commit such violent crimes. And finally, it is always risky to jump from studies with animals to humans; the fact that the right orbitofrontal cortex plays a role in fear conditioning for animals in no way guarantees that it plays the same function for humans. For all these reasons, it is probably best to view these findings as suggestive rather than conclusive.

Still, this study provides a clear example of current efforts to understand the role of various portions of the brain in key aspects of human behavior, so I don't want to sound to critical of it. On the contrary, such research has already added greatly to our understanding of important brain-to-behavior links, and will certainly continue to do so in the future. But this doesn't mean we should jump to hasty conclusions, either; that would be a violation of the basic rules of science that are the foundation of all psychological research.

The Cerebral Cortex: The Core of Complex Thought

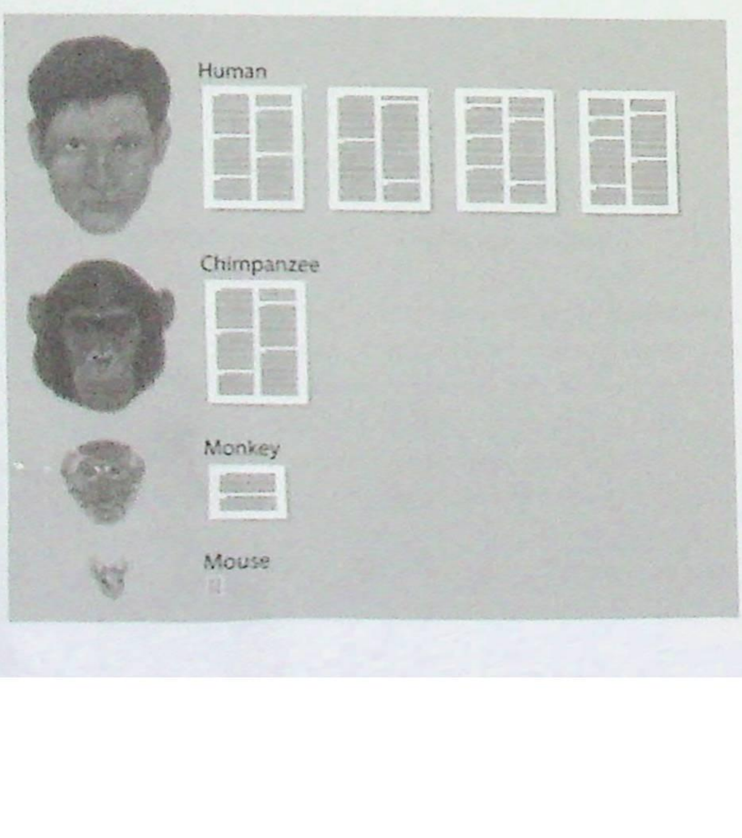
Now, at last, we come to the part of the brain that seems to be responsible for our ability to reason, plan, remember, and imagine—the **cerebral cortex**. This outer surface of the brain is only about one eighth of an inch thick, but it contains billions of neurons, each one connected to thousands of others. The predominance of cell bodies gives the cortex a brownish-gray color. Because of its appearance, the cortex is often referred to as gray matter. Beneath the cortex are myelin-sheathed axons connecting the neurons of the cortex with those of other parts of the brain. The large concentrations of myelin gives this tissue an opaque appearance, and hence it is often referred to as white matter.

Cerebral Cortex: The outer covering of the cerebral hemispheres.

Figure 2.9

Our Cerebral Cortex: Truly "Giant Size" Compared to That of Other Species

As shown here, the human cerebral cortex is much larger in area than that of other species. If it were not folded, we would need much larger skulls to hold it.



It is important to note that the cortex is divided into two nearly symmetrical halves, the cerebral hemispheres. Thus, many of the structures described in the following sections appear in both the left and right *cerebral hemispheres*. As we'll soon see, however, this similarity in structure is not entirely matched by similarity in function. The two hemispheres appear to be somewhat specialized in the functions they perform.

