The Cerebral Cortex

6-3 What are the regions of the outer surface of the brain, the cerebral cortex, and what are the functions of these regions?

Close your eyes and conjure up an image of a brain. What did you see? Probably not the lower-level structures we have been discussing, right? More likely, you thought of the brain's wrinkled outer surface—the **cerebral cortex** (see **Figure 6.7**), an intricate fabric of interconnected neurons that make up the body's ultimate control and information-processing center. The cerebral cortex covers the brain's lower-level structures, just as a glove covers your hand. The word *cortex* is Latin for *bark,* an appropriate name given the tree bark–like appearance of the brain's outer surface. The wrinkles of the cerebral cortex allow more brain tissue to be packed into a confined space, like a sleeping bag into its stuff sack. Thanks to this efficient use of space, an estimated 20 billion to 23 billion neurons with 300 trillion connections among them can exist in a layer of brain tissue only one-eighth of an inch thick.[4] Even more amazing, there are several times as many *glial cells* sharing this space with the neurons. These glial cells assist and support the neurons, much as paramedics assist and support the work of physicians.[5]

cerebral [seh-REE-bruhl] cortex The intricate fabric of interconnected neurons that form the body's ultimate control and information-processing center.

longitudinal fissure The long crevice that divides the cerebral cortex into the left and right hemispheres.

Major Divisions of the Cortex

The most dramatic feature of the cortex is the **longitudinal fissure,** the crevice that divides the cerebral cortex into two halves called *hemispheres* (see Figure 6.7). If you were to poke your pencil down this fissure (not that you should try this,

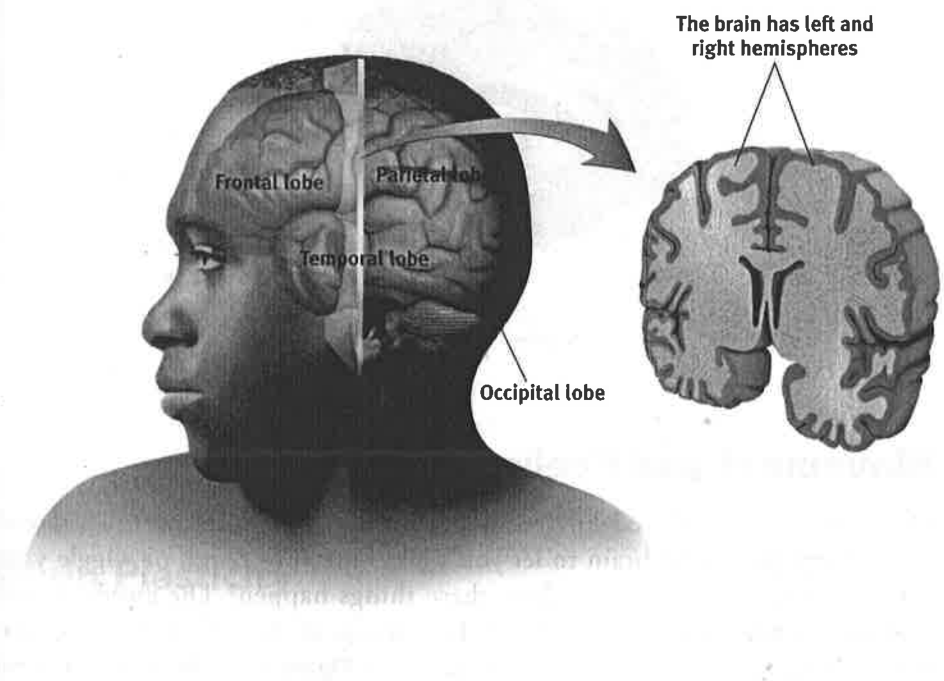

FIGURE 6.7
Basic Landmarks of the Cerebral Cortex
The cerebral cortex is the wrinkled outer surface of the brain. It is divided by fissures into two hemispheres and four major lobes.

corpus callosum [KOR-pus kah-LOW-sum] The large band of neural tissue that connects the two brain hemispheres and allows them to communicate with each other.

