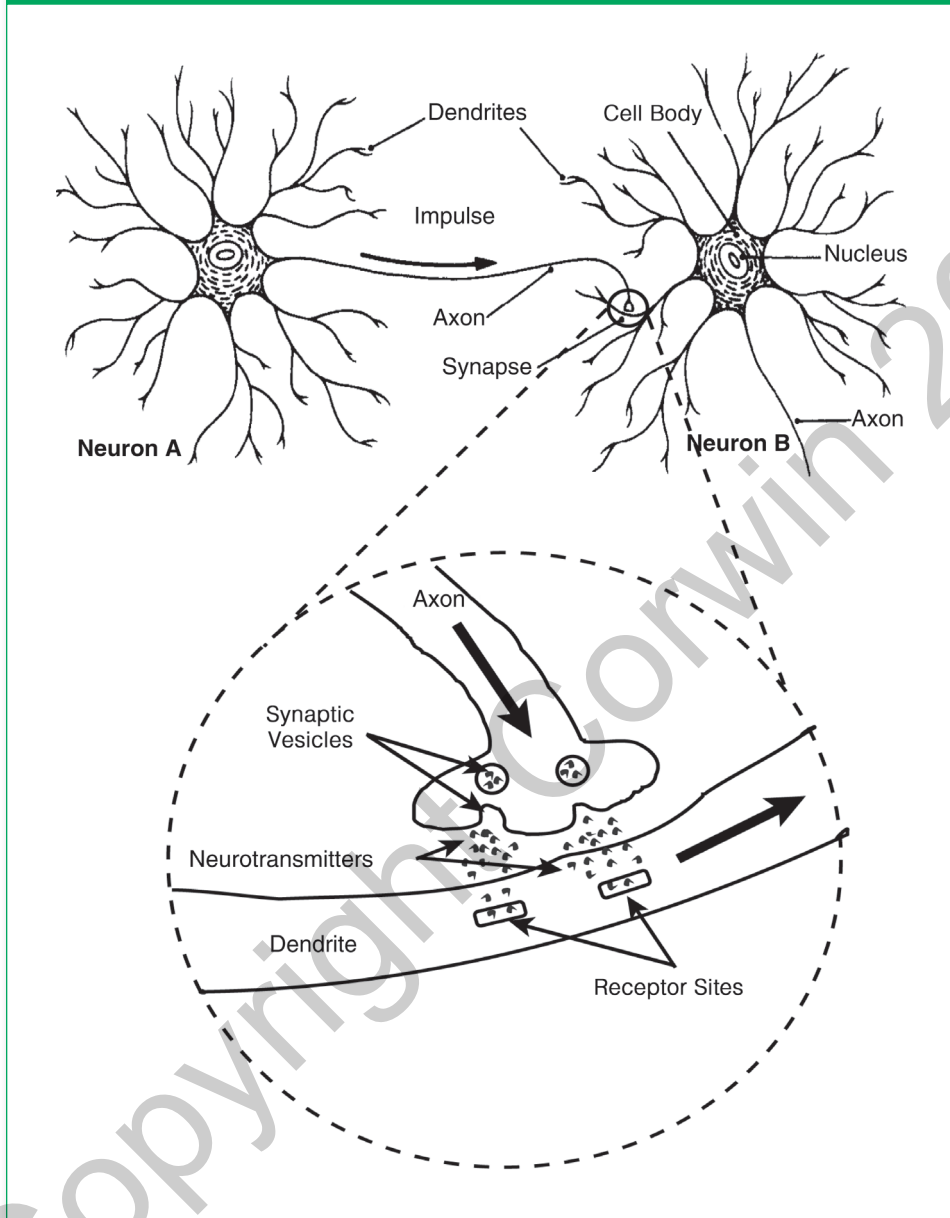
Mirror Neurons

Scientists using scanning technology discovered clusters of neurons in the premotor cortex (the area in front of the motor cortex that plans movements) firing just before a person carries out a planned movement.

Video: To see how nerve impulses travel across the synapse, go to:

<https://www.youtube.com/watch?v=c5cab4hgmoE>

Figure 1.4 Neurons, or nerve cells, transmit impulses along an axon and across the synapse to the dendrites of the neighboring cell. The impulse is carried across the synapse to receptor sites by chemicals called neurotransmitters that lie within the synaptic vesicles.



