Chapter 1

Biopsychology as a Neuroscience

What Is Biopsychology, Anyway?

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Chapter Overview and Learning Objectives

What Is Biopsychology?	**LO 1.1**	Define and discuss what is meant by *biopsychology*.
	LO 1.2	Discuss the origins of the field of biopsychology.
	LO 1.3	List the six fields of neuroscience that are particularly relevant to biopsychological inquiry.
What Types of Research Characterize the Biopsychological Approach?	**LO 1.4**	Compare the advantages and disadvantages of humans and nonhumans as subjects in biopsychological research.
	LO 1.5	Compare experiments, quasiexperimental studies, and case studies, emphasizing their utility in the study of causal effects.
	LO 1.6	Compare pure and applied research.
What Are the Divisions of Biopsychology?	**LO 1.7**	Describe the division of biopsychology known as physiological psychology.

LO 1.8 Describe the division of biopsychology known as psychopharmacology.

LO 1.9 Describe the division of biopsychology known as neuropsychology.

LO 1.10 Describe the division of biopsychology known as psychophysiology.

LO 1.11 Describe the division of biopsychology known as cognitive neuroscience.

LO 1.12 Describe the division of biopsychology known as comparative psychology.

How Do Biopsychologists Conduct Their Work?

LO 1.13 Explain how converging operations has contributed to the study of Korsakoff's syndrome.

LO 1.14 Explain scientific inference with reference to research on eye movements and the visual perception of motion.

Thinking Critically about Biopsychological Claims

LO 1.15 Define critical thinking and evaluate biopsychological claims.

The appearance of the human brain is far from impressive (see Figure 1.1). The human brain is a squishy, wrinkled, walnut-shaped hunk of tissue weighing about 1.3 kilograms. It looks more like something you might find washed up on a beach than one of the wonders of the world—which it surely is. Despite its disagreeable appearance, the human brain is an amazingly intricate network of **neurons** (cells that receive and transmit electrochemical signals) and many other cell types. Contemplate for a moment the complexity of your own brain's neural circuits. Consider the 90 billion neurons in complex array (Walløe, Pakkenberg & Fabricius, 2014), the estimated 100 trillion connections among them, and the almost infinite number of paths that neural signals can follow through this morass (Zimmer, 2011). The complexity of the human brain is hardly surprising, considering what it can do. An organ capable of creating a *Mona Lisa*, an artificial limb, and a supersonic aircraft; of traveling to the moon and to the depths of the sea; and of experiencing the wonders of an alpine sunset, a newborn infant, and a reverse slam dunk *must* be complex. Paradoxically, **neuroscience** (the scientific study of the nervous system) may prove to be the brain's ultimate challenge: Does the brain have the capacity to understand something as complex as itself (see Gazzaniga, 2010)?

Neuroscience comprises several related disciplines. The primary purpose of this chapter is to introduce you to one of them: biopsychology. Each of this chapter's five modules characterizes the neuroscience of biopsychology in a different way. However, before you proceed to the body of this chapter, we would like to tell you about the case of Jimmie G. (Sacks, 1985), which will give you a taste of the interesting things that lie ahead.

Figure 1.1 The human brain: Appearances can be deceiving!

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The Case of Jimmie G., the Man Frozen in Time

Jimmie G. was a friendly 49-year-old. He liked to chat about his school days and his time in the navy, both of which he could describe in remarkable detail. Jimmie was an intelligent man with superior abilities in math and science. So why was he a patient in a neurological ward?

When Jimmie talked about his past, there were hints of his problem. When he talked about his school days, he used the past tense; but when he recounted his early experiences in the navy, he switched to the present tense. More worrisome was that he never talked about anything that happened to him after his time in the navy.

Jimmie was tested by eminent neurologist Oliver Sacks, and a few simple questions revealed a curious fact: Jimmie believed he was 19. When asked to describe what he saw in a mirror, Jimmie became so frantic and confused that Dr. Sacks immediately took the mirror out of the room.

Returning a few minutes later, Dr. Sacks was greeted by a once-again cheerful Jimmie, who acted as if he had never seen Sacks before. Indeed, even when Sacks suggested they had met recently, Jimmie was certain they had not.

Then Dr. Sacks asked where Jimmie thought he was. Jimmie replied that all the beds and patients made him think that the place was a hospital. But he couldn't understand why he would be in a hospital. He was afraid that he might have been admitted because he was sick but didn't know it.

Further testing confirmed what Dr. Sacks feared. Although Jimmie had good sensory, motor, and cognitive abilities, he had one terrible problem: He forgot everything that was said or shown to him within a few seconds. Basically, Jimmie could not remember anything that had happened to him since his early 20s, and he was not going to remember anything that happened to him for the rest of his life. Dr. Sacks was stunned by the implications of Jimmie's condition.

Jimmie's situation was heart-wrenching. Unable to form new lasting memories, he was, in effect, a man frozen in time, a man without a recent past and no prospects for a future, stuck in a continuous present, lacking any context or meaning.

Remember Jimmie G.; you will encounter him again later in this chapter.

Four Major Themes of This Text

You will learn many new facts in this text—new findings, concepts, terms, and the like. But more importantly, many years from now, long after you have forgotten most of those facts, you will still be carrying with you productive new ways of thinking. We have selected four of these for special emphasis: Thinking Creatively, Clinical Implications, the Evolutionary Perspective, and Neuroplasticity.

THINKING CREATIVELY ABOUT BIOPSYCHOLOGY. We are all fed a steady diet of biopsychological information, misinformation, and opinion—by television, newspapers, the Internet, friends, relatives, teachers, and so on. As a result, you likely already hold strong views about many of the topics you will encounter in this text. Because these preconceptions are shared by many biopsychological researchers, they have often impeded scientific progress, and some of the most important advances in biopsychological science have been made by researchers who have managed to overcome the restrictive effects of conventional thinking and have taken creative new approaches. Indeed, **thinking creatively** (thinking in productive, unconventional ways) is the cornerstone of any science. In this text, we describe research that involves thinking "outside the box," we try to be creative in our analysis of the research we are presenting, or we encourage you to base your thinking on the evidence rather than on widely accepted views.

CLINICAL IMPLICATIONS. Clinical (pertaining to illness or treatment) considerations are woven through the fabric of biopsychology. There are two aspects to the clinical implications theme: (1) much of what biopsychologists learn about the functioning of a healthy brain comes from studying dysfunctional brains; and (2) many of the discoveries of biopsychologists have relevance for the treatment of brain dysfunction. One of our major focuses is on the interplay between brain dysfunction and biopsychological research.

THE EVOLUTIONARY PERSPECTIVE. Although the events that led to the evolution of the human species can never be determined with certainty, thinking of the environmental pressures that likely led to the evolution of our brains and behavior often leads to important biopsychological insights. This approach is called the **evolutionary perspective**. An important component of the evolutionary perspective is the comparative approach (trying to understand biological phenomena by comparing them in different species). Throughout this text, you will find that we humans have learned much about ourselves by studying species that are related to us through evolution. Indeed, the evolutionary approach has proven to be one of the cornerstones of modern biopsychological inquiry.

NEUROPLASTICITY. Until the early 1990s, most neuroscientists thought of the brain as a three-dimensional array of neural elements "wired" together in a massive network of circuits. The complexity of this "wiring diagram" of the brain was staggering, but it failed to capture one of the brain's most important features. In the past four decades, research has clearly demonstrated that the adult brain is not a static network of neurons: It is a plastic (changeable) organ that continuously grows and changes in response to an individual's environment and experiences. The discovery of **neuroplasticity** is arguably the single most influential discovery in modern neuroscience. As you will learn, it is a major component of many areas of biopsychological research.

