1.1 What Is Biopsychology?

Biopsychology is the scientific study of the biology of behavior—see Dewsbury (1991). Some refer to this field as *psychobiology, behavioral biology,* or *behavioral neuroscience;* but I prefer the term *biopsychology* because it denotes a biological approach to the study of psychology rather than a psychological approach to the study of biology: Psychology commands center stage in this text. *Psychology* is the scientific study of behavior—the scientific study of all overt activities of the organism as well as all the internal processes that are presumed to underlie them (e.g., learning, memory, motivation, perception, and emotion).

The study of the biology of behavior has a long history, but biopsychology did not develop into a major neuroscientific discipline until the 20th century. Although it is not possible to specify the exact date of biopsychology's birth, the publication of *The Organization of Behavior* in 1949 by D. O. Hebb played a key role in its emergence (see Brown & Milner, 2003; Milner, 1993; Milner & White, 1987). In his book, Hebb developed the first comprehensive theory of how complex psychological phenomena, such as perceptions, emotions, thoughts, and memories, might be produced by brain activity. Hebb's theory did much to discredit the view that psychological functioning is too complex to have its roots in the physiology and chemistry of the brain. Hebb based his theory on experiments involving both humans and laboratory animals, on clinical case studies, and on logical arguments developed from his own insightful observations of daily life. This eclectic approach has become a hallmark of biopsychological inquiry.

In comparison to physics, chemistry, and biology, biopsychology is an infant—a healthy, rapidly growing infant, but an infant nonetheless. In this book, you will reap the benefits of biopsychology's youth. Because biopsychology does not have a long and complex history, you will be able to move directly to the excitement of current research.

1.2 What Is the Relation between Biopsychology and the Other Disciplines of Neuroscience?

Neuroscience is a team effort, and biopsychologists are important members of the team (see Albright, Kandel, & Posner, 2000; Kandel & Squire, 2000). This section of the chapter further defines biopsychology by discussing its relation to other neuroscientific disciplines.

Biopsychologists are neuroscientists who bring to their research a knowledge of behavior and of the methods of behavioral research. It is their behavioral orientation and expertise that make their contribution to neuroscience unique. You will be able to better appreciate the importance of this contribution if you consider that the ultimate purpose of the nervous system is to produce and control behavior (see Doupe & Heisenberg, 2000; Grillner & Dickson, 2002).

Biopsychology is an integrative discipline. Biopsychologists draw together knowledge from the other neuroscientific disciplines and apply it to the study of behavior.

The following are a few of the disciplines of neuroscience that are particularly relevant to biopsychology:

- **Neuroanatomy.** The study of the structure of the nervous system (see Chapter 3).
- **Neurochemistry.** The study of the chemical bases of neural activity (see Chapter 4).
- **Neuroendocrinology.** The study of interactions between the nervous system and the endocrine system (see Chapters 13 and 17).
- **Neuropathology.** The study of nervous system disorders (see Chapter 10).
- **Neuropharmacology.** The study of the effects of drugs on neural activity (see Chapters 4, 15, and 18).
- **Neurophysiology.** The study of the functions and activities of the nervous system (see Chapter 4).

Although biopsychology is only one of many disciplines that contribute to neuroscience, it is itself broad and diverse. Biopsychologists study many different phenomena, and they approach their research in many different ways. In order to characterize biopsychological research, this section discusses three major dimensions along which approaches to biopsychological research vary. Biopsychological research can involve either human or nonhuman subjects; it can take the form of either formal experiments or nonexperimental studies; and it can be either pure or applied.

Human and Nonhuman Subjects

Both human and nonhuman animals are the subject of biopsychological research. Of the nonhumans, rats are the most common subjects; however, mice, cats, dogs, and nonhuman primates are also widely studied.

Humans have several advantages over other animals as experimental subjects of biopsychological research: They can follow instructions, they can report their subjective experiences, and their cages are easier to clean. Of course, I am joking about the cages, but the joke does serve to draw attention to one advantage that humans have over other species of experimental subjects: Humans are often cheaper. Because only the highest standards of animal care are acceptable, the cost of maintaining an animal laboratory can be prohibitive for all but the most well-funded researchers.