In humans, the cerebral hemispheres are folded into many ridges and grooves. In other organisms, there are fewer folds or no folds at all. The result is that the human cortex covers much more area than is true in other species. Each hemisphere is usually described, on the basis of the largest of these grooves or fissures, as being divided into four distinct regions or lobes: the frontal, parietal, occipital, and temporal lobes. We'll discuss each in detail.

Frontal Lobe: The portion of the cerebral cortex that lies in front of the central fissure.

Parietal Lobe: A portion of the cerebral cortex, lying behind the central fissure, that plays a major role in the skin senses: touch, temperature, pressure.

The Frontal Lobe

Occupying the area of the brain nearest the face, the **frontal lobe** is bounded by the deep *central fissure*. Lying along this fissure, just within the frontal lobe, is the *motor cortex*, an area concerned with the control of body movements (see Figure 2.9). Damage to this area does not produce total paralysis. Instead, it often results in a loss of control over fine movements, especially of the fingers. This illustrates an important fact about the human brain: While a specific area may normally perform a given function, other regions can often take up the slack if that area is damaged and may gradually come to perform the same functions. Such *plasticity*, as it is often termed, is greater at a young age than after maturity, but it seems to operate to some extent throughout life.

The Parietal Lobe

Across the central fissure from the frontal lobe is the **parietal lobe**. This area contains the *somatosensory cortex*, to which information from the skin senses—touch, temperature, pressure, and so on—is carried (refer to

Figure 2.10
Major Regions of the Cerebral Cortex
The cerebral cortex is divided into four major lobes (left). Specific areas in these lobes are concerned with sensory and motor functions, as well as with our higher mental processes (right).

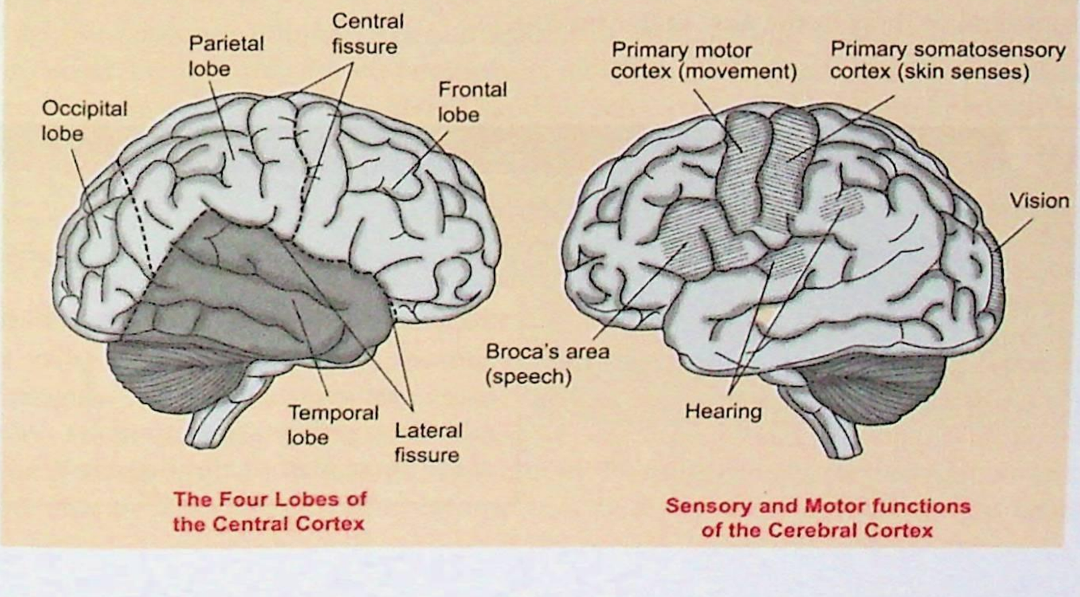


Figure 2.9). Discrete damage to this area produces a variety of effects, depending in part on whether injur occurs to the left or right cerebral hemisphere. If damage involves the left hemisphere, individuals may los the ability to read or write, or they may have difficulty knowing where parts of their own body are located. I contrast, if damage occurs in the right hemisphere, individuals may seem unaware of the left side of their body For example, a man may forget to shave the left side of his face.