You have probably heard of neuroplasticity. It is a hot topic in the popular media, where it is upheld as a panacea: A means of improving brain function or recovering from brain dysfunction. However, contrary to popular belief, the plasticity of the human brain is not always beneficial. For example, it also contributes to various forms of brain dysfunction (e.g., Tomaszczyk et al., 2014). Later on, you will see examples of both the positive and the negative sides of neuroplasticity.

Emerging Themes of This Text

As you read through this text you will start to see other themes in addition to the ones we outlined for you in the previous section. Many of them you will spot on your own. Here we highlight two "emerging" themes: themes that could become major themes in future editions of this text.

THINKING ABOUT EPIGENETICS. Most people believe their genes (see Chapter 2) control the characteristics they are born with, the person they become, and the qualities of their children and grandchildren. In this text, you will learn that genes are only a small part of what determines who you are. Instead, you are the product of ongoing interactions between your genes and your experiences—such interactions are at the core of a field of study known as **epigenetics**. But epigenetics isn't just about you: We now know that the experiences you have during your lifetime can be passed on to future generations. This is a fundamentally different way of thinking about who we are and how we are tied to both our ancestors and descendants. Epigenetics is currently having a major influence on biopsychological research.

CONSCIOUSNESS. As you will see, this text also examines different aspects of **consciousness** (the perception or awareness of some aspect of one's self or the world) from a biopsychological perspective. Indeed, one major goal of biopsychological research is to establish a better understanding of the neural correlates of consciousness (see Ward, 2013; Blackmore, 2018). To give you a taste of this emerging theme, you will soon appreciate that (1) we are not consciously aware of much of the information we receive from our environments, (2) there are many different states of consciousness, and (3) there can be dramatic alterations in consciousness as a result of brain dysfunction.

What Is Biopsychology?

This module introduces you to the discipline of biopsychology. We begin by exploring the definition and origins of biopsychology. Next, we examine how biopsychology is related to the various other disciplines of neuroscience.

Defining Biopsychology

LO 1.1 Define and discuss what is meant by *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 we 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, emotion).

What Are the Origins of Biopsychology?

LO 1.2 Discuss the origins of the field of biopsychology.

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 Donald Hebb played a key role in its emergence (see Brown & Milner, 2003). 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 human and nonhuman 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 text, you will reap the benefits of biopsychology's youth. Because biopsychology does not have a long history, you will be able to move quickly to the excitement of modern research.

How Is Biopsychology Related to the Other Disciplines of Neuroscience?

LO 1.3 List the six fields of neuroscience that are particularly relevant to biopsychological inquiry.

Neuroscience is a team effort, and biopsychologists are important members of the team (see Albright, Kandel, & Posner, 2000; Kandel & Squire, 2000). Biopsychology can be further characterized by 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 (see Cacioppo & Decety, 2009). 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 Grillner & Dickinson, 2002). Think about it.

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 Chapters 4 and 15).
- **Neuroendocrinology**. The study of interactions between the nervous system and the endocrine system (see Chapters 13 and 17).
- **Neuropathology**. The study of nervous system dysfunction (see Chapters 10 and 18).
- **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).

What Types of Research Characterize the Biopsychological Approach?

Biopsychology is broad and diverse. Biopsychologists study many different phenomena, and they approach their research in many different ways. This module discusses three major dimensions along which biopsychological research may vary: It 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

LO 1.4 Compare the advantages and disadvantages of humans and nonhumans as subjects in biopsychological research.

Both human and nonhuman animals are the subjects of biopsychological research. Of the nonhumans, mice and rats are the most common subjects; however, cats, dogs, and nonhuman primates are also commonly 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, we are joking about the cages, but the joke does serve to draw attention to one advantage 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 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 are similar in fundamental ways to the brains of other mammals—they differ mainly 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 clarified by the study of nonhumans (see Hofman, 2014; Katzner & Weigelt, 2013; Krubitzer & Stolzenberg, 2014).

One major difference between human and nonhuman subjects is that humans volunteer to be subjects. To emphasize this point, human subjects are more commonly referred to as *participants* or *volunteers*.

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 participants. Hence, the study of nonhuman species is often 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 participants. This is not to say that the study of nonhuman animals is not governed by a strict code of ethics (see Blakemore et al., 2012)—it is. However, there are fewer ethical constraints on the study of laboratory species than on the study of humans.

In our 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 participants 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).

If you are concerned about the ethics of biopsychological research on nonhuman animals, you aren't alone. Both of us wrestle with various aspects of it. For example, a recurring concern we both have is whether the potential benefits of a research study outweigh the stress induced in the nonhuman subjects.

When people are asked for their opinion on nonhuman animal research, most fall into one of two camps: (1) Those in support of animal research—if and only if both the suffering of animals is minimized and the potential benefits to humankind cannot be obtained by other methods, or (2) those that are opposed to animal research—because it causes undue stress that is not outweighed by the potential benefits to humankind.

Journal Prompt 1.1

What are your initial feelings about biopsychological research on nonhuman animals? If you are sympathetic to one of the two aforementioned camps, explain your reasoning.

Because biopsychological research using nonhuman subjects is controversial, it first has to be approved by a panel of individuals from a variety of backgrounds and with different world views. These *nonhuman animal ethics committees* are tasked with very difficult decisions. Accordingly, it is usually the case that these committees will ask the researchers proposing a particular study to provide additional information or further justification before they approve their research.

Nonhuman animal ethics committees emphasize consideration of the so-called "three R's": Reduction, Refinement, and Replacement. Reduction refers to efforts to reduce the numbers of animals used in research. Refinement refers to refining research studies or the way animals are cared for, so as to reduce suffering. Providing animals with better living conditions is one example of refinement. Finally, replacement refers to the replacing of studies using animal subjects with alternate techniques, such as experimenting on cell cultures or using computer models.

One of the earliest examples of replacement is the now ubiquitous crash-test dummy in the auto industry. Prior to the advent of the crash test dummy, live pigs were sometimes used as passengers in automobile crash tests. This example of replacement makes an important point about how notions of what is ethically acceptable in animal experimentation are in constant flux: Now that dummies are a viable alternative, nobody would be in favor of using pigs for crash tests. The recent development of complex computer models of nonhuman and human brains (see Frackowiak & Markram, 2015) might change the very nature of biopsychological research in your lifetime.

Experiments and Nonexperiments

LO 1.5 Compare experiments, quasiexperimental studies, and case studies, emphasizing their utility in the study of causal effects.

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 study causation, that is, to find out what causes what. As such, it has been almost single-handedly responsible for the knowledge that is the basis for our modern way of life. It is paradoxical that a method capable of such complex feats is 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 being compared. This difference between the conditions is called the **independent variable**. The variable measured by the experimenter to assess the effect of the independent variable is called the **dependent variable**. If the experiment is done correctly, any differences in the dependent variable between the conditions must have been caused by the independent 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.

An experiment by Lester and Gorzalka (1988) illustrates the prevention of confounded variables with good experimental design. The experiment was a demonstration of the **Coolidge effect** (see Lucio et al., 2014; Tlachi-López et al., 2012). 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, we should mention that the subjects in Lester and Gorzalka's experiment were hamsters, not university students.

Figure 1.2 President Calvin Coolidge and Mrs. Grace Coolidge. Many students think 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.