Curiously, these neurons also fired when a person saw someone else perform the movement. For example, the firing pattern of these neurons that preceded the subject grasping a cup of coffee, was identical to the pattern when the subject saw someone else do that. Thus, similar brain areas process both the *production* and *perception* of movement. Neuroscientists believe these **mirror neurons** may help an individual decode the intentions and predict the behavior of others. If you see someone reach for a ball even though his hand is out of sight, your mirror neurons tell you that he is going to pick up the ball even before he does it (Fadiga, Craighero, & Olivier, 2005; Iacoboni et al., 2005).

Studies also show that structures in the limbic system that activate during one's own pain also activate during empathy for pain. Mirror neurons allow us to re-create the experience of others within ourselves and to understand others' emotions and empathize. Seeing the look of disgust or joy on other people's faces causes mirror neurons to trigger similar emotions in us. We start to feel their actions and sensations as though we were doing them (Corradini & Antonietti, 2013; Lamm & Majdandžić, 2015).

Mirror neurons probably explain the mimicry we see in young children when they imitate our smile and many of our other movements. We all experience this phenomenon when we attempt to stifle a yawn after seeing someone else yawning. Neuroscientists believe that mirror neurons may explain a lot about mental behaviors that have remained a mystery. For instance, there is experimental evidence that children with autism spectrum disorders may have a deficit in their mirror-neuron system. That would explain why they have difficulty inferring the intentions and mental state of others (Oberman et al., 2005). However, the evidence is far from conclusive, and some researchers question the mirror neuron-autism connection (Hamilton, 2013). See Chapter 9 for a discussion of these findings and their implications. Researchers also suspect that mirror neurons play a role in our ability to develop articulate speech.

LEARNING AND RETENTION

Learning occurs when the synapses make physical and chemical changes so that the influence of one neuron on another also changes. For instance, a set of neurons "learns" to fire together. Repeated firings make successive firings easier and, eventually, automatic under certain conditions. Thus, a memory is formed.

For all practical purposes, the capacity of the brain to store information is unlimited. That is, with about 100 billion neurons, each with thousands of dendrites, the number of potential neural pathways is incomprehensible. The brain will hardly run out of space to store all that an individual learns in a lifetime. Learning is the process by which we *acquire* new knowledge and skills; memory is the process by which we *retain* knowledge and skills for the future.

Investigations into the neural mechanisms required for different types of learning are revealing more about the interactions between learning new information, memory, and changes in brain structure. Just as muscles improve with exercise, the brain seems to improve with use. Learning allows brain cells to increase their size, their branches, and their ability to form more complex networks.

The brain goes through physical and chemical changes when it stores new information as the result of learning. Storing gives rise to new neural pathways and strengthens existing pathways. Hence every time we learn something, our long-term storage areas undergo anatomical changes that, together with our unique genetic makeup, constitute the expression of our individuality.

Learning and retention also occur in different ways. Learning involves the brain, the nervous system, and the environment, and the process by

which their interplay acquires information and skills. Sometimes, we need information for just a short period of time, such as the telephone number for a pizza delivery, and then the information decays after just a few seconds. Thus learning does not always involve or require long-term retention.