The Occipital Lobe

The occipital lobe is located near the back of the head. Its primary functions are visual, and it contains a sensor area that receives input from the eyes. Damage to this area often produces a "hole" in the person's field of visior Objects in a particular location can't be seen, but the rest of the visual field may remain unaffected. As wit other brain structures, injury to the occipital lobe may produce contrasting effects depending on which cerebral hemisphere is affected. Damage to the occipital lobe in the right hemisphere produces loss of vision in the left visual field, whereas damage to the occipital lobe in the left hemisphere produces loss of vision in the right visual field.

Occipital Lobe: The portion of the cerebral cortex involved in vision.

Temporal Lobe: The lobe of the cerebral cortex that is involved in hearing.

The Temporal Lobe

Finally, the temporal lobe is located along the side of each hemisphere (see Figure 2.9). The location makes sense, for this lobe plays a key role in hearing and contains a sensory area that receives input from the ears. Damage to the temporal lobe, too, car result in intriguing symptoms. When such injuries occur in the left hemisphere, people may lose the ability to understand spoken words. When damage is restricted to the right hemisphere, they may be able to recognize speech but may lose the ability to recognize other organizations of sound—for example, melodies, tones, o rhythms. We'll examine the neural mechanisms that play a role in human speech in more detail in a late section.

It is interesting to note that when added together, areas of the cortex that either control motor movement (*motor cortex*) or receive sensory input (*sensory cortex*) account for only 20 to 25 per cent of the total area. Th remainder is known as the association cortex and, as its name suggests, is assumed to play a critical role in in tegrating the activities in the various sensory systems and in translating sensory input into programs for moto output. In addition, the association cortex seems to be involved in complex cognitive activities such as think ing, reasoning, remembering, language, recognizing faces, and a host of other complex cognitive function We'll return to several of these in the next major section.

REVIEW QUESTIONS

- What structures make up the brain stem? What are their functions?
- What are the functions of the hypothalamus and thalamus?
- What evidence suggests that brain dysfunctions may play a role in violence?
- What is the role of the cerebral cortex?

Food for Thought

Suppose that research clearly identified certain parts of the brain that when they malfunction, cause persons to engage in violence. Would it be ethical to perform operations on these persons to repair these malfunctioning areas?

Two Minds in One Body? Our Divided Brains

At first glance, the two hemispheres of the brain appear to be mirror images of one another. Yet a large body of evidence suggests that the cerebral hemispheres do differ, if not in appearance, then in terms of function. In fact, the right and left hemispheres show a considerable degree of **lateralization of function**: Each specializes, to an extent, in the performance of somewhat different tasks. In general terms the left hemisphere is the verbal hemisphere—it is specialized for speech and other verbal tasks. In contrast, the right specializes in the control of certain motor movements, in synthesis (putting isolated elements together), and in the comprehension and communication of emotion. Evidence from two kinds of research points to these conclusions: (1) studies of persons whose cerebral hemispheres have been isolated from each other through either accident or (more typically) surgery performed for medical reasons, and (2) studies of the rest of us—persons in whom the two cerebral hemispheres are connected in the normal way.

Lateralization of Function: Specialization of the two hemispheres of the brain for the performance of different functions.

Corpus Callosum: A band of nerve fibers connecting the two hemispheres of the brain.

Research with Split-Brain Persons

Under normal conditions, the two hemispheres of the brain communicate with each other through the **corpus callosum**, a wide band of nerve fibers that passes between them (Hoptman & Davidson, 1994). Sometimes, though, it is necessary to cut this link for medical reasons—for example, to prevent the spread of epileptic seizures from one hemisphere to the other. Such operations largely eliminate communication between the two hemispheres, so they provide a unique opportunity to study the effects that result. Careful study of individuals who have undergone such operations provides intriguing evidence for the view that the two hemispheres of the brain are indeed specialized for performing different tasks (Gazzaniga, 1984, 1985; Sperry, 1968).