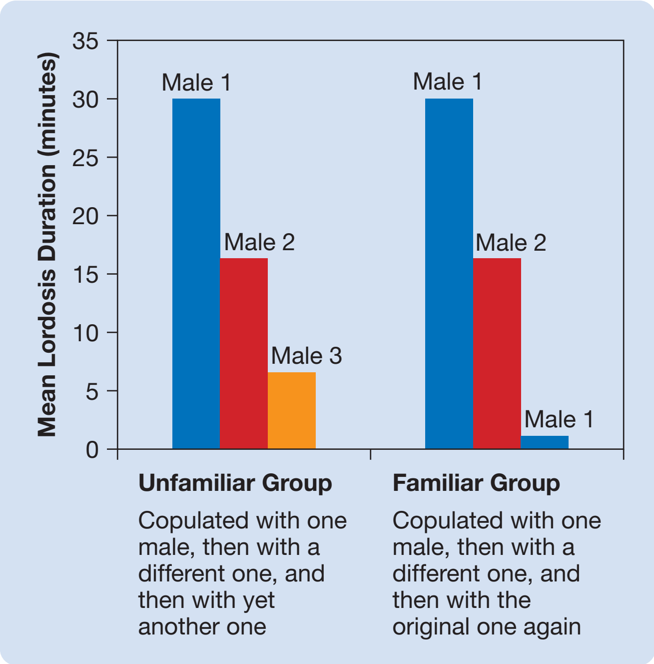
Bettmann/Getty Images

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 the females. As a result, attempts to demonstrate the Coolidge effect in females are almost always 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 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. The purpose of this example—in case you have forgotten—is to illustrate the critical role played by good experimental design in eliminating confounded variables.

QUASIEXPERIMENTAL STUDIES. It is not possible for biopsychologists to bring the experimental method to bear on all problems of interest to them. Physical or ethical impediments frequently make it impossible to assign subjects to particular conditions or to administer particular conditions to the subjects who have been assigned to them. For example, experiments assessing whether frequent marijuana use causes brain dysfunction are not feasible because it would be unethical to assign a human to a condition that involves years of frequent marijuana use. (Some of you may be more concerned about the ethics of assigning humans to a control condition that involves many years of *not* getting high.) In such prohibitive situations, biopsychologists sometimes conduct **quasiexperimental studies**—studies of groups of subjects who have been exposed to the conditions of interest in

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 an unfamiliar male than they were to the male with which they had copulated on the first test.



Based on Lester, G. L. L., & Gorzalka, B. B. (1988)

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 the popular press, quasiexperiments are often confused with experiments. Not a week goes by where one of us doesn't read a news article about how an "experiment" has shown something in human participants, when in reality the so-called experiment is actually a quasiexperiment.

Understanding the distinction between quasiexperiments and experiments is very important. Experiments can tell us whether an independent variable causes a change in a dependent variable (assuming that the experimenter has controlled for all confounding variables); quasiexperiments can tell us only that two variables are correlated with one another. For example, in interpreting experiments we can reach causal conclusions like "frequent alcohol consumption causes brain damage." In contrast, quasiexperimental studies can tell us only that "frequent alcohol use is associated with brain damage."

The importance of thinking clearly about quasiexperimental studies is illustrated by a study that compared 100 detoxified males who had previously been heavy drinkers of alcohol with 50 male nondrinkers (Acker et al., 1984). Overall, those who had been heavy drinkers performed more poorly on various tests of perceptual, motor, and cognitive ability, and their brain scans revealed extensive brain damage. Although this might seem like an experiment, it is not. It is a quasiexperimental study: Because the participants 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 heavy drinkers 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, heavy drinkers 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, although quasiexperimental studies have revealed that people who are heavy drinkers tend to have more brain damage than abstainers, such studies cannot prove that it was caused by the alcohol.

Have you forgotten the case of Jimmie G.? Jimmie's condition was a product of heavy alcohol consumption.

CASE STUDIES. Studies that focus on a single subject, or very small number of subjects, are called **case studies**. Such studies are rarely concerned with having control subjects. Rather, their focus is on providing 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 individuals 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

LO 1.6 Compare 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 researchers involved in their pursuit. **Pure research** is motivated primarily by the curiosity of the researcher—it is done solely for the purpose of acquiring knowledge. In contrast, **applied research** is 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. Moreover, pure research often becomes the topic of **translational research**: research that aims to translate the findings of pure research into useful applications for humankind (see Howells, Sena, & Macleod, 2014).

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 millions 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 functions 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.

Table 1.1 provides a timeline of some of the Nobel Prizes awarded for research related to the brain and behavior. The purpose of this table is to give you a general sense of the official recognition that behavioral and brain research has received, not to have you memorize the list. You will learn later in the chapter that, when it comes to evaluating science, the Nobel Prize Committees have not been infallible.

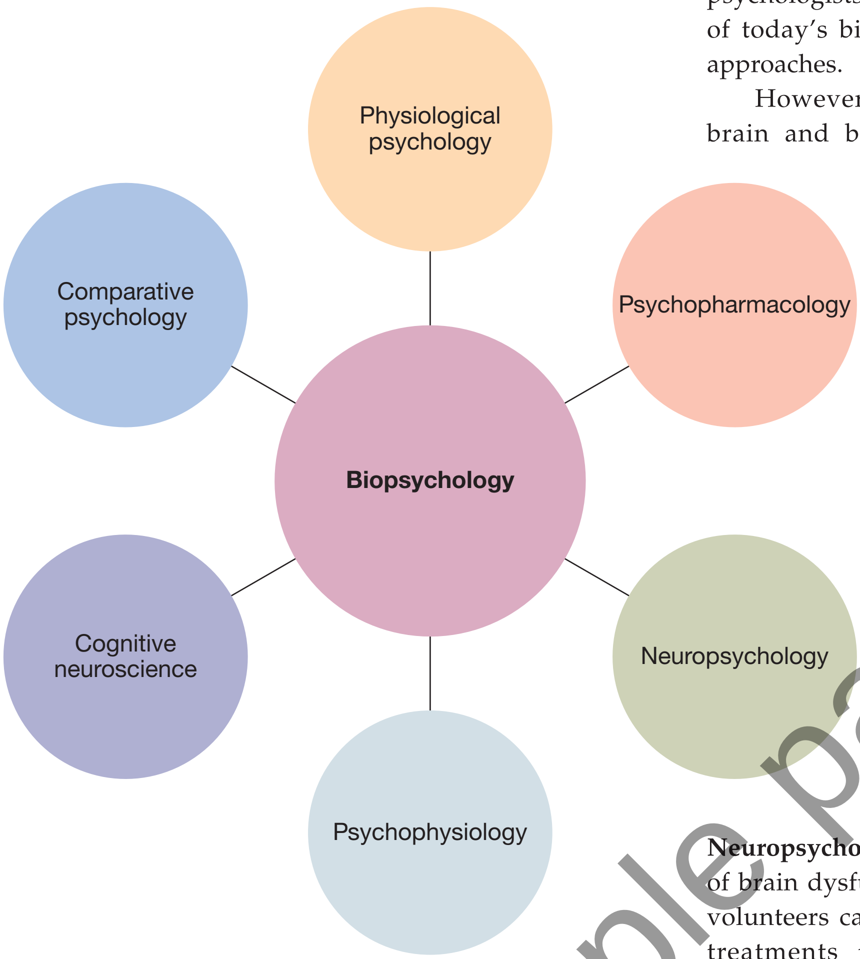
What Are the Divisions of Biopsychology?

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 module is to give you a clearer sense of biopsychology and its diversity by describing six of its major divisions (see Figure 1.4): (1) physiological psychology, (2) psychopharmacology, (3) neuropsychology, (4) psychophysiology, (5) cognitive neuroscience, and (6) comparative psychology. For simplicity, they are presented as distinct approaches, but there is much overlap among them, and many biopsychologists regularly follow more than one approach.

Table 1.1 Nobel prizes specifically related to the nervous system or behavior.