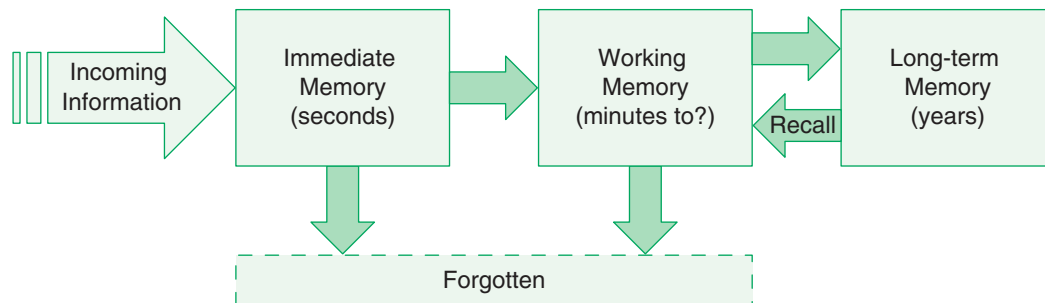
A Look at Memory Systems

A good portion of the teaching done in schools centers on delivering facts and information for building concepts that explain a body of knowledge. We teach numbers, arithmetic operations, ratios, and theorems to explain mathematics. We teach about atoms, momentum, gravity, and cells to explain science. We talk about countries and famous leaders and discuss their trials and battles to explain history. Students may hold on to this information in working memory just long enough to take a test, after which the knowledge readily decays and is lost. Retention, however, requires that the learner not only give conscious attention during learning but also build conceptual frameworks that have sense and meaning for eventual consolidation into long-term storage networks.

Learning is the process by which we acquire knowledge; memory is the process by which we retain it.

Figure 1.5 illustrates the basic components of the human memory systems. Incoming information makes a brief stop at **immediate memory**, a place where information is held for only seconds. This memory is helpful when you need to carry information just long enough to carry out a simple task, such as remembering that phone number for a pizza delivery we mentioned earlier. If we want to actually take time to process and manipulate new information, we move it into **working memory**. Anything that you are thinking about right at this moment is in your working memory. In addition to processing verbal information, a cerebral region called visual working memory processes visual information, including both new and already retained images. Working memory has a limited capacity; that is, it can process only a small number of items at one time. Some students have learning difficulties either because their working memory capacity is lower than average or it does not hold information long

Figure 1.5 The diagram shows the basic components of memory, consisting of two temporary memories (immediate and working) and one permanent memory (long-term).



enough for the student to use it successfully. This can cause serious problems when learning to read, as we will discuss in Chapter 5.

At some point after processing information (and skills) in working memory, the memory systems have an important decision to make: either to tag the new learning for eventual storage into long-term memory or to discard it from the system to be forgotten. As we shall learn in the ensuing paragraphs, how the memory systems make this choice depends on a few important factors. A key point here is that *how* the teacher presents new learning can make the difference between whether the learner remembers it or not. Knowledge of how the brain learns and remembers is a powerful tool for success in the teaching learning process.

Implications for Students With Learning Difficulties

Because students with learning difficulties can have problems focusing for very long, they are even more likely to perceive learning facts as a temporary effort just to please the teacher or to pass a test. It becomes increasingly important, then, for teachers of these students to emphasize *why* they need to learn certain material. Meaning (or relevancy) becomes the key to focus, learning, and retention.

Retention is the process whereby long-term memory preserves a learning in such a way that the memory can be located, identified, and retrieved accurately in the future. This is an inexact process influenced by many factors, including the degree of student focus, the length and type of rehearsal that occurred, the critical attributes that may have been identified, the student's learning style, the impact of any learning difficulties, and, of course, the inescapable influence of prior learning.

Rehearsal

The brain's decision to retain a learning seems to be based primarily on two criteria: *sense* and *meaning*. Sense refers to whether the student understands the learning: "Does this fit my perception of how the world works?" Meaning, on the other hand, refers to relevancy. Although the student may understand the learning, the more important question may be, "So what? What's this got to do with me?" Attaching sense and meaning to new learning can occur only if the learner has adequate time to process and reprocess it. This continuing reprocessing is called *rehearsal* and is a critical component in the transference of information from working memory to long-term storage.

Two major factors should be considered in evaluating rehearsal: the amount of time devoted to it, which determines whether there is both initial and secondary rehearsal, and the type of rehearsal carried out, which can be rote or elaborative.

Time for Initial and Secondary Rehearsal

Learning is likely to be remembered if it makes sense and has meaning for the learner.

Time is a critical component of rehearsal. Initial rehearsal occurs when the information first enters working memory. If the learner cannot attach sense or meaning and if there is no time for further processing, the new information is

likely to be lost. Providing sufficient time to go beyond initial processing to secondary rehearsal allows the learner to review the information, to make sense of it, to elaborate on the details, and to assign value and relevance, thus increasing significantly the chance of long-term storage.