Consider, for instance, the following demonstration. A man whose corpus callosum has been cut is seated before a screen and told to stare, with his eyes as motionless as possible, at a central point on the screen. Then simple words such as *tenant* are flashed across the screen so that the letters *ten* appear to the left of the central point and the letters *ant* appear to the right. What does the man report seeing? Before you guess, consider the following fact: Because of the way our visual system is constructed, stimuli presented to the *left* visual field of each eye stimulate only the *right* hemisphere of the brain; items on the *right* side of the visual field of each eye stimulate only the *left* hemisphere.

Now, what do you think our split-brain person reports? If you said "ant," you are correct; see Figure 2.10. This would be expected, because only the left hemisphere, which controls speech, can answer verbally. However, when asked to point to the word he saw with his left hand (which is controlled by the right hemisphere), the man reacts differently: He points with his left hand to the word *ten* (part of the word *tenant*). So the right hemisphere has indeed seen and recognized this stimulus; it can't describe it in words, but it can point to it. Thus, the fact that the right hemisphere is less verbal than the left does not mean that it is inferior in other respects. In fact, it is *superior* to the left hemisphere in copying drawings, recognizing faces, and expressing emotion.

Research with Persons Whose Hemispheres Are Connected

Additional evidence for specialization of function in the two hemispheres is provided by research on persons whose corpus callosum is intact—as in the great majority of us. For instance, consider the following kind of research, conducted with persons who are about to undergo brain surgery. First, participants are asked to describe traumatic emotional events (e.g., a near fatal traffic accident). Not surprisingly, they do so in vivid terms. Then, as preparation for surgery, they receive a drug injected into an artery that leads to the right hemisphere; as a result, this hemisphere is anesthetized. When asked to describe the same events again, they do so in much l intense terms. This provides evidence for the view that the right hemisphere plays a key role in the experien and expression of emotions.

Figure 2.11
Some Intriguing Effects of Severing the Corpus Callosum
A man whose corpus callosum has been cut stares at a central point on a screen. The word tenant is flashed across t screen so that the letters ten appear to the left of the central point and the letters ant appear to the right. Because o the way our visual system is constructed, stimuli presented to the left visual field of each eye stimulate only the righ hemisphere of the brain; items on the right side of the visual field of each eye stimulate only the left hemisphere. Therefore, when asked "What do you see?" the man answers: "Ant." But when asked to point to the word he saw w his left hand he points to the "ten" in the word "tenant." Findings such as these provide evidence for lateralization function in the two cerebral hemispheres.