frontal lobes The portion of the cerebral cortex lying just behind the forehead that is involved in planning and judgment; it includes the motor cortex.

parietal [puh-RYE-uh-tuhl] lobes The portion of the cerebral cortex lying at the top of the head and toward the rear; it includes the somatosensory cortex and general association areas used for processing information.

occipital [ahk-SIP-uh-tuhl] lobes The portion of the cerebral cortex lying at the back of the head; it includes the primary visual processing areas of the brain.

temporal lobes The portion of the cerebral cortex lying roughly above the ears; it includes the auditory (hearing) areas of the brain.

mind you), you would eventually meet resistance at the **corpus callosum,** a large band of neural tissue that connects the two brain hemispheres and allows them to communicate with each other. The corpus callosum is clearly visible in **Figure 6.8**.

If you look back at Figure 6.7 (and use your imagination), you may note that the brain resembles a side view of a boxing glove. If you make your way around the boxing glove, you can see that additional fissures—a lateral fissure and a central fissure—create major divisions of tissue on each side. These divisions create four brain lobes—frontal, parietal, occipital, and temporal (see Figure 6.7). Lying just behind the forehead, the **frontal lobes** (left hemisphere and right hemisphere) enable your most advanced cognitive (thinking) abilities, such as judgment and planning. The frontal lobes' rational abilities literally lie atop, and connect with, the more primitive limbic region where the roots of emotion are found. This means that both emotion and reason are going to influence the decisions you make. The frontal lobes include the motor cortex (discussed later).

Behind the frontal lobes, at the top of the head and toward the rear, are the **parietal lobes**. The parietal lobes include the somatosensory cortex (discussed later), but they are largely designated as *association areas*—regions that make up most of the cerebral cortex and are available for the general processing of information, including much mathematical reasoning and integration of memory. At the rear of the cerebral cortex are the **occipital lobes,** the primary visual processing areas of the brain. You may not have eyes in the back of your head, but you do see with the back of your brain. Finally, the thumb region of the boxing glove, lying roughly above the ears, holds the **temporal lobes,** which include the auditory (sound) processing areas of the brain.

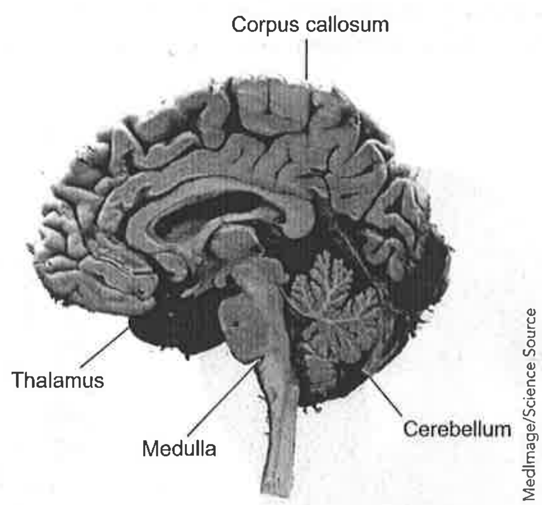

FIGURE 6.8
The Corpus Callosum
The corpus callosum is clearly visible in this photograph of a brain, made by cutting straight down through the longitudinal fissure. You can also see other structures we have discussed: the thalamus, the medulla, and the cerebellum.

Movement and Feeling

Have you ever wondered how your brain tells your body parts to move? What happens in your brain to let you walk, raise your hand, or wiggle your ears? Is there a specific spot where these things happen? The answer is *yes*. The **motor cortex** is a strip of tissue on the rear edge of the frontal lobes that controls voluntary movements of your body parts (see **Figure 6.9**). Different points on the motor cortex control different parts of your body, but they do so in a curious cross-wired pattern. Thus, the motor cortex in your right hemisphere takes care of movement on the *left* side of your body, and the motor cortex in your left hemisphere controls movement on the *right* side of your body.

motor cortex A strip of brain tissue at the rear of the frontal lobes that controls voluntary movements.