Scanning studies of the brain indicate that the frontal lobe is very much involved during the rehearsal process and, ultimately, in long-term memory formation. This makes sense because working memory is also located in the frontal lobe. Several studies using scans of humans showed that, during longer and frequent rehearsals, the amount of activity in the frontal lobe determined whether items were stored or forgotten (Buckner, Kelley, & Petersen, 1999; Fegen, Buchsbaum, & D'Esposito, 2015; Philips, Kopec, & Carew, 2013).

Students carry out initial and secondary rehearsal at different rates of speed and in different ways, depending on the type of information in the new learning and on their learning styles, including any learning difficulties. As the learning task changes, learners automatically shift to different patterns of rehearsal.

Rote and Elaborative Rehearsal

Rote Rehearsal. Rote rehearsal is used when learners need to remember and store information exactly as it is entered into working memory. It is a simple strategy necessary for learning information or a skill in a specific form or sequence. We employ rote rehearsal to remember a poem, the lyrics and melody of a song, multiplication tables, telephone numbers, and steps in a procedure. This rehearsal usually involves direct instruction. However, students with learning difficulties often perceive rote rehearsal as intensely boring, forcing the teacher to find creative and interesting ways to accomplish the rehearsal while keeping students on task.

Elaborative Rehearsal. Elaborative rehearsal is used when it is unnecessary to store information exactly as learned and when it is important to associate new learnings with prior learnings to detect relationships. In this complex thinking process, learners review the information several times to make connections to previous learnings and assign meaning. Students use rote rehearsal to memorize a poem but elaborative rehearsal to interpret its message. When students get very little time for, or training in, elaborative rehearsal, they resort more frequently to rote rehearsal. Consequently, they fail to make the associations or discover the relationships that only elaborative rehearsal can provide. Also, they continue to believe that the value of learning is merely the recalling of information as learned rather than the generating of new ideas, concepts, and solutions.

Students with learning difficulties need more time and guidance than others to rehearse the new learning in order to determine sense and recognize meaning. They need help with both types of rehearsal, including a rationale for each. When deciding how to use rehearsal in a lesson, teachers should consider the time available and the type of rehearsal appropriate for the specific learning objective. Keep in mind that rehearsal only contributes to, but does not guarantee, information transfer into long-term storage. However, there is almost no long-term retention *without* rehearsal.

Learning Motor Skills

Scanning studies show that a person uses the frontal lobe, motor cortex, and cerebellum while learning a new physical skill. Learning a motor skill involves following a set of procedures and can be eventually carried out largely without conscious attention. In fact, too much conscious attention directed to a motor skill while performing it can diminish the quality of its execution.

When first learning the skill, attention and awareness are obviously required. The frontal lobe is engaged because working memory is needed, and the motor cortex of the cerebrum (located across the top of the brain) interacts with the cerebellum to control muscle movement. As practice continues, the activated areas of the motor cortex become larger as nearby neurons are recruited into the new skill network. However, the memory of the skill is not established (i.e., stored) until after practice stops (Boutin, Panzer, & Blandin, 2013). It takes about 4–12 hours for this consolidation to take place in the cerebellum, and most of it occurs during deep sleep. Once the skill is mastered, brain activity shifts to the cerebellum, which organizes and coordinates the movements and the timing to perform the task. Procedural memory is the mechanism, and the brain no longer needs to use its higher order processes as the performance of the skill becomes automatic (Borragán, Urbain, Schmitz, Mary, & Peigneux, 2015; Tzvi, Münte, & Krämer, 2014).

Continued practice of the skill changes the brain structurally, and the younger the learner is, the easier it is for these changes to occur. Most music and sports prodigies began practicing their skills very early in life. Because their brains were most sensitive to the structural changes needed to acquire the skills, they can perform them masterfully. These skills become so much a part of the individual that they are difficult to change later in life (Schack & Mechsner, 2006).

Learning Difficulties and Motor Skills

Children with low motor ability will have difficulty learning motor skills. But it is a mistake to assume that low motor ability also means low perceptual or intellectual ability. Research studies indicate that individuals with low motor ability often have problems interpreting visual scenes involving movement, but that this limitation does not affect their intellectual or perceptual abilities (Bonifacci, 2004). One promising technique for helping individuals with low motor ability involves the stimulation of the motor cortex (see Figure 1.1) with a strong magnetic field. The procedure, called repetitive transcranial magnetic stimulation, appears to facilitate the learning of sequential motor skills (Kaminski et al., 2013; Stagg et al., 2011).

