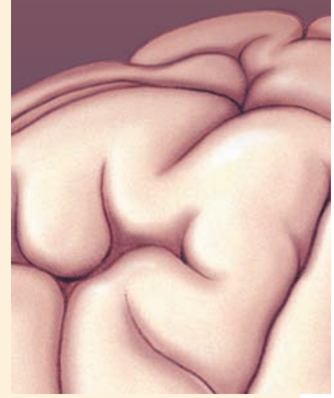
CHAPTER

1

Neuroscience: Past, Present, and Future



INTRODUCTION

Men ought to know that from nothing else but the brain come joys, delights, laughter and sports, and sorrows, griefs, despondency, and lamentations. And by this, in an especial manner, we acquire wisdom and knowledge, and see and hear and know what are foul and what are fair, what are bad and what are good, what are sweet and what are unsavory . . . . And by the same organ we become mad and delirious, and fears and terrors assail us . . . . All these things we endure from the brain when it is not healthy . . . . In these ways I am of the opinion that the brain exercises the greatest power in the man.

—Hippocrates, *On the Sacred Disease* (Fourth century B.C.)

It is human nature to be curious about how we see and hear; why some things feel good and others hurt; how we move; how we reason, learn, remember, and forget; the nature of anger and madness. These mysteries are starting to be unraveled by basic neuroscience research, and the conclusions of this research are the subject of this textbook.

The word "neuroscience" is young. The Society for Neuroscience, an association of professional neuroscientists, was founded as recently as 1970. The study of the brain, however, is as old as science itself. Historically, the scientists who devoted themselves to an understanding of the nervous system came from different scientific disciplines: medicine, biology, psychology, physics, chemistry, mathematics. The neuroscience revolution occurred when these scientists realized that the best hope for understanding the workings of the brain comes from an interdisciplinary approach, a combination of traditional approaches to yield a new synthesis, a new perspective. Most people involved in the scientific investigation of the nervous system today regard themselves as neuroscientists. Indeed, while the course you are now taking may be sponsored by the psychology or biology department at your university or college and may be called biopsychology or neurobiology, you can bet that your instructor is a neuroscientist.

The Society for Neuroscience is the largest and fastest-growing association of professional scientists in all of experimental biology. Far from being overly specialized, the field is as broad as nearly all of natural science, with the nervous system serving as the common point of focus. Understanding how the brain works requires knowledge about many things, from the structure of the water molecule to the electrical and chemical properties of the brain to why Pavlov's dog salivated when a bell rang. In this book, we will explore the brain with this broad perspective.

We begin the adventure with a brief tour of neuroscience. What have scientists thought about the brain over the ages? Who are the neuroscientists of today, and how do they approach studying the brain?

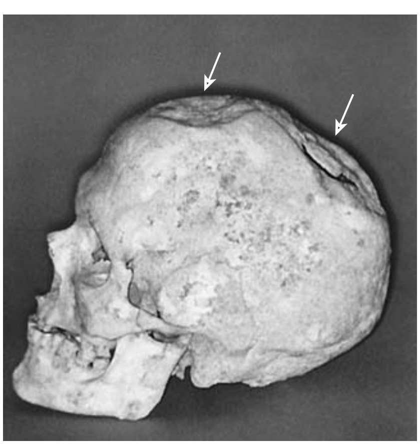


FIGURE 1.1
Evidence of prehistoric brain surgery. This skull of a man over 7000 years old was surgically opened while he was still alive. The arrows indicate two sites of trepanation. (Source: Alt et al., 1997, Fig. 1a.)

THE ORIGINS OF NEUROSCIENCE

You probably already know that the nervous system—the brain, spinal cord, and nerves of the body—is crucial for life and enables you to sense, move, and think. How did this view arise?

Evidence suggests that even our prehistoric ancestors appreciated that the brain was vital to life. The archeological record is rife with examples of hominid skulls, dating back a million years and more, bearing signs of fatal cranial damage, presumably inflicted by other hominids. As early as 7000 years ago, people were boring holes in each other's skulls (a process called trepanation), evidently with the aim not to kill but to cure (Figure 1.1).