Of course, the greatest advantage that humans have as subjects in a field aimed at understanding the intricacies of human brain function is that they have human brains. In fact, you might wonder why biopsychologists would bother studying nonhuman subjects at all. The answer lies in the evolutionary continuity of the brain. The brains of humans differ from the brains of other mammals primarily in their overall size and the extent of their cortical development. In other words, the differences between the brains of humans and those of related species are more quantitative than qualitative, and thus many of the principles of human brain function can be derived from the study of nonhumans (e.g., Nakahara et al., 2002).

Evolutionary Perspective

Conversely, nonhuman animals have three advantages over humans as subjects in biopsychological research. The first is that the brains and behavior of nonhuman subjects are simpler than those of human subjects. Hence, the study of nonhuman species is more likely to reveal fundamental brain–behavior interactions. The second advantage is that insights frequently arise from the **comparative approach**, the study of biological processes by comparing different species. For example, comparing the behavior of species that do not have a cerebral cortex with the behavior of species that do can provide valuable clues about cortical function. The third advantage is that it is possible to conduct research on laboratory animals that, for ethical reasons, is not possible with human subjects. This is not to say that the study of nonhuman animals is not governed by a strict code of ethics (see Institute of Laboratory Animal Resources, 1996)—it is. However, there are fewer ethical constraints on the study of laboratory species than on the study of humans.

In my experience, most biopsychologists display considerable concern for their subjects, whether they are of their own species or not; however, ethical issues are not left to the discretion of the individual researcher. All biopsychological research, whether it involves human or nonhuman subjects, is regulated by independent committees according to strict ethical guidelines: "Researchers cannot escape the logic that if the animals we observe are reasonable models of our own most intricate actions, then they must be respected as we would respect our own sensibilities" (Ulrich, 1991, p. 197).

Experiments and Nonexperiments

Biopsychological research involves both experiments and nonexperimental studies. Two common types of nonexperimental studies are quasiexperimental studies and case studies.

Experiments The experiment is the method used by scientists to find out what causes what, and, as such, it is almost single-handedly responsible for our modern way of life. It is paradoxical that a method capable of such complex feats is itself so simple. To conduct an experiment involving living subjects, the experimenter first designs two or more conditions under which the subjects will be tested. Usually, a different group of subjects is tested under each condition (**between-subjects design**), but sometimes it is possible to test the same group of subjects under each condition (**within-subjects design**). The experimenter assigns the subjects to conditions, administers the treatments, and measures the outcome in such a way that there is only one relevant difference between the conditions that are being compared. This difference between the conditions is called the **independent variable**. The variable that is measured by the experimenter to assess the effect of the independent variable is called the **dependent variable**.

Why is it critical that there be no differences between conditions other than the independent variable? The reason is that when there is more than one difference that could affect the dependent variable, it is difficult to determine whether it was the independent variable or the unintended difference—called a confounded variable—that led to the observed effects on the dependent variable.

Although the experimental method is conceptually simple, eliminating all confounded variables can be quite difficult. Readers of research papers must be constantly on the alert for confounded variables that have gone unnoticed by the experimenters themselves.

An experiment by Lester and Gorzalka (1988) illustrates the experimental method in action. The experiment was a demonstration of the Coolidge effect. The Coolidge effect is the fact that a copulating male who becomes incapable of continuing to copulate with one sex partner can often recommence copulating with a new sex partner (see Figure 1.2). Before your imagination starts running wild, I should mention that the subjects in Lester and Gorzalka's experiment were hamsters, not students from the undergraduate subject pool.

Lester and Gorzalka argued that the Coolidge effect had not been demonstrated in females because it is more difficult to conduct well-controlled Coolidge-effect experiments with females—not because females do not display a Coolidge effect. The confusion, according to Lester and Gorzalka, stemmed from the fact that the males of most mammalian species become sexually fatigued more readily than do the females. As a result, attempts to demonstrate the Coolidge effect in females are often confounded by the fatigue of the males. When, in the midst of copulation, a female is provided with a new sex partner, the increase in her sexual receptivity could be either a legitimate Coolidge effect or a reaction to the greater vigor of the new male. Because female mammals usually display little sexual fatigue, this confounded variable is not a serious problem in demonstrations of the Coolidge effect in males.