Individuals with developmental dyslexia often have problems learning motor skills. Researchers suspect that people with this disorder may suffer from an implicit motor learning deficit that not only affects their reading but also impairs their ability to acquire motor skills easily and accurately (Nicolson & Fawcett, 2008; Stoodley, Harrison, & Stein, 2006).

Children with attention deficits may have difficulty focusing sufficiently to acquire some specific motor skills. Often, what little focus they have is directed internally. Studies show that getting students to focus externally (i.e., on objects outside the body) enhances the acquisition and

accuracy of motor skills. In these studies, the researchers suggested that the external focus of attention improves the efficiency of body movement and reduces the noise signals in the motor system that hamper the movement control and make it less reliable (Zachry, Wulf, Mercer, & Bezodis, 2005). Studies also show that students who are on medication for their attention difficulties can improve their motor skills (Kaiser, Schoemaker, Albaret, & Geuze, 2015).

HOW DIFFERENT ARE THE BRAINS OF TODAY'S STUDENTS?

Teachers remark more than ever that students of today are different in the way they learn. They seem to have shorter attention spans and become bored more easily than ever before. Why is that? Is something happening in the environment of learners that alters the way they approach the learning process? Does this mean that more students will have learning problems?

The Search for Novelty

Part of our success as a species can be attributed to the brain's persistent interest in novelty—that is, changes occurring in the environment. The brain is constantly scanning its environment for stimuli. When an unexpected stimulus arises—such as a loud noise from an empty room—a rush of adrenaline closes down all unnecessary activity and focuses the brain's attention so it can spring into action. It needs to determine quickly whether the unexpected stimulus is a threat and, if so, what to do about it. Conversely, an environment that contains mainly predictable or repeated stimuli (such as some classrooms?) lowers the brain's interest in the outside world and tempts it to turn within for novel sensations.

Recent and profound changes in our culture, such as the pervasive use of technology, have enhanced the brain's interest in novelty. Let's compare the environment that a child grew up in, say 20 years ago, compared to the environment that encompasses the developing brain today.

The Environment of the Past

The home environment for many children several decades ago was quite different from that of today. For example,

- The home was quieter.
- Parents and children did a lot of talking and reading.
- The family unit was more stable and ate together, and the dinner hour was an opportunity for parents to discuss their children's activities as well as reaffirm their love and support.
- If the home had a television, it was in a common area and controlled by adults. What children watched could be carefully monitored.
- School was an interesting place because it had television, films, field trips, and guest speakers. There were few other distractions, so school was an important influence in a child's life and the primary source of information.

- The neighborhood was also an important part of growing up. Children played together, developing their motor skills and learning the social skills needed to interact successfully with other children in the neighborhood.

The Environment of Today

In recent years, children have been growing up in a very different environment.

- Family units are not as stable as they once were. Single-parent families are more common, and children have fewer opportunities to talk with the adults who care for them. Their dietary habits are changing as home cooking is becoming a lost art.
- They are surrounded by media: cell phones, multiple televisions, movies, computers, video games, e-mail, and the Internet. According to the Pew Research Center, 92 percent of teens report going online daily, and 24 percent go online almost constantly (Pew Research Center, 2015). Many 10- to 18-year-olds can now watch television, play video games, and use other technology in their own bedrooms, leading to sleep deprivation. The average 6- to 12-year old needs about 10.5 hours of sleep but is getting 7.5 hours, and the average teenager needs 8.5 hours but is getting 6.5 hours (National Sleep Foundation, 2014). This accumulated sleep deprivation leads to irritability, hyperactivity, and lack of focus. Furthermore, with no adult present, what kind of moral compass is evolving in the impressionable preadolescent mind as a result of watching programs containing violence and sex on television and the Internet? See more about sleep later in this chapter.
- They get information from many different sources besides school, but they often do not know how to evaluate the reliability and veracity of these sources.
- The multimedia environment divides their attention. Even newscasts are different. In the past, only the reporter's face was on the screen. Now, the TV screen is loaded with information set in the corners and scrolling across the bottom. Children have become accustomed to these information-rich and rapidly changing messages. They try to pay attention to several things at once, but they do not go into any one thing in depth.
- They spend much more time indoors with their technology, thereby missing outdoor opportunities to develop gross motor skills and socialization skills necessary to communicate and interact personally with others. One unintended consequence of spending so much time indoors is the rapid rise in the number of overweight children and adolescents, now more than 17 percent of 2- to 19-year-olds, according to the National Institute of Child Health and Human Development.
- Because of neuroplasticity, young brains have responded to the technology by rewiring some functions and reorganizing neural networks to accommodate the large amount of stimulation occurring in the environment. By acclimating itself to these changes, brains respond

