Studying the Brain

Reader’s Guide

Main Idea
There are many parts in the human brain that work together to coordinate movement and stimulate thinking and emotions.

Vocabulary
- hindbrain
- midbrain
- forebrain
- lobes
- electroencephalograph (EEG)
- computerized axial tomography (CT)
- positron emission tomography (PET)
- magnetic resonance imaging (MRI)

Objectives
- Identify the structure and functions of the human brain.
- Discuss the different ways psychologists study the brain.

Exploring Psychology

Origins of Thoughts
Early Greeks were not impressed with the brain. They suggested that the brain’s main function was to cool the blood. They were much more impressed by the heart. They proposed that the heart was the source of feelings and thoughts. Hippocrates, however, observed the effect of head injuries on people’s thoughts and actions and noted, “[F]rom the brain, and from the brain only, arise our pleasures, joys, laughter and jests, as well as our sorrows, pains, griefs and tears. Through it, in particular, we think, see, hear. . . . Eyes, ears, tongue, hands and feet act in accordance with the discernment [judgment] of the brain.”
—adapted from Psychology by Peter Gray, 2006

Greek physician Hippocrates was right. In the 24 centuries since his observations, many attempts have been made to explain how the mass of soggy gray tissue known as the human brain could create the theory of relativity, the Sistine Chapel ceiling, and global warming. The mind, however, remains a mystery to itself.

THE THREE BRAINS

The brain is composed of three parts: the hindbrain, midbrain, and forebrain (see Figure 6.5). The hindbrain, located at the rear base of the skull, is involved in the most basic processes of life. The hindbrain
includes the cerebellum, medulla, and the pons. The cerebellum, located behind the spinal cord, helps control posture, balance, and voluntary movements. The medulla controls breathing, heart rate, and a variety of reflexes, while the pons functions as a bridge between the spinal cord and the brain. The pons is also involved in producing chemicals the body needs for sleep.

The midbrain is a small part of the brain above the pons that arouses the brain, integrates sensory information, and relays it upward. The medulla and pons extend upward into the midbrain. The medulla, pons, and midbrain compose most of the brain stem, and the reticular activating system (RAS) spans across all these structures. The RAS serves to alert the rest of the brain to incoming signals and is involved in the sleep/wake cycle.

The forebrain, covering the brain's central core, includes the thalamus, which integrates sensory input. The thalamus is a relay station for all the information that travels to and from the cortex. All sensory information with the exception of smell enters the thalamus. All information from the eyes, ears, and skin enters the thalamus and then is sent to the appropriate areas in the cortex. Just below the thalamus is the hypothalamus. It controls functions such as hunger, thirst, and sexual behavior. It also controls the body's reactions to changes in temperature, so when we are warm, we begin to sweat, and when we are cold, we shiver.

The higher thinking processes—those that make us unique—are housed in the forebrain. The outer layer of the forebrain consists of the cerebral cortex. The inner layer is the cerebrum. The cerebral cortex and cerebrum surround the hindbrain and brain stem like the way a mushroom surrounds its stem. The cerebral cortex gives you the ability to learn and store complex and abstract information, and to project your thinking into the future. Your cerebral cortex allows you to see, read, and understand this sentence. The cortex, or bark, of the cerebrum is the site of your conscious thinking processes, yet it is less than one-fourth inch thick.

The limbic system, found in the core of the forebrain, is composed of a number of different structures in the brain that regulate our emotions and motivations. The limbic system includes the hypothalamus, amygdala, thalamus, and hippocampus. The amygdala controls violent
emotions such as rage and fear. The hippocampus is important in the formation of memories. If the hippocampus is damaged, it would be difficult to form new memories. Covering all these parts is the cerebrum.

**The Lobes of the Brain**

The cerebrum is really two hemispheres, or two sides. The cerebral hemispheres are connected by a band of fibers called the corpus callosum. Each cerebral hemisphere has deep grooves, some of which mark regions, or lobes (see Figure 6.6). The occipital lobe is where the visual signals are processed. Damage to this area can cause visual problems, even selective or total blindness. The parietal lobe is concerned with information from the senses from all over the body. The temporal lobe is concerned with hearing, memory, emotion, and speaking. The frontal lobe is concerned with organization, planning, and creative thinking.

The front of the parietal lobe receives information from the skin senses and from muscles. The number of touch sensors in a body part determines its sensitivity, and, along with the complexity of the part's movement, governs the amount of brain tissue associated with the part. The touch and movement of the hands, for example, involve more brain area than the more limited calves. The somatosensory cortex, at the back of the frontal lobe, receives information from the touch sensors. The motor cortex sends information to control body movement. The more sophisticated the movements (such as those used in speaking), the bigger the brain area involved in their control.