Lester and Gorzalka devised a clever procedure to control for this confounded variable. At the same time that a female subject was copulating with one male (the familiar male), the other male to be used in the test (the unfamiliar male) was copulating with another female. Then, both males were given a rest while the female was copulating with a third male. Finally, the female subject was tested with either the familiar male or the unfamiliar male. The dependent variable was the amount of time that the female displayed lordosis (the arched-back, rump-up, tail-diverted posture of female rodent sexual receptivity) during each sex test. As Figure 1.3 illustrates, the females responded more vigorously to the unfamiliar males than they did to the familiar males during the third test, despite the fact that both the unfamiliar and familiar males were equally fatigued and both mounted the females with equal vigor. This experiment illustrates the importance of good experimental design as well as a point made in Chapter 13: that males and females are more similar than most people appreciate.

FIGURE 1.2 President Calvin Coolidge and Mrs. Grace Coolidge. Many students think that the Coolidge effect is named after a biopsychologist named Coolidge. In fact, it is named after President Calvin Coolidge, of whom the following story is told. (If the story isn't true, it should be.) During a tour of a poultry farm, Mrs. Coolidge inquired of the farmer how his farm managed to produce so many eggs with such a small number of roosters. The farmer proudly explained that his roosters performed their duty dozens of times each day.

"Perhaps you could point that out to Mr. Coolidge," replied the First Lady in a pointedly loud voice.

The President, overhearing the remark, asked the farmer, "Does each rooster service the same hen each time?"

"No," replied the farmer, "there are many hens for each rooster."

"Perhaps you could point that out to Mrs. Coolidge," replied the President.

Quasiexperimental Studies It is not possible for biopsychologists to bring the experimental method to bear on all problems of interest to them. There are frequently physical or ethical impediments that make it impossible to assign subjects to particular conditions or to administer the conditions once the subjects have been assigned to them. For example, experiments on the causes of brain damage in human alcoholics are not feasible be-

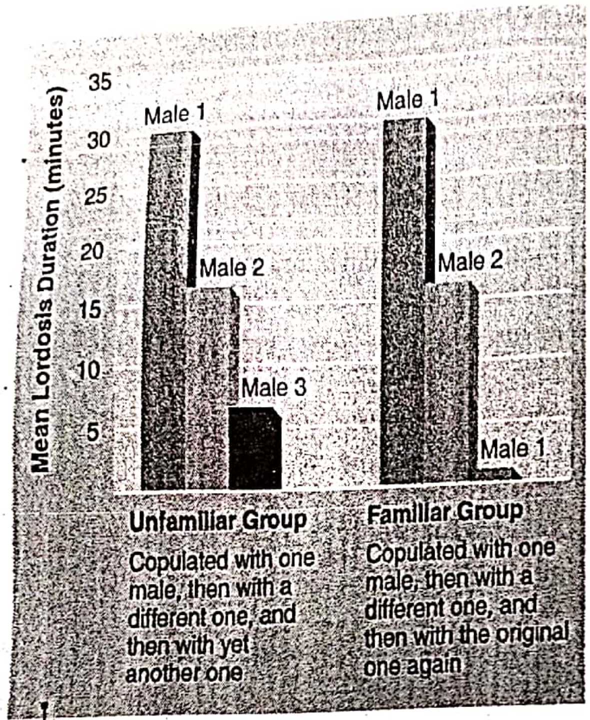

FIGURE 1.3 The experimental design and results of Lester and Gorzalka (1988). On the third test, the female hamsters were more sexually receptive to unfamiliar males than they were to the males with which they had copulated on the first test.

cause it would not be ethical to assign a subject to a condition that involves years of alcohol consumption. (Some of you may be more concerned about the ethics of assigning subjects to a control condition that involves years of sobriety.) In such prohibitive situations, biopsychologists sometimes conduct **quasiexperimental studies**—studies of groups of subjects who have been exposed to the conditions of interest in the real world. These studies have the appearance of experiments, but they are not true experiments because potential confounded variables have not been controlled—for example, by the random assignment of subjects to conditions.