more than ever to the unique and different—what is called *novelty*. There is a dark side to this increased novelty-seeking behavior. Some adolescents who perceive little novelty in their environment may turn to mind-altering drugs, such as ecstasy and amphetamines, for stimulation. This drug dependence can further enhance the brain's demand for novelty to the point that it becomes unbalanced and resorts to extremely risky behavior.

- Their diet contains increasing amounts of substances that can affect brain and body functions. Caffeine is a strong brain stimulant, considered safe for most adults in small quantities. But caffeine is found in many of the foods and drinks that teens consume daily. Too much caffeine causes insomnia, anxiety, irritability, headaches, and nausea. Some teens can also develop allergies to aspartame (an artificial sugar found in children's vitamins and many "lite" foods) and other food additives. Possible symptoms of these allergic reactions include hyperactivity, difficulty concentrating, and headaches (Nigg, Lewis, Edinger, & Falk, 2012). Some children considered learning disabled may be merely displaying the symptoms of serious allergic reactions to their diet. Many states now limit or prohibit the sale of foods high in caffeine and sugar in public schools and encourage the sale of fresh fruit and other nutritious items.
- Their social behavior is changing dramatically. Instead of face-to-face socializing with their peers, they now do it face-to-screen, greatly minimizing the human connection and missing the nonverbal communication cues that help them understand a person's true intent. This impersonal interaction increases the risk that students will text someone something inappropriate and hurtful that they would never say to that person's face.
- No matter where they are, their attention turns immediately to a buzzing phone, leading to an addiction of "being in the know" right now, and giving them no tolerance for delayed gratification.

When we add the changes in family lifestyles, the narcissistic values of hip-hop, as well as the temptations of alcohol and drugs, we can realize how very different the environment of today's child is from that of just 20 years ago.

Have Schools Changed to Deal With This Different Brain?

Many educators are recognizing the characteristics of the new brain, but they do not always agree on what to do about it. Granted, teaching methodologies are changing, new technologies are being used, and teachers are even introducing pop music and culture to supplement traditional classroom materials. But schools and teaching are not changing fast enough. In high schools, lecturing continues to be the main method of instruction, and the interactive whiteboard is often the most advanced technology used. Many students remark that school is a dull, nonengaging environment that is much less

The brains of today's students are attracted more than ever to the unique and different—what is called novelty.

interesting than what is available outside of school. They have a difficult time focusing for extended periods and are easily distracted. Because they see little novelty and relevancy in what they are learning, they keep asking the eternal question, “Why do we need to know this?” Some teachers interpret this attitude as alienation from school while other teachers see it as a sign of a learning difficulty. In both instances, they are likely to refer the student for counseling and diagnosis. Consequently, it is possible that more children are being referred for special education evaluation not because they have true learning difficulties but because an inflexible (though well-meaning) school environment has not adapted to their changing brains.

Rather than ignoring the changing brain and culture, we should recognize that we must adjust schools to accommodate these changes. As we gain a more scientifically based understanding about today’s novel brain and how it learns, we must rethink what we do in classrooms and schools. Maybe then more children will stay in the educational mainstream rather than be sidelined for labeling.

Some students, of course, do develop learning difficulties that need to be accurately diagnosed and addressed. The following chapters will discuss several types of learning difficulties, review recent research about them, and suggest ways of helping students who demonstrate them. Is it possible that some children are referred for special education evaluation not because they have true learning difficulties but because a school has not adapted to their changing brains?