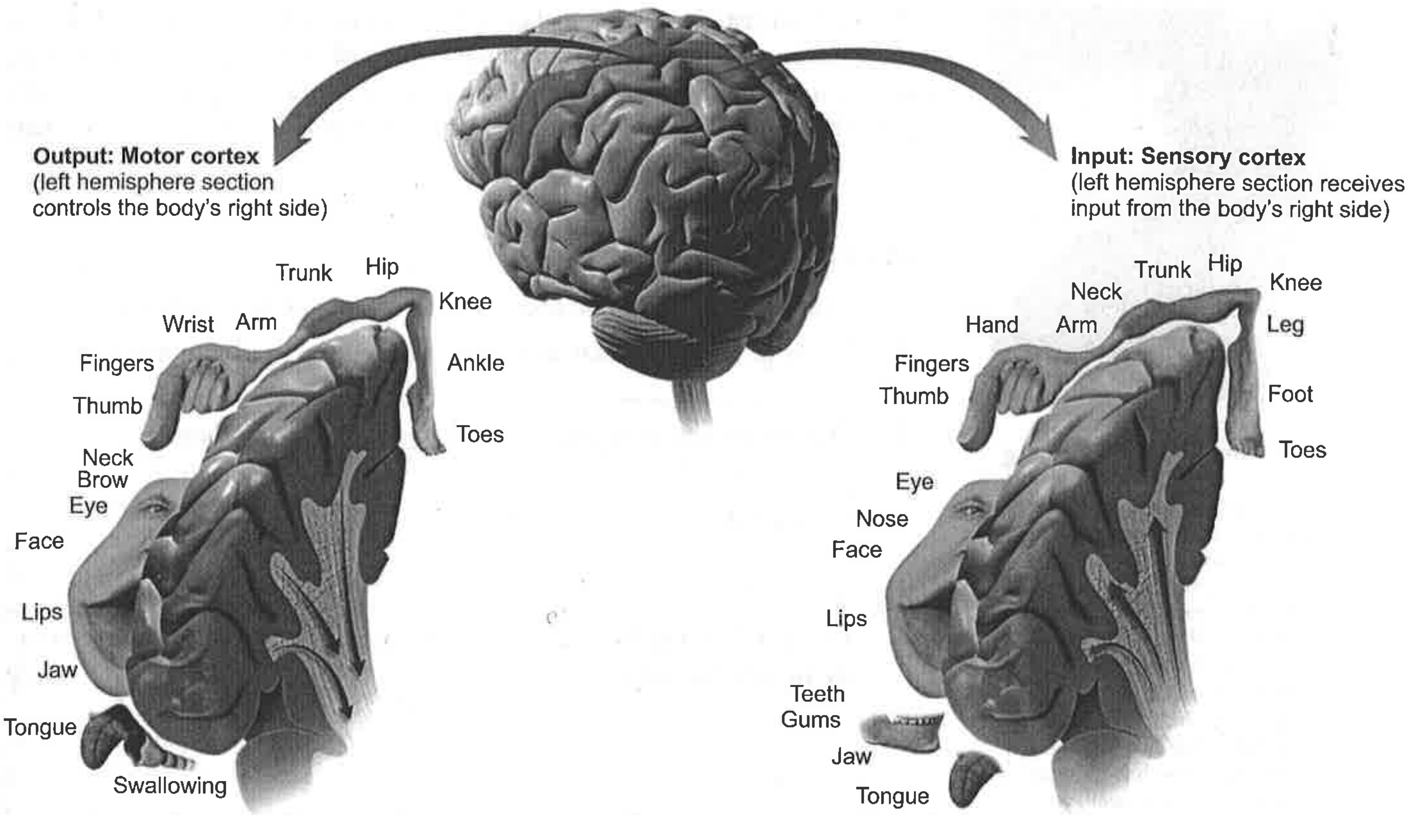

FIGURE 6.9
The Motor Cortex and the Somatosensory Cortex
On both sides of the central fissure, two strips of brain tissue handle information flowing from your senses to your body parts. The motor cortex is part of the frontal lobes, and the somatosensory cortex is part of the parietal lobes. The figure drawn on the expanded version of each strip roughly represents the amount of brain tissue devoted to particular body parts.