In one quasiexperimental study, a team of researchers compared 100 detoxified male alcoholics from an alcoholism treatment unit with 50 male nondrinkers obtained from various sources (Acker et al., 1984). The alcoholics as a group performed more poorly on various tests of perceptual, motor, and cognitive ability, and their brain scans revealed extensive brain damage. Although this quasiexperimental study seems like an experiment, it is not. Because the subjects themselves decided which group they would be in—by drinking alcohol or not—the researchers had no means of ensuring that exposure to alcohol was the only variable that distinguished the two groups. Can you think of differences other than exposure to alcohol that could reasonably be expected to exist between a group of alcoholics and a group of abstainers—differences that could have contributed to the neuroanatomical or intellectual differences that were observed between them? There are several. For example, alcoholics as a group tend to be more poorly educated, more prone to accidental head injury, more likely to use other drugs, and more likely to have poor diets. Accordingly, quasiexperimental studies have revealed that alcoholics tend to have more brain damage than nonalcoholics, but they have not indicated why.

Have you forgotten Jimmie G.? He was a product of long-term alcohol consumption.

Case Studies Studies that focus on a single case or subject are called **case studies**. Because they focus on a single case, they often provide a more in-depth picture than that provided by an experiment or a quasiexperimental study, and they are an excellent source of testable hypotheses. However, there is a major problem with all case studies: their **generalizability**—the degree to which their results can be applied to other cases. Because humans differ from one another in both brain function and behavior, it is important to be skeptical of any biopsychological theory based entirely on a few case studies.

Pure and Applied Research

Biopsychological research can be either pure or applied. Pure research and applied research differ in a number of respects, but they are distinguished less by their own attributes than by the motives of the individuals involved in their pursuit. **Pure research** is research motivated primarily by the curiosity of the researcher—it is done solely for the purpose of acquiring knowledge. In contrast, **applied research** is research intended to bring about some direct benefit to humankind.

Many scientists believe that pure research will ultimately prove to be of more practical benefit than applied research. Their view is that applications flow readily from an understanding of basic principles and that attempts to move directly to application without first gaining a basic understanding are shortsighted. Of course, it is not necessary for a research project to be completely pure or completely applied; many research programs have elements of both approaches.

One important difference between pure and applied research is that pure research is more vulnerable to the vagaries of political regulation because politicians and the voting public have difficulty understanding why research of no immediate practical benefit should be supported. If the decision were yours, would you be willing to grant hundreds of thousands of dollars to support the study of squid *motor neurons* (neurons that control muscles), learning in recently hatched geese, the activity of single nerve cells in the visual systems of monkeys, the hormones released by the *hypothalamus* (a small neural structure at the base of the brain) of pigs and sheep, or the function of the *corpus callosum* (the large neural pathway that connects the left and right halves of the brain)? Which, if any, of these projects would you consider worthy of support? Each of these seemingly esoteric projects was supported, and each earned a Nobel Prize for its author.

Table 1.1 lists some of the Nobel Prizes awarded for research related to the brain and behavior (see Benjamin, 2003). The purpose of this list is to give you a g eral sense of the official recognition that behavioral a brain research has received, not to have you memo the list. You will learn later in the chapter that, whe comes to evaluating science, the Nobel committee not been infallible.

1.4 What Are the Divisions of Biopsychology?

As you have just learned, biopsychologists conduct their research in a variety of fundamentally different ways. Biopsychologists who take the same approaches to their research tend to publish their research in the same journals, attend the same scientific meetings, and belong to the same professional societies. The particular approaches to biopsychology that have flourished and grown have gained wide recognition as separate divisions of biopsychological research. The purpose of this section of the chapter is to give you a clearer sense of biopsychology and its diversity by describing six of its major divisions: (1) physiological psychology, (2) psychopharmacology, (3) neuropsychology, (4) psychophysiology, (5) co tive neuroscience, and (6) comparative psychology. simplicity, they are presented as distinct approaches there is much overlap among them, and many bio chologists regularly follow more than one approach