DIFFICULTIES WITH SLEEP

In recent years, researchers have given more attention to the increasing number of students who are having problems with adequate sleep and the effect that sleep loss is having on their ability to learn. The American Academy of Pediatrics recommends that children 6–13 years of age should get 9–11 hours of sleep per night, while those from 14 to 17 years should get 8–10 hours (Moon, 2013). When a student is not getting enough sleep, there are three possible causes: (1) engaging distractions in the bedroom are robbing the student of sleep time, (2) the student actually has a sleep-related disorder, such as sleep apnea, or (3) the loss of sleep is a side effect of some other medical condition, such as **attention-deficit hyperactivity disorder (ADHD)**.

Sleep Deprivation

Of the three potential causes, studies show that distractions in the bedroom are the major cause of preadolescent and adolescent sleep loss. We mentioned earlier about the large percentage of students who are not getting enough sleep and who are arriving at school sleep-deprived. The effects of sleep deprivation are worrisome to say the least. The immediate and obvious signs include sleepiness, yawning, grogginess, and irritability. Chronic sleep deprivation is serious and often leads to weight gain and memory loss as well as to problems with muscle coordination and balance. Even temporary sleep loss can affect decision-making abilities,

leading to a decline in general alertness (Killgore, 2010). Learning new information becomes tedious as attention drifts.

Effects on Memory

Sleep has a big impact on memory. The encoding of new learning into long-term memory occurs during sleep, specifically during the rapid eye movement (REM) cycles. Most individuals who get about eight hours of sleep will have five REM cycles. However, with just five to six hours of sleep, there are only three REM cycles. In other words, two of those valuable times, when the retention of new learning should be occurring, are eliminated when sleep time is reduced. Furthermore, REM time is also when new learning can be consolidated and linked to what the student already has stored in long-term memory. This is a slow process that needs all REM cycles to complete (Cipolli, Mazzetti, & Plazzi, 2013). Persistent sleep loss in students with learning difficulties means that they have another obstacle to overcome in order to remember what they have learned during their school day.

Sleep loss can affect teenagers' perception of their quality of life. A study of nearly 3,500 adolescents revealed that those who were sleep deprived had increasing difficulty falling asleep, felt they had a lower quality of life than before the sleep loss, and had more health complaints (mainly headaches) than adolescents who were not sleep deprived (Paiva, Gaspar, & Matos, 2015). Sleep loss also has an impact on our emotional brain, making it easier for us to get angry, confused, or anxious (Short & Louca, 2015). Eventually, consistent sleep loss can degrade the body's immune system, leaving one susceptible to systemic inflammation and various infections (Irwin, Olmstead, & Carroll, in press). Contrary to popular belief, stimulants such as caffeine are unable to override the body's acute need for sleep.

Some of the negative effects of sleep deprivation can be misread by educators as signs of a disorder. For example, students whose sleep loss makes them particularly vulnerable to irritation and inattentiveness may be considered as possibly having an attention disorder, such as ADHD. In these instances, educators should first investigate whether the student is sleep deprived before looking for a more serious condition. The good news is that sleep deprivation in many teenagers can be eliminated by removing the distractions that they have in their bedrooms. Surveys indicate that about 75 percent of children have at least one electronic device in their bedrooms, with 51 percent having two or more devices (National Sleep Foundation, 2014). Instead of sleeping, these devices allow students to spend time surfing the Internet or sending messages through social media (Wolfe et al., 2014). This practice is known as *vamping*. The message is clear: Make certain that all students, including those with learning difficulties, get adequate sleep.

Sleep Disorders

There are some causes of sleep loss that are neurobiological and genetic and are independent of the voluntary sleep deprivation scenario we just discussed. These disorders include breathing-related conditions, such as

sleep apnea and sleep-related hypoventilation (abnormally slow breathing); an irregular sleep-wake cycle; rapid eye movement sleep behavior disorder; and restless legs syndrome. These conditions should be treated by medical specialists.

Some sleeping difficulties are the result of a coexisting condition (medical or mental). For example, students with emotional and behavioral disorders, attention-deficit hyperactivity disorder, and anxiety disorders often have difficulty sleeping. Successful treatment of the underlying condition often results in improved sleep patterns.

Copyright Corwin 2016