Nobel Winner(s)	Date	Accomplishment
Ivan Pavlov	1904	Research on the physiology of digestion
Camillo Golgi and Santiago Ramón y Cajal	1906	Research on the structure of the nervous system
Charles Sherrington and Edgar Adrian	1932	Discoveries about the functions of neurons
Henry Dale and Otto Loewi	1936	Discoveries about the transmission of nerve impulses
Joseph Erlanger and Herbert Gasser	1944	Research on the functions of single nerve fibers
Walter Hess	1949	Research on the role of the brain in behavior
Egas Moniz	1949	Development of the prefrontal lobotomy
Georg von Békésy	1961	Research on the auditory system
John Eccles, Alan Hodgkin, and Andrew Huxley	1963	Research on the ionic basis of neural transmission
Ragnar Granit, Haldan Hartline, and George Wald	1967	Research on the chemistry and physiology of vision
Bernard Katz, Ulf von Euler, and Julius Axelrod	1970	Discoveries related to synaptic transmission
Karl Von Frisch, Konrad Lorenz, and Nikolaas Tinbergen	1973	Studies of animal behavior
Roger Guillemin and Andrew Schally	1977	Discoveries related to hormone production by the brain
Herbert Simon	1979	Research on human cognition
Roger Sperry	1981	Research on separation of the cerebral hemispheres
David Hubel and Torsten Wiesel	1981	Research on neurons of the visual system
Rita Levi-Montalcini and Stanley Cohen	1986	Discovery and study of nerve growth factors
Erwin Neher and Bert Sakmann	1991	Research on ion channels
Alfred Gilman and Martin Rodbell	1994	Discovery of G-protein–coupled receptors
Arvid Carlsson, Paul Greengard, and Eric Kandel	2000	Discoveries related to synaptic transmission
Linda Buck and Richard Axel	2004	Research on the olfactory system
John O'Keefe, May-Britt Moser, and Edvard Moser	2014	Research on the brain's system for recognizing locations
Jeffrey Hall, Michael Rosbach, and Michael Young	2017	Discoveries related to the molecular mechanisms controlling the circadian rhythm

Figure 1.4 The six major divisions of biopsychology.



Physiological Psychology

LO 1.7 Describe the division of biopsychology known as physiological psychology.

Physiological psychology is the division of biopsychology that studies the neural mechanisms of behavior through the direct manipulation and recording of the brain in controlled experiments—surgical and electrical methods 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 participants 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 of immediate practical benefit.

Psychopharmacology

LO 1.8 Describe the division of biopsychology known as 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 brain and behavior has become so specialized that psychopharmacology is regarded as a separate discipline. A substantial portion of psychopharmacological research is applied. 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.

Neuropsychology

LO 1.9 Describe the division of biopsychology known as neuropsychology.

Neuropsychology is the study of the psychological effects of brain dysfunction in human patients. Because human volunteers cannot ethically be exposed to experimental treatments that endanger normal brain function, neuropsychology deals almost exclusively with case studies and quasiexperimental studies of patients with brain dysfunction 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 treatments (see Benton, 1994). They can also be an important basis for patient care and counseling; Kolb and Whishaw (1990) described such an application in the case study of Mr. R.

The Case of Mr. R., the Student with a Brain Injury Who Switched to Architecture

Mr. R. was a 21-year-old honors student at a university. One day he was involved in a car accident in which he struck his head against the dashboard. Following the accident, Mr. R's grades began to decline; his once exceptional academic performance was now only average. He seemed to have particular trouble completing his term papers. Finally, after a year of struggling academically, he went for a neuropsychological assessment. The findings were striking.

Mr. R. turned out to be one of roughly one-third of left-handers whose language functions are represented in the right hemisphere of their brain, rather than in their left hemisphere. Furthermore, although Mr. R. had a superior IQ score, his verbal memory and reading speed were below average—something that is quite unusual for a person who had been so strong academically.

The neuropsychologists concluded that he may have suffered some damage to his right temporal lobe during the car accident, which would help explain his diminished language skills. The neuropsychologists also recommended that R. pursue a field that didn't require superior verbal memory skills. Following his exam and based on the recommendation of his neuropsychologists, Mr. R. switched majors and began studying architecture with substantial success.

Psychophysiology

LO 1.10 Describe the division of biopsychology known as psychophysiology.

Psychophysiology is the division of biopsychology that studies the relation between physiological activity and psychological processes in humans. Because the subjects of psychophysiological research are humans, 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)** (see Chapter 5). 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 (see Chapter 3).

Most psychophysiological research focuses on understanding the physiology of psychological processes, such as attention, emotion, and information processing, but there have been some interesting clinical applications of the psychophysiological method. For example, psychophysiological experiments have indicated that people with schizophrenia have difficulty smoothly tracking a moving object with their eyes (see Meyhöfer et al., 2014)—see Figure 1.5.

Journal Prompt 1.2

What implications could the finding that people with schizophrenia have difficulty smoothly tracking moving objects have for the diagnosis of schizophrenia? (For a discussion of schizophrenia, see Chapter 18.)

Cognitive Neuroscience

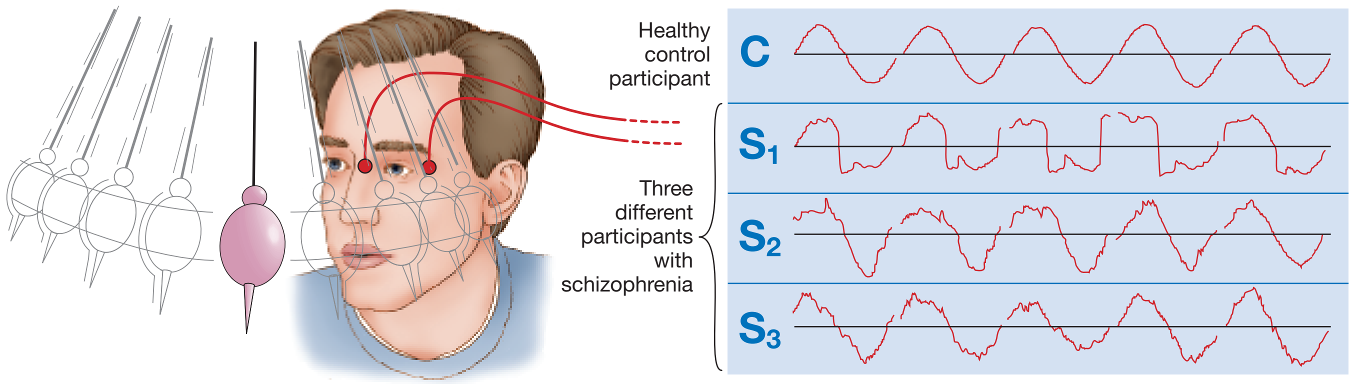
LO 1.11 Describe the division of biopsychology known as cognitive neuroscience.

Cognitive neuroscience is the youngest division of biopsychology. 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 Gutchess, 2014; Raichle, 2008). Because of its focus on cognition, most cognitive neuroscience research involves human participants, and because of its focus on human participants, its methods tend to be noninvasive, rather than involving penetration or direct manipulation of the brain.

The major method of cognitive neuroscience is *functional brain imaging*: recording images of the activity of the living human brain (see Chapter 5) while a participant is engaged in a particular mental activity. For example, Figure 1.6 shows that the visual areas of the left and right cerebral cortex at the back of the brain became active when the participant viewed a flashing light.

Because the theory and methods of cognitive neuroscience are so complex and pertinent to so many fields, cognitive neuroscience research often involves interdisciplinary

Figure 1.5 Visual tracking of a pendulum by a healthy control participant (top) and three participants with schizophrenia.



Based on Iacono, W. G., & Koenig, W. G. (1983).

Figure 1.6 Functional brain imaging is the major method of cognitive neuroscience. This image—taken from the top of the head with the participant lying on her back—reveals the locations of high levels of neural activity at one level of the brain as the participant viewed a flashing light. The red and yellow areas indicate high levels of activity in the visual cortex at the back of the brain. (Courtesy of Dr. Todd Handy, Department of Psychology, University of British Columbia.)