Another odd thing about the motor cortex is that the bigger parts of your body don't have the largest amount of brain area. Instead, the parts of the body that are capable of more intricate movements (like the hands and the face) demand more brain tissue than body parts for which intricate movement is not possible (like the arm and the ankle). If you were to draw a body along the motor cortex so that the body parts were proportionate to the amount of brain tissue, you would have a distorted drawing indeed, like the one in Figure 6.9.

Just behind the motor cortex, a similar strip of tissue stretches along the front edge of the parietal lobes. This is the **somatosensory cortex,** a brain area that registers and processes body sensations. This term sounds more difficult than it really is. If you remember that *soma* is Greek for *body*, you'll remember that this strip of cortex is where your body senses register. For example, when you feel a tickle under your nose or the pain of a stubbed toe, your brain will register that stimulation in the somatosensory cortex. As you can see in Figure 6.9, the somatosensory cortex allots more brain tissue to parts of your body that are more sensitive to touch (like your fingertips) than to those that are less sensitive (like your arms).

Brain Plasticity

The brain has an extraordinary ability to compensate for damage or injury. While damage to the brain is always serious, under some circumstances, especially in young people, the cerebral cortex can actually reprogram itself to compensate for a problem. For example, if a tumor in one brain hemisphere starts to disrupt language ability, language function may transfer to the other hemisphere.[6] This remarkable ability is called **plasticity**.

somatosensory cortex A strip of brain tissue at the front of the parietal lobes that registers and processes body sensations.

plasticity The brain's ability to change, especially during childhood, by reorganizing after damage or experience.

When Does One Point Become Two?
Your sensitivity to touch increases as you move down the inside of your forearm toward your wrist and the palm of your hand. To test this yourself, unfold a paper clip so the two tips are about half an inch apart. Then drag the two-pointed clip slowly and gently down a friend's arm while he has his eyes closed. If all goes well, your friend will report that the two tips of the paper clip feel like one point when they are higher on his arm. The two tips will begin to feel like two points lower on the arm as you approach the wrist again. This happens because the wrist and hand have more brain tissue on the somatosensory cortex, and thus more sensitivity, than does the upper arm.

The brain's plasticity is what makes some forms of therapy effective. There was a stroke victim who lost much of the ability to use his arm. His therapists did not allow him to use his good arm. By forcing him to use the damaged arm, he gradually regained function as his brain adjusted to the forced usage. Eventually, he was able to write and play tennis with the arm.[7]

MAKE IT STICK!

1. Describe where the brain processes movement and body sensations.
2. The large band of neural tissue that connects the two brain hemispheres is the ___________.
3. Visual information is processed in the ___________ lobes.
   a. parietal
   b. occipital
   c. temporal
   d. frontal
4. True or False? The longitudinal fissure separates the left hemisphere from the right hemisphere.

Differences Between the Brain's Two Hemispheres

6-4 Are the left hemisphere and the right hemisphere responsible for different thoughts and behaviors?

Have you ever heard people speak of the right brain and the left brain or even describe someone as being left-brained or right-brained? Like many popular ideas, this pop psychology notion is partly right and partly wrong. In truth, you have only one brain, not two. Yes, your single brain *is* divided into two hemispheres, and some functions differ significantly between the two halves. But the two sides of your brain are allies, not enemies. They communicate constantly via the corpus callosum, and to accomplish most tasks, you must use both the right side and the left side of your brain.

Language and Spatial Abilities

Language is the best example of a clear-cut difference between the functions of your brain's two hemispheres. In most people, language functions are located primarily in the left hemisphere. A small percentage of the population seems to be wired for language in the right hemisphere, but nobody is quite sure why.