The skulls show signs of healing after the operation, indicating that this procedure was carried out on live subjects and was not merely a ritual conducted after death. Some individuals apparently survived multiple skull surgeries. What early surgeons hoped to accomplish is not clear, although some have speculated that this procedure may have been used to treat headaches or mental disorders, perhaps by giving the evil spirits an escape route.

Recovered writings from the physicians of ancient Egypt, dating back almost 5000 years, indicate that they were well aware of many symptoms of brain damage. However, it is also very clear that the heart, not the brain, was considered to be the seat of the soul and the repository of memories. Indeed, while the rest of the body was carefully preserved for the afterlife, the brain of the deceased was simply scooped out through the nostrils and discarded! The view that the heart was the seat of consciousness and thought was not seriously challenged until the time of Hippocrates.

Views of the Brain in Ancient Greece

Consider the notion that the different parts of your body look different because they serve different purposes. The structures of the feet and hands are very different, and they perform very different functions: We walk on our feet and manipulate objects with our hands. Thus, we can say that there appears to be a very clear *correlation between structure and function*. Differences in appearance predict differences in function.

What can we glean about function from the structure of the head? Quick inspection and a few simple experiments (like closing your eyes) reveal that the head is specialized for sensing the environment. In the head are your eyes and ears, your nose and tongue. Even crude dissection shows that the nerves from these organs can be traced through the skull into the brain. What would you conclude about the brain from these observations?

If your answer is that the brain is the organ of sensation, then you have reached the same conclusion as several Greek scholars of the fourth century B.C. The most influential scholar was Hippocrates (460–379 B.C.), the father of Western medicine, who stated his belief that the brain not only was involved in sensation but also was the seat of intelligence.

However, this view was not universally accepted. The famous Greek philosopher Aristotle (384–322 B.C.) clung to the belief that the heart was the center of intellect. What function did Aristotle reserve for the brain? He proposed it to be a radiator for the cooling of blood that was overheated by the seething heart. The rational temperament of humans was thus explained by the large cooling capacity of our brain.

Views of the Brain During the Roman Empire

The most important figure in Roman medicine was the Greek physician and writer Galen (130–200 A.D.), who embraced the Hippocratic view of brain function. As physician to the gladiators, he must have witnessed the unfortunate consequences of spinal and brain injury. However, Galen's opinions about the brain probably were influenced more by his many careful animal dissections. Figure 1.2 is a drawing of the brain of a sheep, one of Galen's favorite subjects. Two major parts are evident: the *cerebrum* in the front and the *cerebellum* in the back. (The structure of the brain is the subject of Chapter 7.) Just as we were able to deduce function from the structure of

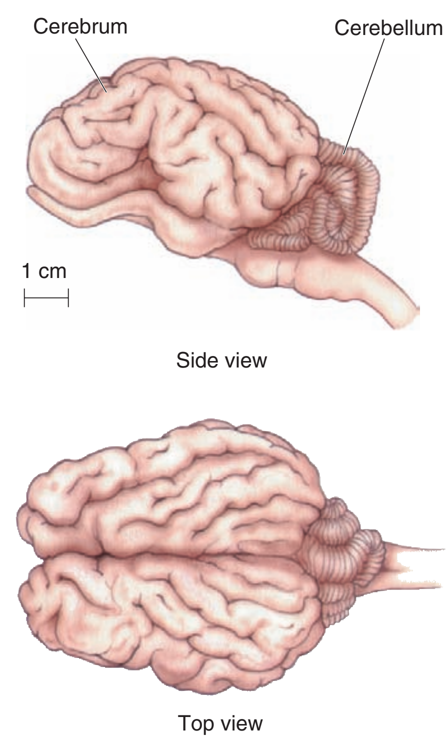


FIGURE 1.2
The brain of a sheep. Notice the location and appearance of the cerebrum and the cerebellum.