The association areas mediate between the other areas and do most of the synthesizing of information. For example, association areas turn sensory input into meaningful information. Different neurons are activated when we see different shapes and figures. The association areas arrange the incoming information into meaningful perceptions, such as the face of a friend or a favorite shirt.

**Left and Right Hemispheres** There is much concern that information about properties of the left and right hemispheres is misinterpreted. Popular books have oversimplified the properties of the two hemispheres. In reality, the left and right sides complement and help each other, so be aware of this as we list the properties of each hemisphere. The two hemispheres in the cortex are roughly mirror images of each other. (Each of the four lobes is present in both hemispheres.) The corpus callosum carries messages back and forth.
between the two hemispheres to jointly control human functions. Each hemisphere is connected to one-half of the body in a crossbarred fashion. The left hemisphere controls the movements of the right side of the body. For most people, the left side of the brain is where speech is located. The left side is also specialized for mathematical ability, calculation, and logic.

The right hemisphere controls the left side of the body. (Thus a stroke that causes damage to the right hemisphere will result in numbness or paralysis on the left side of the body.) The right hemisphere is more adept at visual and spatial relations. Putting together a puzzle requires spatial ability. Perceptual tasks seem to be processed primarily by the right hemisphere. The right side is better at recognizing patterns. Thus, music and art are better understood by the right hemisphere. Creativity and intuition are also found in the right hemisphere (see Figure 6.7) (Levy, 1985).

**Split-Brain Operations** In a normal brain, the two hemispheres communicate through the corpus callosum. Whatever occurs on one side is communicated to the other side. Some people have grand mal seizures, the most severe kind of seizure. Separating the brain hemispheres lessens the number and severity of the seizures (Kalat, 2006). As a result, the person has a split brain. The person has two brains that operate independently of each other. Since the corpus callosum is severed, there no longer is any communication between the hemispheres.

Many psychologists became interested in differences between the cerebral hemispheres when split-brain operations were tried on epileptics like Harriet Lees. For most of her life Lees's seizures were mild and could be controlled with drugs. However, at age 25 they began to get worse, and by 30 Lees was having as many as a dozen violent seizures a day. An epileptic seizure involves massive uncontrolled electrical activity that begins in either hemisphere and spreads across both. To enable Lees to live a normal life, she and the doctors decided to sever the corpus callosum so that seizures could not spread.
Roger Sperry first became well-known in the specialized area of developmental neurobiology. He devised experiments that helped establish the means by which nerve cells become wired in particular ways in the central nervous system.

Sperry is probably best known for his pioneering split-brain research. In the 1950s and 1960s, Sperry devised a number of experiments to test the functions of each hemisphere of the brain. He argued that two separate hemispheres of consciousness could exist under one skull. Sperry pioneered the behavioral investigation of split-brain animals and humans. His experiments and techniques laid the groundwork for constructing a map of mental functions. In 1981 he became coreipient of the Nobel Prize for Physiology and Medicine for his investigation of brain functions.

Not only did the operation reduce the severity of seizures, but it also resulted in fewer seizures (Kalat, 2006). Psychologists were even more interested in the potential side effects of this operation. Despite the fact that patients who had this operation now had two functionally separate brains, they seemed remarkably normal. Researchers went on to develop a number of techniques to try to detect subtle effects of the split-brain operation.

If a man whose brain has been split holds a ball in his right hand, he would be able to say it is a ball. Place the ball in his left hand and he would not be able to say what it is. Information from the left hand is sent to the right hemisphere of the brain. Since the corpus callosum is severed, information cannot cross to the speech center in the left hemisphere.

Another experiment with split-brain patients involves tactile stimulation, or touch. In this experiment, objects are held in a designated hand but are blocked from the split-brain patient’s view. Researchers project a word describing an object on a screen to either the right or left visual field. The patient’s task is to find the object corresponding to the word they are shown. When words are presented for the right hemisphere to see, patients cannot say the word, but they can identify the object with their left hand touching it behind the screen.

To explore emotional reactions in split-brained individuals, researchers designed tests to incorporate emotional stimuli with objects in view. In one of these experiments, a picture of a nude person was flashed to either hemisphere. When researchers flashed the picture to the left hemisphere, the patient laughed and described what she saw.
the same was done to the right hemisphere, the patient said nothing, but her face became flush and she began to grin.

Research on split-brain patients has presented evidence that each hemisphere of the brain is unique with specialized functions and skills. Individuals who have had split-brain operations remained practically unchanged in intelligence, personality, and emotions.