Two particularly important language regions of the left hemisphere are Broca's area and Wernicke's area (see **Figure 6.10**):

- **Broca's area,** located in the left frontal lobe, directs the muscle movements involved in *expressive language* (speech). Damage to Broca's area, which often happens to victims of strokes, results in difficulty with spoken language. The stroke victim can form ideas but cannot turn those ideas into coherent speech.

Broca's area A brain area of the left frontal lobe that directs the muscle movements involved in speech.

- **Wernicke's area,** located in the left temporal lobe, is involved with *receptive language* (your ability to understand what someone else says). Damage to Wernicke's area might leave a person able to hear words but unable to comprehend the meaning of sentences created with the words. She would be able to recognize the individual parts of a computer (monitor, mouse, keyboard, and so on) but not understand that these parts together constitute a computer.

The right hemisphere, however, is not just a bystander. It houses most of your brain's *spatial* abilities. The word spatial relates to your ability to perceive or organize things in a given space, such as judging distance, understanding geometric objects, or packing a car's trunk efficiently. The right hemisphere also provides the insight to help us make connections among words. What word goes with *painting, ring,* and *nail*? Our right hemisphere finds the answer: *finger*. For a small handful of people with a surgically severed corpus callosum, however, the differing roles of the two hemispheres are much more dramatic.

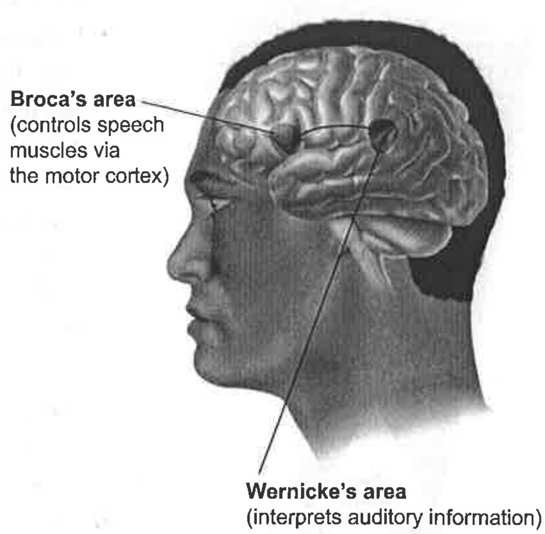

FIGURE 6.10
Broca's Area and Wernicke's Area
These two language areas are found only in the left hemisphere in most people.

The Split Brain

What would happen if the two halves of your brain were separated? Could you still function as a normal person? Why would anyone even consider such a dramatic procedure?

The last question is the easiest to answer. In the 1960s, scientists were working on ways to treat severe epilepsy, a brain disorder in which a person may have uncontrollable seizures. In an attempt to prevent these seizures from spreading from one side of the brain to the other, surgeons performed a split-brain operation, in which they cut the corpus callosum. The operation was successful—seizures no longer plagued the patients whose brains were split—but there were side effects.

Wernicke's [VER-nik-ees] area A brain area of the left temporal lobe involved in language comprehension and expression.

Cutting the corpus callosum prevents the two hemispheres of the brain from communicating with each other. Surprisingly, neuropsychologists Roger Sperry and Michael Gazzaniga found that the surgery left patients' personality and intellect unchanged.[8, 9] However, it altered perception—and corresponding behaviors—in some interesting ways. To understand why these changes occurred, we need to take a closer look at the roles of the two hemispheres.

As you can see in **Figure 6.11**, we normally route visual information efficiently from the eyes to the brain. The important thing is that information from your left visual field (the area to the left of your nose) falls on the right side of the retina at the back of each of your two eyes. In an intact brain, this design includes distributing the information across the corpus callosum so that the visual information is available to both hemispheres.

So, what happens when the information is *not* shared between the two hemispheres? In cleverly designed experiments, Gazzaniga and Sperry asked split-brain patients to focus on a spot at the center of a screen while images were projected to either the left or the right visual field.[10] The results demonstrated some interesting gaps in perception among people whose corpus callosum had been severed. Here are two examples:

1. When the picture of an item was projected to the *left visual field,* the patient was unable to identify the object verbally. Why? Because information from the left visual field is processed in the right hemisphere, but the speech center is located in the left hemisphere. There is no way to move the information from the right to the left hemisphere if the corpus callosum has been cut.