Physiological Psychology

Physiological psychology is the division of biopsy ogy that studies the neural mechanisms of beh through the direct manipulation of the brain in trolled experiments—surgical and electrical me of brain manipulation are most common. The subjects of physiological psychology research are almost always laboratory animals, because the focus on direct brain manipulation and controlled experiments precludes the use of human subjects in most instances. There is also a tradition of pure research in physiological psychology; the emphasis is usually on research that contributes to the development of theories of the neural control of behavior rather than on research that is of immediate practical benefit.

Psychopharmacology

Psychopharmacology is similar to physiological psychology, except that it focuses on the manipulation of neural activity and behavior with drugs. In fact, many of the early psychopharmacologists were simply physiological psychologists who moved into drug research, and many of today's biopsychologists identify closely with both approaches. However, the study of the effects of drugs on the brain and behavior has become so specialized that psychopharmacology is regarded as a separate discipline.

A substantial portion of psychopharmacological research is applied (see Brady, 1993). Although drugs are sometimes used by psychopharmacologists to study the basic principles of brain–behavior interaction, the purpose of many psychopharmacological experiments is to develop therapeutic drugs (see Chapter 18) or to reduce drug abuse (see Chapter 15). Psychopharmacologists study the effects of drugs on laboratory species—and on humans, if the ethics of the situation permits it.

Clinical Implications

Neuropsychology

Neuropsychology is the study of the psychological effects of brain damage in human patients. Obviously, human subjects cannot ethically be exposed to experimental treatments that endanger normal brain function. Consequently, neuropsychology deals almost exclusively with case studies and quasiexperimental studies of patients with brain damage resulting from disease, accident, or neurosurgery. The outer layer of the cerebral hemispheres—the **cerebral cortex**—is most likely to be damaged by accident or surgery; this is one reason why neuropsychology has focused on this important part of the human brain.

Neuropsychology is the most applied of the biopsychological subdisciplines; the neuropsychological assessment of human patients, even when part of a program of pure research, is always done with an eye toward benefiting them in some way. Neuropsychological tests facilitate diagnosis and thus help the attending physician prescribe effective treatment (see Benton, 1994). They can also be an important basis for patient care and counseling; Kolb and Whishaw (1990) described such an application.

Clinical Implications

The Case of Mr. R., the Brain-Damaged Student Who Switched to Architecture

Mr. R., a 21-year-old left-handed man, struck his head on the dashboard in a car accident. . . . Prior to his accident Mr. R. was an honor student at a university. However, a year after the accident he had become a mediocre student who had particular trouble completing his term papers. . . . He was referred to us for neuropsychological assessment, which revealed several interesting facts.

First, Mr. R. was one of about one-third of left-handers whose language functions are represented in the right rather than left hemisphere. . . . In addition, although Mr. R. had a superior IQ, his verbal memory and reading speed were only low-average, which is highly unusual for a person of his intelligence and education. These deficits indicated that his right temporal lobe may have been slightly damaged in the car accident, resulting in an impairment of his language skills. On the basis of our neuropsychological investigation we were able to recommend vocations to Mr. R. that did not require superior verbal memory skills, and he is currently studying architecture.

(From *Fundamentals of Human Neuropsychology*, 3rd Edition, by Bryan Kolb and Ian Q. Whishaw, p. 128. Copyright © 1980, 1985, 1990 W. H. Freeman and Company. Reprinted with permission.)

Psychophysiology

Psychophysiology is the division of biopsychology that studies the relation between physiological activity and psychological processes in human subjects (Coles, 2003; Gratton & Fabiani, 2003). Because the subjects of psychophysiological research are human, psychophysiological recording procedures are typically noninvasive; that is, the physiological activity is recorded from the surface of the body. The usual measure of brain activity is the scalp **electroencephalogram (EEG)**. Other common psychophysiological measures are muscle tension, eye movement, and several indicators of autonomic nervous system activity (e.g., heart rate, blood pressure, pupil dilation, and electrical conductance of the skin). The **autonomic nervous system (ANS)** is the division of the nervous system that regulates the body's inner environment.