Todd C. Handy/University of British Columbia Department of Psychology

collaboration among many researchers with different types of training. Biopsychologists, cognitive psychologists, social psychologists, economists, computing and mathematics experts, and various types of neuroscientists commonly contribute to the field. Cognitive neuroscience research sometimes involves noninvasive electrophysiological recording, and it sometimes focuses on patients with brain dysfunction; in these cases, the boundaries between cognitive neuroscience and psychophysiology and neuropsychology, respectively, are blurred.

Comparative Psychology

LO 1.12 Describe the division of biopsychology known as comparative psychology.

Although most biopsychologists study the neural mechanisms of behavior, there is more to biopsychology than neural mechanisms. A biopsychologist should never lose sight of the fact that the purpose of their research is to understand the integrated behavior of the whole animal. The last division of biopsychology that we describe here is one that focuses on the behavior of animals in their natural environments. This division 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 behavior in an animal's natural environment.

As a reminder, the purpose of this module was to demonstrate the diversity of biopsychology by describing six of its major divisions; these are summarized for you in Table 1.2. You will see all six of these divisions in action in subsequent chapters.

Table 1.2 The six major divisions of biopsychology with examples of how they have approached the study of memory.

Division of Biopsychology	Example from Memory Research
Physiological psychology: study of the neural mechanisms of behavior by manipulating the nervous systems of nonhuman animals in controlled experiments	Physiological psychologists have studied the contributions of one brain structure, the hippocampus, to memory by surgically removing it in rats and assessing their ability to perform various memory tasks.
Psychopharmacology: study of the effects of drugs on the brain and behavior	Psychopharmacologists have tried to improve the memory of Alzheimer's patients by administering drugs that alter brain chemistry.
Neuropsychology: study of the psychological effects of brain dysfunction in human patients	Neuropsychologists have shown that patients with damage to the hippocampus and surrounding structures are incapable of forming new long-term memories.
Psychophysiology: study of the relation between physiological activity and psychological processes in human volunteers by noninvasive physiological recording	Psychophysiologists have shown that familiar faces elicit the usual changes in autonomic nervous system activity even when patients with brain damage report that they do not recognize a face.
Cognitive neuroscience: study of the neural mechanisms of human cognition, largely through the use of functional brain imaging	Cognitive neuroscientists have used brain-imaging technology to observe the changes that occur in various parts of the brain while human volunteers perform memory tasks.
Comparative psychology: study of the evolution, genetics, and adaptiveness of behavior, largely through the use of the comparative method	Comparative psychologists have shown that species of birds that cache their seeds tend to have larger hippocampi, confirming that the hippocampus is involved in memory for location.

Scan Your Brain

To see if you are acquainted with the main premises of biopsychology and allied disciplines, fill in each of the following blanks with the most appropriate terms. The correct answers are provided at the end of the exercise. Before proceeding, review material related to your errors and omissions.

1. _______ is a branch of psychology that uses data from patients with brain damage to understand structure and function of the human brain.
2. Over the past few decades, researchers have realized that the adult brain connections are not static but changeable in response to the individual's genes and experiences. This is known as _______.
3. In a _______ design, participants are placed into different groups and exposed to different experimental conditions.
4. Studies that focus on a single participant rather than a group of participants are called _______.
5. The major method of cognitive neuroscience is _______, recording images of the activity of the living human brain.
6. _______ is a branch of biopsychology that studies genetic, evolutionary, and behavior differences across species.

Scan Your Brain answers: (1) Neuropsychology, (2) neuroplasticity, (3) between-subjects, (4) case studies, (5) functional brain imaging, (6) Evolutionary behavioral genetics.

How Do Biopsychologists Conduct Their Work?

This module explains how biopsychologists typically conduct their work. First, you will learn how biopsychologists collaborate with one another, and the importance of such collaboration in advancing a field of research. Second, you will learn about how biopsychologists make inferences about brain function that is not directly observable. These are important components of biopsychological research, and you will see in the next module what goes wrong when such collaboration and scientific inference are thrown by the wayside.

Converging Operations: How Do Biopsychologists Work Together?

LO 1.13 Explain how converging operations has contributed to the study of Korsakoff's syndrome.

Because each of the six biopsychological approaches to research has its own particular strengths and shortcomings and because the mechanisms by which the brain controls behavior are so complex, major biopsychological issues are rarely resolved by a single experiment or even by a series of experiments taking the same general approach. Progress is most likely when different approaches are focused on a single problem in such a way that the strengths of one approach compensate for the weaknesses of the others; this combined approach is called **converging operations** (see Thompson, 2005).

Consider, for example, the relative strengths and weaknesses of neuropsychology and physiological psychology in the study of the psychological effects of damage to the human cerebral cortex. In this instance, the strength of the neuropsychological approach is that it deals directly with human patients; its weakness is that its focus on human patients precludes experiments. In contrast, the strength of the physiological psychology approach is that it can use the power of experimental research on nonhuman animals; its weakness is that the relevance of research on laboratory animals to human brain damage is always open to question (see Couzin-Frankel, 2013; Reardon, 2016). Clearly these two approaches complement each other well; together they can answer questions that neither can answer individually.

To examine converging operations in action, let's return to the case of Jimmie G. The neuropsychological disorder from which Jimmie suffered was first described in the late 19th century by Sergei Korsakoff, a Russian physician, and subsequently became known as **Korsakoff's syndrome**. The primary symptom of Korsakoff's syndrome is severe memory loss, which is made all the more heartbreaking—as you have seen in Jimmie G.'s case—by the fact that its sufferers are often otherwise quite capable. Because Korsakoff's syndrome commonly occurs in heavy drinkers of alcohol, it was initially believed to be a direct consequence of the toxic effects of alcohol on the brain. This conclusion proved to be a good illustration of the inadvisability of inferring causality from the results of quasiexperimental studies. Subsequent research showed that Korsakoff's syndrome is largely caused by the brain damage associated with *thiamine* (vitamin B_1) deficiency.

Journal Prompt 1.3

Korsakoff's syndrome accounts for approximately 10 percent of adult dementias in the United States. Despite its relatively high prevalence, few people have heard of it. Why do you think this is the case?

The first support for the thiamine-deficiency interpretation of Korsakoff's syndrome came from the discovery of the syndrome in malnourished persons who consumed little or no alcohol. Additional support came from experiments in which thiamine-deficient rats were compared with otherwise identical groups of control rats. The thiamine-deficient rats displayed memory deficits and patterns of brain damage similar to those observed in many people who had been heavy drinkers of alcohol (Mumby, Cameli, & Glenn, 1999). Such people often develop Korsakoff's syndrome because most of their caloric intake comes in the form of alcohol, which lacks vitamins, and because alcohol interferes with the metabolism of what little thiamine they do consume. However, alcohol has been shown to accelerate the development of brain damage in thiamine-deficient rats, so it may have a direct toxic effect on the brain as well (Ridley, Draper, & Withall, 2013).

The point of this discussion of Korsakoff's syndrome is to show you that progress in biopsychology typically comes from converging operations—in this case, from the convergence of neuropsychological case studies (case studies of Korsakoff patients), quasiexperiments with human participants (comparisons of heavy drinkers with abstainers), and controlled experiments on laboratory animals (comparison of thiamine-deficient and control rats). The strength of biopsychology lies in the diversity of its methods and approaches. This means that, in evaluating biopsychological claims, it is rarely sufficient to consider the results of one study or even of one line of experiments using the same method or approach.

So what has all the research on Korsakoff's syndrome done for Jimmie G. and others like him? Today, heavy drinkers are counseled to stop drinking and are treated with large doses of thiamine. The thiamine limits the development of further brain damage and often leads to a slight improvement in the patient's condition; unfortunately, the acquired brain dysfunction is mostly irreversible.

Scientific Inference: How Do Biopsychologists Study the Unobservable Workings of the Brain?