2. Look at the situation in **Figure 6.12**. In this case, the split-brain patient focuses on the dot while the *HE* is projected to the left visual field and *ART* is projected to the right visual field. The results are perfectly predictable, based on our understanding of the way the brain is organized. The patient will respond, *ART*, when asked what was seen, but to her own surprise will point to the word *HE* when asked to use her left hand to identify what she saw. What would the person do if asked to use her right hand to select the word she saw? That's right—she would point to *ART*. And, of course, a person with an intact corpus callosum would see the whole word, *HEART*.

These results are pretty strange—a bizarre but literal case of the left hand not knowing what the right hand is doing. Why, then, did the researchers conclude that the side effects of the surgery were minimal? Remember that to find these results, Sperry and Gazzaniga set up a procedure that required participants to focus on a dot at the center of the visual field. In real life, split-brain patients would be constantly moving their heads and eyes from side to side. Both visual fields would continually detect significant amounts of information and would make that information available to both brain hemispheres, despite the severed corpus callosum.

This is not to say the split-brain procedure has no lingering aftereffects. People who have had this surgery know that the left and right sides of the body seem at times to be under the command of different masters (because they are). When there is a conflict between the two hemispheres, the left brain usually tries to make

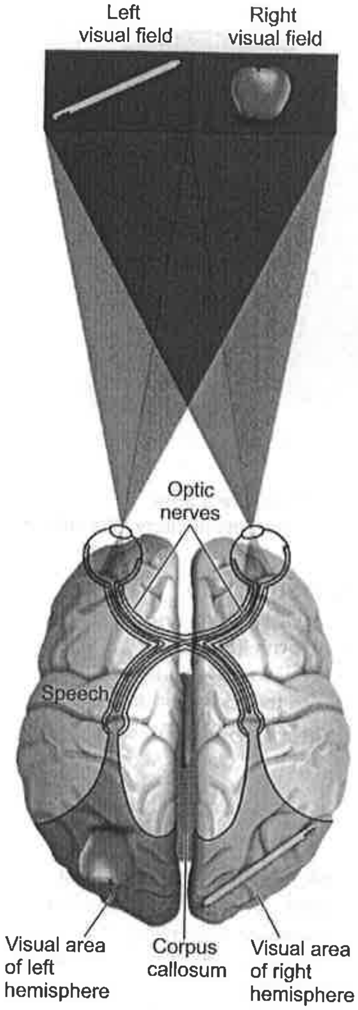

FIGURE 6.11 The Flow of Visual Information
Both eyes receive information from both visual fields, but all information from the left visual field ends up in the right hemisphere. The right visual field is processed in the left hemisphere. When the corpus callosum is cut, the two hemispheres cannot share information.