Most psychophysiological research focuses on understanding the physiology of psychological processes,

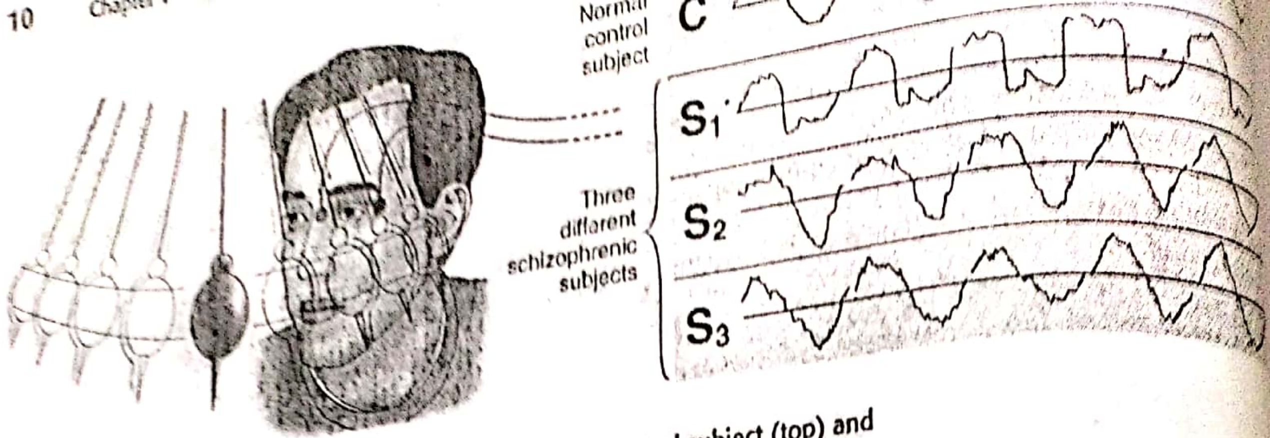

FIGURE 1.4 Visual tracking of a pendulum by a normal control subject (top) and three schizophrenics. (Adapted from Iacono & Koenig, 1983.)

such as attention, emotion, and information processing, but there have also been a number of interesting clinical applications of the psychophysiological method. For example, psychophysiological experiments have indicated that schizophrenics have difficulty smoothly tracking a moving object such as a pendulum (Avila et al., 2003; Holzman, 2000; Hong et al., 2003)—see Figure 1.4.

Clinical Implications

Cognitive Neuroscience

Cognitive neuroscience is the youngest division of biopsychology, but it is currently among the most active and exciting. Cognitive neuroscientists study the neural bases of cognition, a term that generally refers to higher intellectual processes such as thought, memory, attention, and complex perceptual processes (see Albright, Kandel, & Posner, 2000; Cabeza & Kingston, 2002). Because of its focus on cognition, most cognitive neuroscience research involves human subjects; and because of its focus on human subjects, its major method is noninvasive recording rather than the direct manipulation of the brain.

Cognitive Neuroscience

The major method of cognitive neuroscience is functional brain imaging (recording images of the activity of the living human brain; see Chapter 5) while the subjects are engaged in particular cognitive activities. For example, Figure 1.5 shows that the visual areas of the left and right cerebral cortex at the back of the brain became active when the subject viewed a flashing light.

ON THE CD Take a look at the *Visit to a Cognitive Neuroscience Laboratory* module.