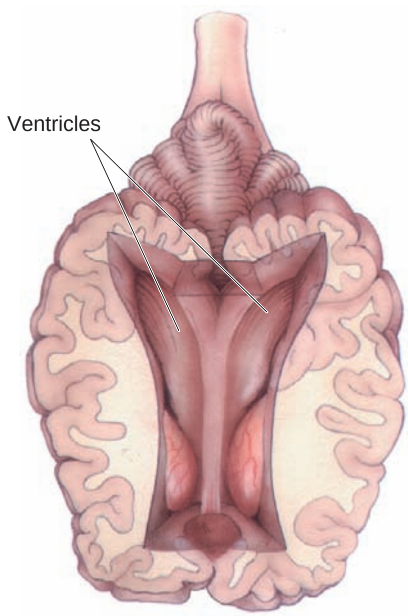


FIGURE 1.3
A dissected sheep brain showing the ventricles.

the hands and feet, Galen tried to deduce function from the structure of the cerebrum and the cerebellum. Poking the freshly dissected brain with a finger reveals the cerebellum to be rather hard and the cerebrum to be rather soft. From this observation, Galen suggested that the cerebrum must be the recipient of sensations and the cerebellum must command the muscles. Why did he propose this distinction? He recognized that to form memories, sensations must be imprinted onto the brain. Naturally, this must occur in the doughy cerebrum.

As improbable as his reasoning may seem, Galen's deductions were not that far from the truth. The cerebrum, in fact, is largely concerned with sensation and perception, and the cerebellum is primarily a movement control center. Moreover, the cerebrum is a repository of memory. We will see that this is not the only example in the history of neuroscience in which the right general conclusions were reached for the wrong reasons.

How does the brain receive sensations and move the limbs? Galen cut open the brain and found that it is hollow (Figure 1.3). In these hollow spaces, called *ventricles* (like the similar chambers in the heart), there is fluid. To Galen, this discovery fit perfectly with the prevailing theory that the body functioned according to a balance of four vital fluids, or humors. Sensations were registered and movements initiated by the movement of humors to or from the brain ventricles via the nerves, which were believed to be hollow tubes, like the blood vessels.

Views of the Brain From the Renaissance to the Nineteenth Century

Galen's view of the brain prevailed for almost 1500 years. More detail was added to the structure of the brain by the great anatomist Andreas Vesalius (1514–1564) during the Renaissance (Figure 1.4). However, ventricular localization of brain function remained essentially unchallenged. Indeed, the whole concept was strengthened in the early seventeenth century, when French inventors began developing hydraulically controlled mechanical devices. These devices supported the notion that the brain could be machinelike in its function: Fluid forced out of the ventricles through the nerves might literally "pump you up" and cause the movement of the limbs. After all, don't the muscles bulge when they contract?

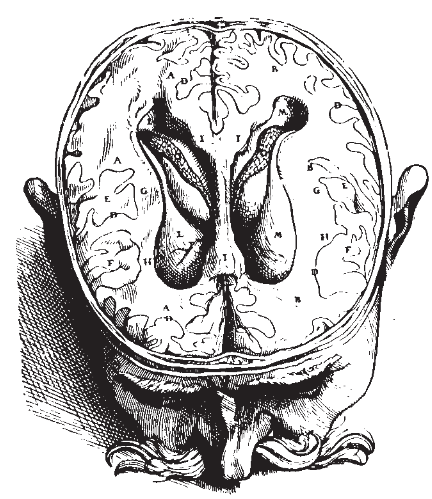


FIGURE 1.4
Human brain ventricles depicted during the Renaissance. This drawing is from *De humani corporis fabrica* by Vesalius (1543). The subject was probably a decapitated criminal. Great care was taken to be anatomically correct in depicting the ventricles. (Source: Finger, 1994, Fig. 2.8.)