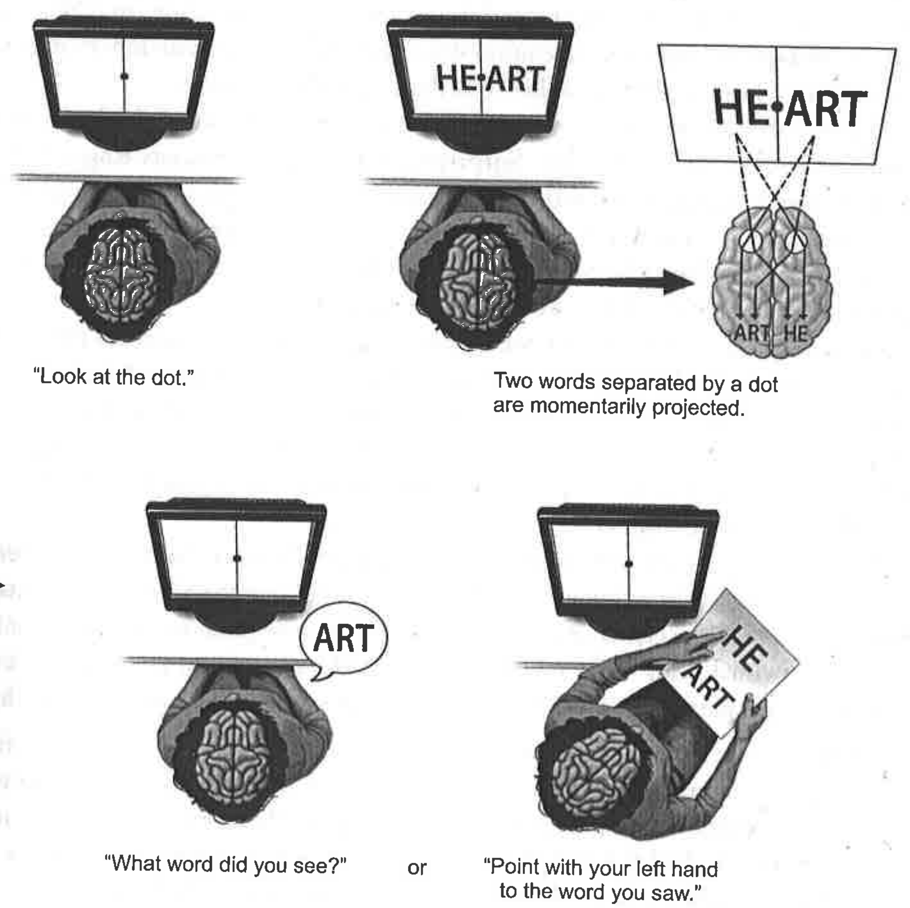

FIGURE 6.12 Wonders of the Split Brain
This split-brain patient says she sees only the word ART because the speech center can receive information only from the left hemisphere, which processes the right visual field. Her left hand *points* to HE because it's controlled by the right hemisphere. The right hemisphere can process information only from the left visual field.

sense of it all. Thus, if the right hemisphere of the brain implements a behavior, like walking, the left hemisphere will try to explain the reason (I'm going to get a Coke). It must be unnerving to have a brain at odds with itself, but these strange events would not significantly reduce a person's ability to function, and they usually would not be obvious to other people.

This historic attempt to control epileptic seizures yielded important information about the role of the brain's two hemispheres. The information has since been verified with modern brain-scanning techniques that were not available in the 1960s. Maybe the most important lesson of this research relates to the vital communication that travels between the hemispheres via the corpus callosum. Our left and right hemispheres form one integrated brain. A recent book on the great myths of popular psychology reminds us that those trying to sell us products to develop one side of the brain or the other are more interested in our bank accounts than in science.[11]

LIFE MATTERS

How well can you explain what would happen with a split-brain procedure? Before moving on, try to internally describe how you would communicate that you saw a dog in your left visual field and a cat in your right, if your corpus callosum was severed.

MAKE IT STICK!

1. One method of examining differences between the two hemispheres is to study patients
   a. with a split corpus callosum.
   b. who were born with no brainstem.
   c. who developed both a left and a right frontal lobe.
   d. with a limbic system that includes both a hippocampus and an amygdala.
2. ____________ area controls expressive speech and ____________ area controls receptive speech.
3. True or false: Split-brain research proved effective in controlling epilepsy, but it did not reveal much about the functioning of the brain's two hemispheres.

Module 6 Summary and Assessment

The Brain

6-1 What tools are available to psychological scientists for studying the brain?

- Case studies of brain injuries were the only method available before more current technological advances.
- Brain-scanning techniques can reveal a range of information about brain structure and function.
  - CT and MRI scans provide detailed images of brain structures.
  - EEGs reveal brain waves, an indication of brain activity levels.
  - PET and fMRI scans can provide information about activity levels of different regions of the brain.

6-2 What kinds of behaviors and thoughts are controlled by the innermost parts of our brain, the lower-level brain structures?

- The innermost parts of our brain, the lower-level brain structures, control basic life-support functions, such as breathing, wakefulness, muscle coordination, and routing sensory messages.
- The limbic system is key to our emotional experiences and memory system.