Because the theory and methods of cognitive neuroscience are so complex and interesting to people in so many fields (see Cacioppo et al., 2003; Ochsner & Lieberman, 2001), most cognitive neuroscientific research is an interdisciplinary collaboration among individuals with different types of training. For example, in addition to conventionally trained biopsychologists, cogniti psychologists, computing and mathematics experts, a various types of neuroscientists commonly contribu to the field. Cognitive neuroscience research sometime involves noninvasive electrophysiological recording, an

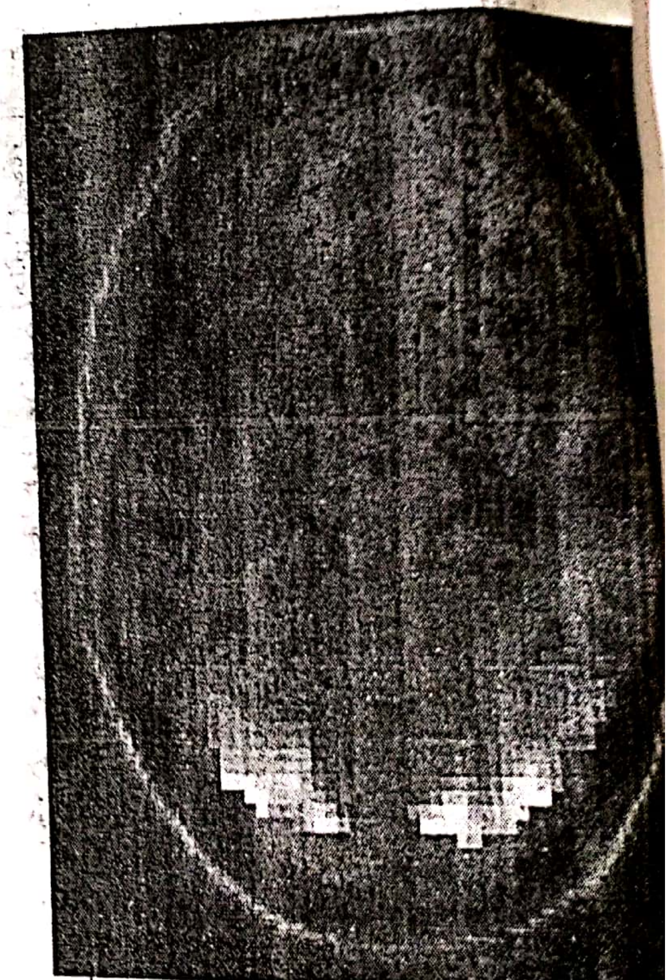

FIGURE 1.5 Functional brain imaging is the m method of cognitive neuroscience. This image—taken f the top of the head with the subject lying on her back reveals the locations of high levels of neural activity at level of the brain as the subject views a flashing light. red and yellow areas indicate high levels of activity in visual cortex at the back of the brain. (Courtesy of Todd Department of Psychology, University of British Columbia.)

it sometimes focuses on subjects with brain pathology; in these cases, the boundaries between cognitive neuroscience and psychophysiology and neuropsychology, respectively, are blurry.

Comparative Psychology

Although most biopsychologists study the neural mechanisms of behavior, there is more to biopsychology than this. As Dewsbury (1991) asserted:

> The "biology" in "psychobiology" should include the whole-animal approaches of ethology, ecology, evolution . . . as well as the latest in physiological methods and thought. . . . The "compleat psychobiologist" should use whatever explanatory power can be found with modern physiological techniques, but never lose sight of the problems that got us going in the first place: the integrated behavior of whole, functioning, adapted organisms. (p. 198)

The division of biopsychology that deals generally with the biology of behavior, rather than specifically with the neural mechanisms of behavior, is comparative psychology. Comparative psychologists compare the behavior of different species in order to understand the evolution, genetics, and adaptiveness of behavior. Some comparative psychologists study behavior in the laboratory; others engage in ethological research—the study of animal behavior in its natural environment.

Evolutionary Perspective

Because two important areas of biospsychological research often employ comparative analysis, I have included them as part of comparative psychology. One of these is *evolutionary psychology* (a subfield that focuses on understanding behavior by considering its likely evolutionary origins; see Caporael, 2001; Duchaine, Cosmides, & Tooby, 2001; Kenrick, 2001). The other is *behavioral genetics* (the study of genetic influences on behavior; see Carson & Rothstein, 1999; Plomin et al., 2002).

In case you have forgotten, the purpose of this section has been to demonstrate the diversity of biopsychology by describing its six major divisions. These are summarized for you in Table 1.2. You will learn about the progress being made in each of these divisions in subsequent chapters.