LO 1.14 Explain scientific inference with reference to research on eye movements and the visual perception of motion.

Scientific inference is the fundamental method of biopsychology and of most other sciences—it is what makes being a scientist fun. This section provides further insight into the nature of biopsychology by defining, illustrating, and discussing scientific inference.

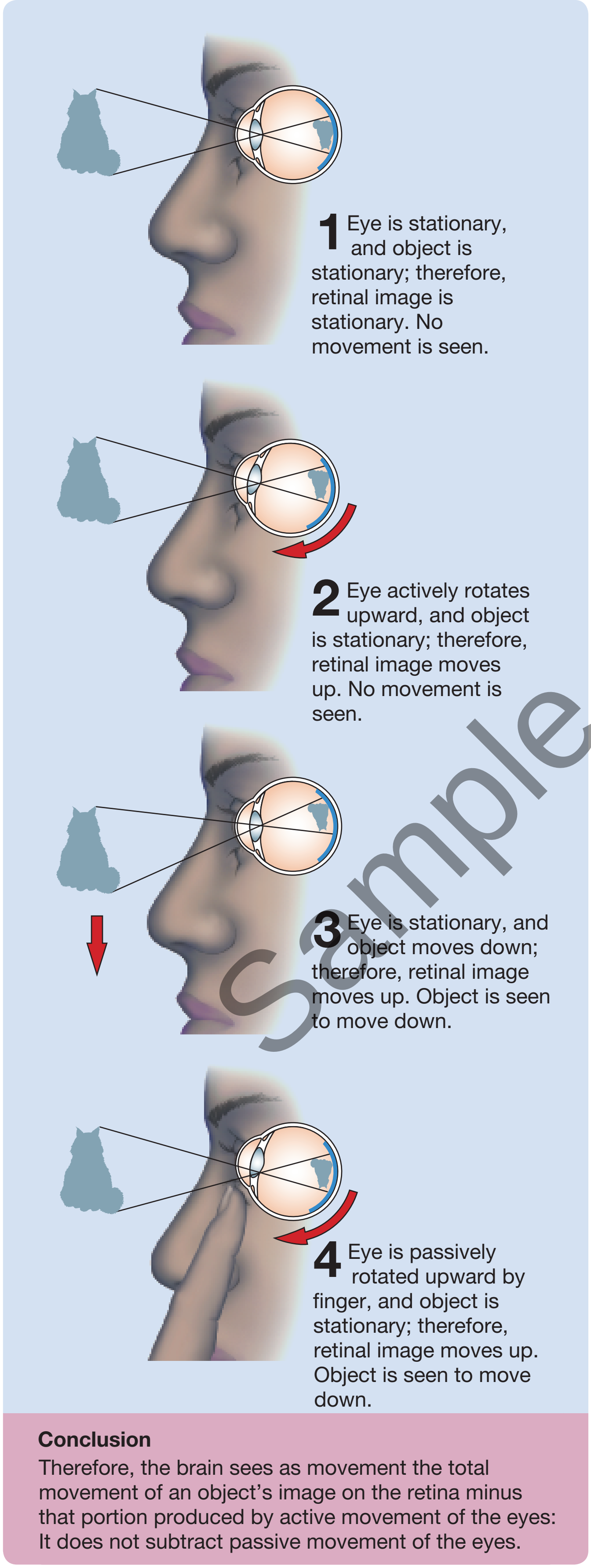
The scientific method is a system for finding things out by careful observation, but many of the processes studied by scientists cannot be observed. For example, scientists use empirical (observational) methods to study ice ages, gravity, evaporation, electricity, and nuclear fission—none of which can be directly observed; their effects can be observed, but the processes themselves cannot. Biopsychology is no different from other sciences in this respect. One of its main goals is to characterize, through empirical methods, the unobservable processes by which the nervous system controls behavior.

The empirical method that biopsychologists and other scientists use to study the unobservable is called **scientific inference**. Scientists carefully measure key events they can observe and then use these measures as a basis for logically inferring the nature of events they cannot observe. Like a detective carefully gathering clues from which to re-create an unwitnessed crime, a biopsychologist carefully gathers relevant measures of behavior and neural activity from which to infer the nature of the neural processes that regulate behavior. The fact that the neural mechanisms of behavior cannot be directly observed and must be studied through scientific inference is what makes biopsychological research such a challenge—and, as we said before, so much fun.

To illustrate scientific inference, we have selected a research project in which you can participate. By making a few simple observations about your own visual abilities under different conditions, you will be able to discover the principle by which your brain translates the movement of images on your retinas into perceptions of movement (see Figure 1.7). One feature of the mechanism is immediately obvious. Hold your hand in front of your face, and then move its image across your retinas by moving your eyes, by moving your hand, or by moving both at once. You will notice that only those movements of the retinal image produced by the movement of your hand are translated into the perception of motion; movements of the retinal image produced by your own eye movements are not. Obviously, there must be a part of your brain that monitors the movements of your retinal image and subtracts from the total those image movements produced by your own eye movements, leaving the remainder to be perceived as motion.

Now, let's try to characterize the nature of the information about your eye movements used by your brain in its perception of motion. Try the following. Shut one eye, then rotate your other eye slightly upward by gently pressing on your lower eyelid with your fingertip. What do you see? You see all of the objects in your visual field moving downward. Why? It seems that the brain mechanism responsible for the perception of motion does not consider eye movement per se. It considers only those eye movements that are actively produced by neural signals from the brain to the eye muscles, not those that are passively produced by

Figure 1.7 The perception of motion under four different conditions.



other means (e.g., by your finger). Thus, when your eye was moved passively, your brain assumed it had remained still and attributed the movement of your retinal image to the movement of objects in your visual field.

It is possible to trick the visual system in the opposite way; instead of the eyes being moved when no active signals have been sent to the eye muscles, the eyes can be held stationary despite the brain's attempts to move them. Because this experiment involves paralyzing the eye muscles, you cannot participate. Hammond, Merton, and Sutton (1956) injected a *paralytic* (movement-inhibiting) substance into the eye muscles of their participant—who was Merton himself. This paralytic substance was the active ingredient of *curare*, a drug with which some Indigenous people of South America coat their blow darts. What do you think Merton saw when he then tried to move his eyes? He saw the stationary visual world moving in the same direction as his attempted eye movements. If a visual object is focused on part of your retina, and it stays focused there despite the fact that you have moved your eyes to the right, it too must have moved to the right. Consequently, when Merton sent signals to his eye muscles to move his eyes to the right, his brain assumed the movement had been carried out, and it perceived stationary objects as moving to the right.

The point of the eye-movement example is that biopsychologists can learn much about the activities of the brain through scientific inference without directly observing them—and so can you. By the way, neuroscientists are still interested in the kind of feedback mechanisms inferred from the demonstrations of Hammond and colleagues, and they have refined our understanding of the mechanisms using modern neural recording techniques (e.g., Joiner et al., 2013; Wurtz et al., 2011).

Thinking Critically about Biopsychological Claims

We have all heard or read that we use only a small portion of our brains, that it is important to eat three meals a day, that intelligence is inherited, that everybody needs at least 8 hours of sleep per night, that there is a gene for schizophrenia, that heroin is a particularly dangerous (hard) drug, and that neurological diseases can now be cured by genetic engineering. These are but a few of the claims about biopsychological phenomena that have been widely disseminated (see Howard-Jones, 2014). You may believe many of these claims. But are they all true? How does one find out? And if they are not true, why do so many people believe them?

We hope that you will learn how to differentiate between flawed claims and exciting new discoveries. This, the final module of the chapter, begins teaching this lesson.

Evaluating Biopsychological Claims

LO 1.15 Define critical thinking and evaluate biopsychological claims.