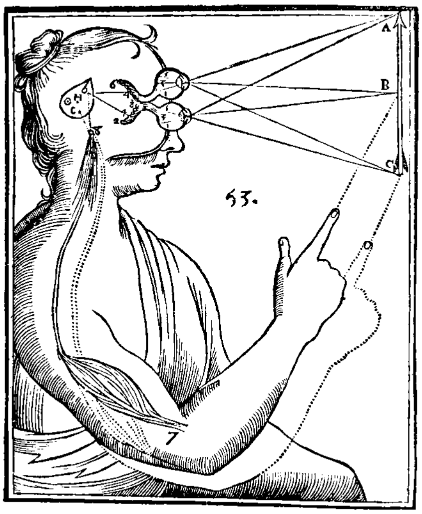


FIGURE 1.5
The brain according to Descartes.
This drawing appeared in a 1662 publication by Descartes. Hollow nerves from the eyes project to the brain ventricles. The mind influences the motor response by controlling the pineal gland (H), which works like a valve to control the movement of animal spirits through the nerves that inflate the muscles. (Source: Finger, 1994, Fig. 2.16.)

A chief advocate of this fluid-mechanical theory of brain function was the French mathematician and philosopher René Descartes (1596–1650). Although he thought this theory could explain the brain and behavior of other animals, it was inconceivable to Descartes that it could account for the full range of *human* behavior. He reasoned that unlike other animals, people possess intellect and a God-given soul. Thus, Descartes proposed that brain mechanisms control human behavior only to the extent that this behavior resembles that of the beasts. Uniquely human mental capabilities exist outside the brain in the "mind." Descartes believed that the mind is a spiritual entity that receives sensations and commands movements by communicating with the machinery of the brain via the pineal gland (Figure 1.5). Today, some people still believe that there is a "mind-brain problem," that somehow the human mind is distinct from the brain. However, as we shall see in Part III, modern neuroscience research supports another conclusion: The mind has a physical basis, which is the brain.

Fortunately, other scientists during the seventeenth and eighteenth centuries broke away from Galen's tradition of focusing on the ventricles and began to give the substance of the brain a closer look. One of their observations was that brain tissue is divided into two parts: the *gray matter* and the *white matter* (Figure 1.6). What structure-function relationship did they propose? White matter, because it was continuous with the nerves of the body, was correctly believed to contain the fibers that bring information to and from the gray matter.

By the end of the eighteenth century, the nervous system had been completely dissected, and its gross anatomy had been described in detail. Scientists recognized that the nervous system has a central division, consisting of the brain and spinal cord, and a peripheral division, consisting of the network of nerves that course through the body (Figure 1.7). An important breakthrough in neuroanatomy was the observation that the same general pattern of bumps (called *gyri*) and grooves (called *sulci* and *fissures*) could be identified on the surface of the brain in every individual (Figure 1.8). This pattern, which enables the parceling of the cerebrum into *lobes*, was the basis for speculation that different functions might be localized to the different bumps on the brain. The stage was now set for the era of cerebral localization.

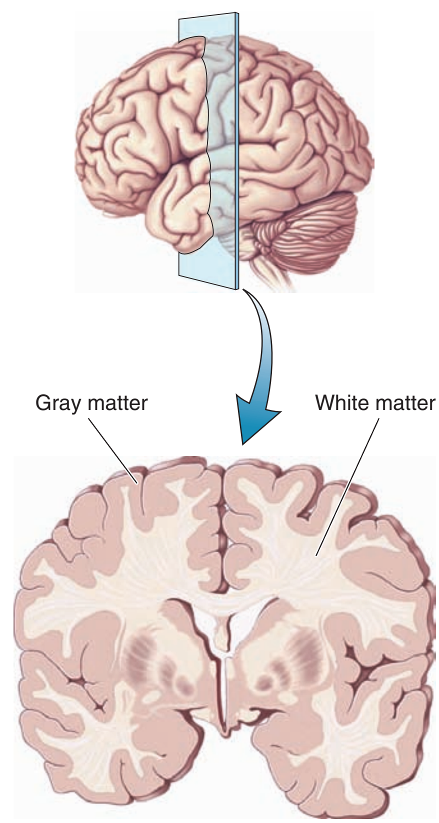


FIGURE 1.6
White matter and gray matter.
The brain has been cut open to reveal these two types of tissue.