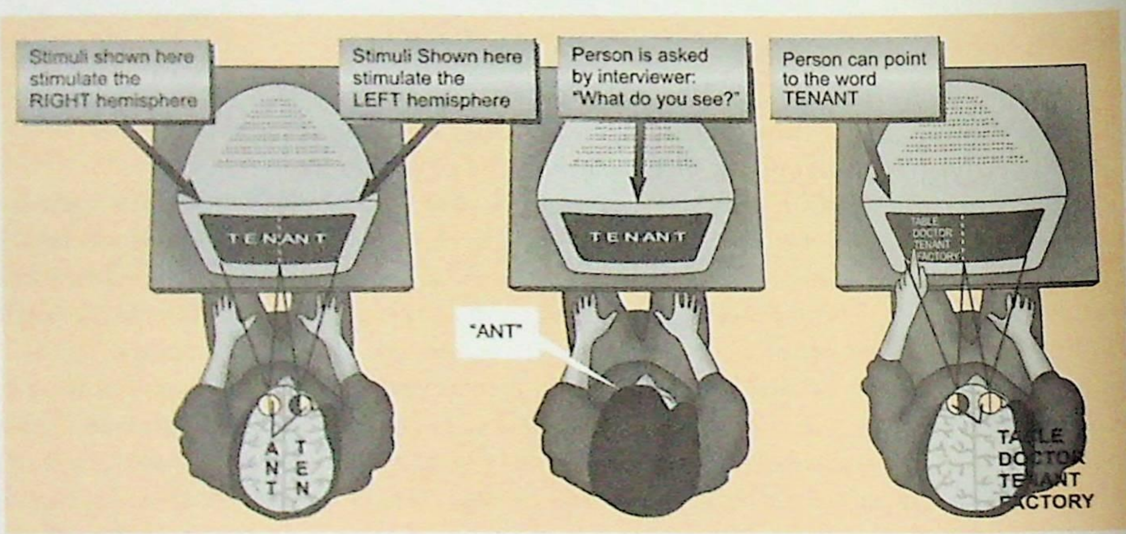


Figure 2.12
Evidence for Superiority of the Right Hemisphere in the Expression of Emotions
Which face shows most clearly the emotion of disgust? Most people choose photo 3, which is constructed from mirror images of the *left* side of the face–the side controlled by the right cerebral hemisphere. In contrast, photo constructed from mirror images of the *right* side of the face–the side controlled by the left hemisphere. It seems t show much less intense emotion. (Photo 2 shows the person as she really appears.)

Studies using a procedure we'll consider in the following **Research Methods** section, known as PET scanning, provide further support for the view that the two hemispheres are specialized for different functions. PET scans can reveal which parts of the brain are active when people perform specific tasks. Studies using this technique indicate that when individuals speak or work with numbers, activity in the left hemisphere increases. In contrast, when they work on perceptual tasks—for instance, tasks in which they compare various shapes—activity increases in the right hemisphere. Interestingly, additional research suggests that while individuals are making up their minds about some issue, activity is higher in the left than in the right hemisphere (Cacioppo, Petty, & Quintanar, 1982). Once logical thought is over and a decision has been made, however, heightened activity occurs in the right hemisphere, which seems to play a larger role in global, nonanalytic thought—for instance, overall reactions of the "I like it" or "I don't like it" type.

In sum, a large body of evidence suggests that in a sense, we do seem to possess two minds in one brain: The two cerebral hemispheres are specialized for performing somewhat different asks. We are unaware of this fact in everyday life, because the hemispheres generally work together in a unified manner. Why does such specialization exist? From an evolutionary perspective, the answer might be "Because it is beneficial and increases our chances of survival." Because of specialization of the two hemispheres, we don't have to think in words to recognize a threat—we can respond in a quicker gut-level manner. The specialization in our two hemispheres may produce synergy—a case in which the whole is indeed more than the sum of its parts.

Now that we've examined the structure of the brain and the functions of its major parts, we are just about ready to explore its complex and fascinating role in many forms of behavior. Before discussing this topic, however, we'll pause to survey briefly the ingenious methods used by psychologists to find out what happens in our brains, and where this activity occurs, when we speak, reason, and perform many other kinds of behavior. These methods are described in the following Research Methods section.

Research Methods

How Psychologists Study the Nervous System and the Brain

Throughout this chapter, we've stressed the fact that modern technology has provided psychologists and other scientists with an impressive array of new tools for studying the brain—especially for studying the brain in living organisms, including human beings. These new tools are impressive, and worthy of our careful attention. They are not, however, the only techniques available to *physiological psychologists* and other *neuroscientists* (scientists who study the structure and functions of the nervous system). In this section, then, we'll examine not only the newly developed tools but more traditional ones as well. While many procedures for studying the nervous system exist, most fit under these major headings: *observing the effects of damage*—(e.g., damage caused by accidents, disease, medical operations, or experimental procedures); recording and stimulating neural activity; and *studying the intact living brain* through new high-tech methods.

Observing the Effects of Naturally Produced Damage

The world, unfortunately, can be a dangerous place. Many people sustain damage to their brains in automobile or industrial accidents; many others