As you have already learned, one of the major goals of this text is to teach you how to think creatively (to think in productive, unconventional ways) about biopsychological information. Often, the first step in creative thinking is spotting the weaknesses of existing ideas and the evidence on which they are based—the process by which these weaknesses are recognized is called **critical thinking**. The identification of weaknesses in existing beliefs is one of the major stimuli for scientists to adopt creative new approaches.

Journal Prompt 1.4

Do you think that improving your critical thinking abilities will impact your everyday life? Why or why not? (Suggestion: Revisit this journal prompt once you have finished this course!)

The purpose of this final module of the chapter is to develop your own critical thinking abilities by analyzing two claims that played major roles in the history of biopsychology. In both cases, the evidence proved to be grossly flawed. Notice that if you keep your wits about you, you do not have to be an expert to spot the weaknesses.

The first step in judging the validity of any scientific claim is to determine whether the claim and the research on which it is based were published in a reputable scientific journal. The reason is that, in order to be published in a reputable scientific journal, an article must first be reviewed by experts in the field—usually three or four of them—and judged to be of good quality. Indeed, the best scientific journals publish only a small proportion of the manuscripts submitted to them. You should be particularly skeptical of scientific claims that have not gone through this rigorous review process.

The first case that follows deals with an unpublished claim that was largely dispensed through the news media. The second deals with a claim that was initially supported by published research. Because both of these cases are part of the history of biopsychology, we have the advantage of 20/20 hindsight in evaluating their claims.

Case 1: José and the Bull

José Delgado, a particularly charismatic neuroscientist, demonstrated to a group of newspaper reporters a remarkable new procedure for controlling aggression. Delgado strode into a Spanish bullfighting ring carrying only a red cape and a small radio transmitter. With the transmitter, he could activate a battery-powered stimulator that had previously been mounted on the horns of the other inhabitant of the ring. As the raging bull charged, Delgado calmly activated the stimulator and sent a weak electrical current from the stimulator through an electrode that had been implanted in the caudate nucleus (see Chapter 3), a structure deep in the bull's brain. The bull immediately veered from its charge. After a few such interrupted charges, the bull stood tamely as Delgado swaggered about the ring. According to Delgado, this demonstration marked a significant scientific breakthrough—the discovery of a caudate taming center and the fact that stimulation of this structure could eliminate aggressive behavior, even in bulls specially bred for their ferocity.

To those present at this carefully orchestrated event—and to most of the millions who subsequently read about it—Delgado's conclusion was compelling. Surely, if caudate stimulation could stop the charge of a raging bull, the caudate must be a taming center. It was even suggested that caudate stimulation through implanted electrodes might be an effective treatment for human psychopathy. What do you think?

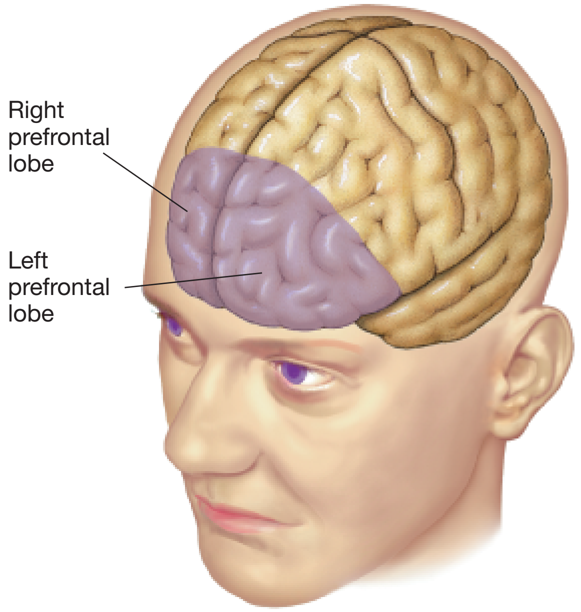
Analysis of Case 1 Delgado's demonstration provided little or no support for his conclusion. It should have been obvious to anyone who did not get caught up in the provocative nature of Delgado's media event that brain stimulation can abort a bull's charge in numerous ways, most of which are simpler, and thus more probable, than the one suggested by Delgado. For example, the stimulation may have simply rendered the bull confused, dizzy, nauseous, sleepy, or temporarily blind rather than nonaggressive; or the stimulation could have been painful. Clearly, any observation that can be interpreted in so many different ways provides little support for any one interpretation. When there are several possible interpretations for a behavioral observation, the rule is to give precedence to the simplest one; this rule is called **Morgan's Canon**. The following comments of Valenstein (1973) provide a reasoned view of Delgado's demonstration:

> Actually there is no good reason for believing that the stimulation had any direct effect on the bull's aggressive tendencies. An examination of the film record makes it apparent that the charging bull was stopped because as long as the stimulation was on it was forced to turn around in the same direction continuously. After examining the film, any scientist with knowledge in this field could conclude only that the stimulation had been activating a neural pathway controlling movement. (p. 98)

Case 2: Two Chimpanzees, Moniz, and the Prefrontal Lobotomy

In 1949, Dr. Egas Moniz was awarded the Nobel Prize in Physiology and Medicine for the development of **prefrontal lobotomy**—a surgical procedure in which the connections between the prefrontal lobes and the rest of the brain are cut as a treatment for mental illness. The **prefrontal lobes** are the large areas, left and right, at the very front of the brain (see Figure 1.8). Moniz's discovery was based on the report that two

Figure 1.8 The right and left prefrontal lobes, whose connections to the rest of the brain are disrupted by prefrontal lobotomy.



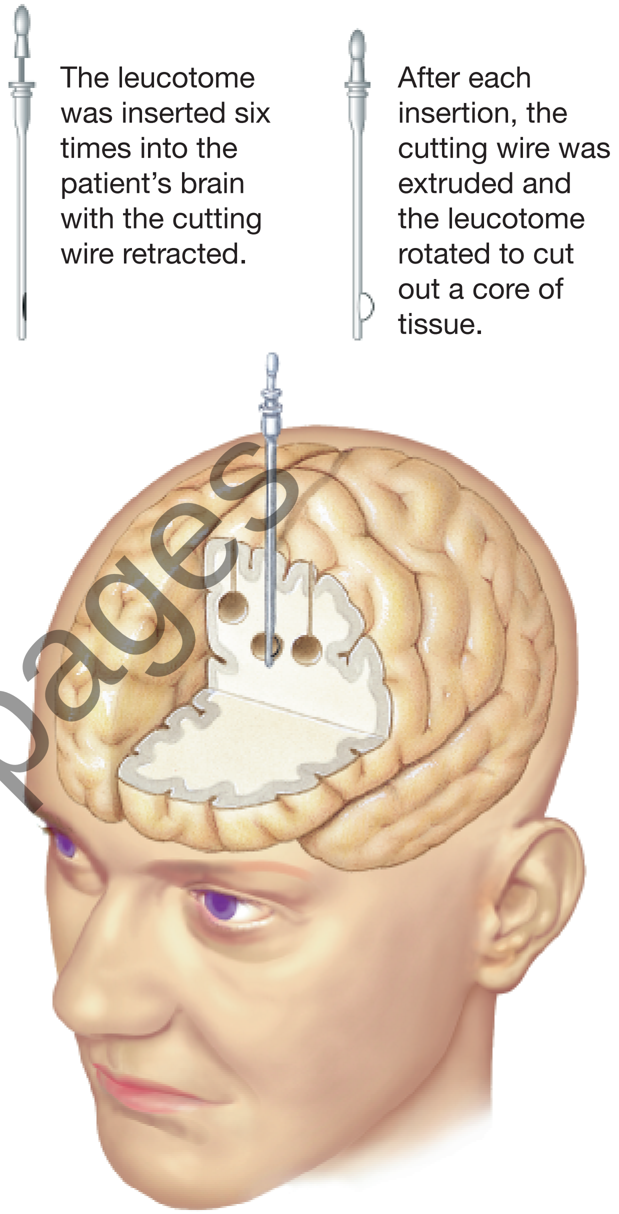
chimpanzees that frequently became upset when they made errors during the performance of a food-rewarded task, did not do so following the creation of a large *bilateral lesion* (an area of damage to both sides of the brain) of their prefrontal lobes. After witnessing a demonstration of this result at a scientific meeting in 1935, Moniz convinced neurosurgeon Almeida Lima to operate on a series of psychiatric patients (see Heller et al., 2006). Lima cut out six large cores of prefrontal tissue with a surgical device called a **leucotome** (see Figure 1.9).