**HOW PSYCHOLOGISTS STUDY THE BRAIN**

Mapping the brain's fissures and inner recesses has supplied scientists with fascinating information about the role of the brain in behavior. Psychologists who do this kind of research are called physiological psychologists, psychobiologists, or neuroscientists. Among the methods they use to explore the brain are recording, stimulating, lesioning, and imaging.

**Recording**

Electrodes are wires that can be inserted into the brain to record electrical activity in the brain. By inserting electrodes in the brain, it is possible to detect the minute electrical changes that occur when neurons fire. The wires are connected to electronic equipment that amplifies the tiny voltages produced by the firing neurons. Even single neurons can be monitored.

The electrical activity of whole areas of the brain can be recorded with an electroencephalograph (EEG). Wires from the EEG machine are attached to the scalp so that millions upon millions of neurons can be monitored at the same time (see Figure 6.8). Psychologists have observed that the overall electrical activity of the brain rises and falls rhythmically and that the pattern of the rhythm depends on whether a person is awake, drowsy, or asleep (as illustrated in Chapter 7). These rhythms, or brain waves, occur because the neurons in the brain tend to increase or decrease their amount of activity in unison.

**Stimulation**

Electrodes may be used to set off the firing of neurons as well as to record it. Brain surgeon Wilder Penfield stimulated the brains of his patients during surgery to determine what functions the various parts of the brain perform. In this way he could localize the malfunctioning part for which surgery was required, for example, for epilepsy. When Penfield applied a tiny electric current to points on the temporal lobe of the brain,
he could trigger whole memory sequences. During surgery, one woman heard a familiar song so clearly that she thought a record was being played in the operating room (Penfield & Rasmussen, 1950).

Stimulation techniques have aroused great medical interest. They have been used with terminal cancer patients to relieve them of intolerable pain without using drugs. A current delivered through electrodes implanted in certain areas of the brain may provide a sudden temporary relief (Delgado, 1969). Furthermore, some psychiatrists have experimented with similar methods to control violent emotional behavior in otherwise uncontrollable patients.

Lesions

Scientists sometimes create lesions by cutting or destroying part of an animal’s brain. If the animal behaves differently after the operation, they assume that the destroyed brain area is involved with that type of behavior. For example, in one classic lesion study, two researchers removed a certain area of the temporal lobe from rhesus monkeys. Normally, these animals are fearful, aggressive, and vicious, but after the operation, they became less fearful and at the same time less violent (Kliver & Bucoy, 1937). The implication was that this area of the brain controlled aggression. The relations revealed by this type of research are far more subtle and complex than people first believed.

Accidents

Psychologists can learn from the tragedies when some people suffer accidents. These accidents may involve the brain. Psychologists try to draw a connection between the damaged parts of the brain and a person’s behavior. One such case involved an unusual accident in 1848. Phineas Gage was a respected railroad foreman who demonstrated restraint, good judgment, and the ability to work well with other men. His crew of men was about to explode some dynamite to clear a path for the railroad rails. As Gage filled a narrow hole with dynamite and tamped it down, it suddenly exploded. The tamping iron had caused a spark that ignited the dynamite. The tamping iron, which weighed over 13 pounds and was over 3 feet in length, shot into the air! It entered Gage’s head right below the left eye, and it exited through the top of the skull.

Gage survived the accident, but his personality changed greatly. He became short-tempered, was difficult to be around, and often said inappropriate things. Gage lived for several years after the accident. In 1994 psychologists Hanna and Antonio Damasio examined Gage’s skull using the newest methods available. They reported that the tamping iron had caused damage to parts of the frontal cortex. They found that damage to the frontal lobes prevents censoring of thoughts and ideas.
Another unusual case took place in the nineteenth century. Dr. Paul Broca had a young patient who could only respond with hand gestures and the word “tan.” Broca theorized that a part of the brain on the left side was destroyed, limiting the young man’s communication processes. Many years later, researchers examined the young man’s brain using modern methods. They discovered that Dr. Broca’s theory was correct. The left side of the cortex, which is involved with the production of speech, was damaged. This area of the cortex is now known as Broca’s area.

**Images**

Dr. Paul Broca uncovered the connection between the brain and speech. Researchers proved Dr. Broca’s theory using PET scans. Today psychologists and medical researchers are using this and other sophisticated techniques, including CT scans and fMRI scans.

In the 1970s, computerized axial tomography (CT) scans were used to pinpoint injuries and other problems in brain deterioration. During a CT scan, a moving ring passes X-ray beams around and through a subject’s head. Radiation is absorbed in different amounts depending on the density of the brain tissue. Computers measure the amount of radiation absorbed and transform this information into a three-dimensional view of the brain.