Following Moniz's claims that prefrontal surgery was therapeutically useful, there was a rapid proliferation of various forms of prefrontal psychosurgery. One such variation was **transorbital lobotomy**, which was developed in Italy and then popularized in the United States by Walter Freeman in the late 1940s. It involved inserting an ice pick-like device under the eyelid, driving it through the orbit (the eye socket) with a few taps of a mallet, and pushing it into the prefrontal lobes, where it was waved back and forth to sever the connections between the prefrontal lobes and the rest of the brain (see Figure 1.10). This operation was frequently performed in doctors' offices.

Analysis of Case 2 Incredible as it may seem, Moniz's program of **psychosurgery** (any brain surgery, such as prefrontal lobotomy, performed for the treatment of a psychological problem) was largely based on the observation of two chimpanzees. Thus, Moniz displayed a lack of appreciation for the diversity of brain and behavior, both within and between species. No program of psychosurgery should ever be initiated without a thorough assessment of the effects of the surgery on a large sample of subjects from various nonhuman mammalian species. To do so is not only unwise, it is unethical.

A second major weakness in the scientific case for prefrontal lobotomy was the failure of Moniz and others to carefully

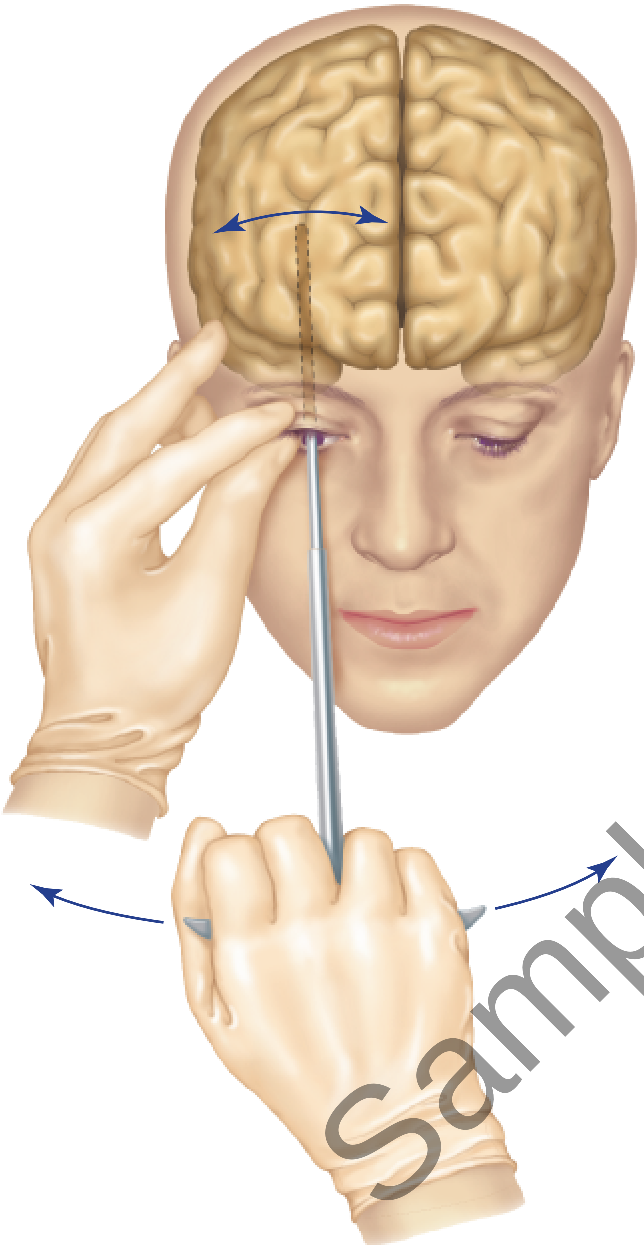
Figure 1.9 The prefrontal lobotomy procedure developed by Moniz and Lima.



evaluate the consequences of the surgery in the first patients to undergo the operation (see Mashour, Walker, & Martuza, 2005; Singh, Hallmayer, & Illes, 2007). The early reports that the operation was therapeutically effective were based on the impressions of the individuals who were the least objective—the physicians who had prescribed the surgery and their colleagues. Patients were frequently judged as improved if they were more manageable, and little effort was made to evaluate more important aspects of their psychological adjustment or to document the existence of adverse side effects.

Eventually, it became clear that prefrontal lobotomies are of little therapeutic benefit and that they can produce a wide range of undesirable side effects, such as socially inappropriate behavior, lack of foresight, emotional unresponsiveness, epilepsy, and urinary incontinence. This led to the abandonment of prefrontal lobotomy in many parts of the world—but not before more

Figure 1.10 The transorbital procedure for performing prefrontal lobotomy.



than 40,000 patients had been lobotomized in the United States alone. And prefrontal lobotomies still continue to be performed in some countries.

A particularly troubling aspect of the use of prefrontal lobotomy is that not only informed, consenting adults received this "treatment." In his memoir, Howard Dully described how he had been lobotomized at the age of 12 (Dully & Fleming, 2007). The lobotomy was arranged by Dully's stepmother, agreed to by his father, and performed in 10 minutes by Walter Freeman. Dully spent most of the rest of his life in asylums, jails, and halfway houses, wondering what he had done to deserve the lobotomy and how much it had been responsible for his troubled life. Subsequent investigation of the case indicated that Dully was a normal child whose stepmother was obsessed by her hatred for him. Tragically, neither his father nor the medical profession intervened to protect him from Freeman's ice pick.

Some regard sound scientific methods as unnecessary obstacles in the paths of patients seeking treatment and therapists striving to provide it. However, the unforeseen consequences of prefrontal lobotomy should caution us against abandoning science for expediency. Only by observing the rules of science can scientists protect the public from bogus claims (see Rousseau & Gunia, 2016).

Thankfully, biopsychology has learned from the mistakes and faulty thinking of Delgado, Moniz, Freeman, and others. The practice of the scientific method and well-reasoned inference are nearly ubiquitous in modern biopsychology.

You are about to enter the amazing world of biopsychology. We hope your brain enjoys learning about itself.

Themes Revisited

The seeds of three of the major themes were planted in this chapter, but the thinking creatively theme predominated. First, you saw the creative approach that Lester and Gorzalka took in their research on the Coolidge effect in females. Then, you learned three important new ideas that will help you think about biopsychological claims: (1) the experimental method, (2) converging operations, and (3) scientific inference. Finally, you were introduced to two biopsychological claims that were once widely believed and saw how critical thinking identified their weaknesses and replaced them with creative new interpretations.

You also learned that two of the other major themes—clinical implications and the evolutionary perspective—tend to be associated with particular divisions of biopsychology. Clinical implications most commonly emerge from neuropsychological, psychopharmacological, and psychophysiological research; the evolutionary perspective is a defining feature of comparative psychology.

The two emerging themes, thinking about epigenetics and consciousness, will appear in later chapters.

Key Terms

Neurons, p. 26
Neuroscience, p. 26
Thinking creatively, p. 27
Clinical, p. 27
Evolutionary perspective, p. 27
Neuroplasticity, p. 28
Epigenetics, p. 28
Consciousness, p. 28

What Is Biopsychology?

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