The positron emission tomography (PET) scan can capture a picture of the brain as different parts are being used. It involves injecting a slightly radioactive solution into the blood and then measuring the amount of radiation absorbed by blood cells. Active neurons absorb more radioactive solution than nonactive ones (see Figure 6.9). Researchers use the PET scan to see which areas are being activated while performing a task (Raichle, 1994). PET scans show activity in different areas of the brain when a person is thinking, speaking, and looking at objects. The scan changes when one is talking and when one is looking at a piece of art. These pictures change as the activity changes.

Another process, magnetic resonance imaging, or MRI, enables researchers to study both activity and brain structures (see Figure 6.10). It

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**Figure 6.9 Brain Activity on a PET Scan**

A computer transforms the different levels of absorption by neurons of radioactive solution into colors. Red and yellow indicate maximum activity of neurons, while blue and green indicate minimal activity.

Why would psychologists use a PET scan?
Magnetic resonance imaging (MRI) studies the activities of the brain. *Why does an MRI of the brain give a more thorough picture than a CT or PET scan would give?*

Researchers use MRIs to study the structure of the brain as well as to identify tumors or types of brain damage. Researchers use a new technique of imaging, functional magnetic resonance imaging (fMRI), to directly observe both the functions of different structures of the brain and which structures participate in specific functions. The fMRI provides high-resolution reports of neural activity based on signals that are determined by blood oxygen level. The fMRI actually detects an increase in blood flow to the active structure of the brain. So, unlike the MRI, the fMRI does not require passing radio frequencies through the brain. With this new method of imaging, researchers have confirmed their hypotheses concerning the functions of areas such as the visual cortex, the motor cortex, and Broca's area of speech and language-related activities.

**SECTION 2**

**Assessment**

1. **Review the Vocabulary** List and describe the main functions of the lobes of the human brain.

2. **Visualize the Main Idea** In a diagram similar to the one below, list the parts of the brain.

   ![Parts of the Human Brain Diagram]

3. **Recall Information** What are the functions of the thalamus and hypothalamus?

4. **Think Critically** If a person suffers a traumatic head injury and then begins behaving differently, can we assume that brain damage is the reason for the personality change? Why or why not?

5. **Application Activity** A woman severely injured the right hemisphere of her brain. Create a scenario in which you describe two body functions that might be affected by the woman's injury.
**One Person . . . Two Brains?**

**Period of Study:** 1967

**Introduction:** Victoria had experienced intense epileptic seizures since she was six years old. Doctors placed Victoria on medication that prevented seizures for a period of time. However, after many years, the seizures returned with greater intensity. Weary and disgusted from living her life with the uncontrolable and agonizing seizures, Victoria decided it was time to seek a new treatment.

Doctors suggested and Victoria opted for a split-brain operation—an innovative procedure that has proved successful in treating patients with seizures. This operation involved opening the patient's skull and separating the two brain hemispheres by cutting the corpus callosum. Split-brain operations disrupt the major pathway between the brain hemispheres but leave each hemisphere functioning almost completely independently. The procedure prevents the spread of seizures from one hemisphere to the other. This reduces the chance of having a seizure or shortens the seizure if one does occur.

Upon completion of Victoria's split-brain operation, the time came to test her various brain functions that now involved nonconnected, independent hemispheres.

**Hypothesis:** Researchers wanted to explore the degree to which the two halves of the brain could communicate and function on their own after the operation.

**Method:** Researchers asked Victoria to stare at a black dot between the letters HE and ART. The information from each side of the black dot will be interpreted by the opposite hemisphere in Victoria's split brain. Victoria's right hemisphere will see HE and her left will only see ART (see diagram).

When Victoria was asked what she had seen, she reported to have seen the word ART. The word ART was projected to her left hemisphere, which contains the ability for speech. She did indeed see the word HE; however, the right hemisphere could not make Victoria say what she had seen. With her left hand, though, Victoria could point to a picture of a man, or HE. This indicated that her right hemisphere could understand the meaning of HE.

**Results:** Four months after Victoria's split-brain operation, she was alert and could easily remember and speak of past and present events in her life. Her reading, writing, and reasoning abilities were all intact. She could easily carry out everyday functions such as dressing, eating, and walking. Although the effects of her operation became apparent under special testing, they were not apparent in everyday life. Victoria, now free of her once-feared seizures, could live her life seizure-free, split-brained but unchanged.

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**Analyzing the Case Study**

1. Why did Victoria choose to have a split-brain operation? What did the operation involve?
2. What questions did researchers set out to answer after Victoria's operation?
3. **Critical Thinking** What problems do you think Victoria might encounter in everyday life?