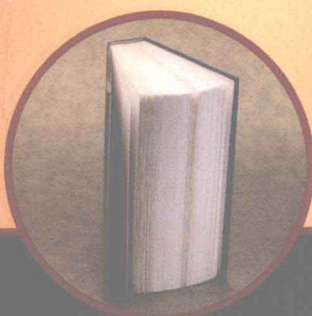
LEARNING AND MEMORY

MICHAEL DOMJAN
IAN NEATH



THOMSON LEARNING™
CUSTOM PUBLISHING

LEARNING AND MEMORY

MICHAEL DOMJAN
University of Texas
IAN NEATH
Purdue University

Brooks/Cole Publishing Company
ITP An International Thomson Publishing Company
Boston * Albany * Bonn * Cincinnati * Detroit * London * Madrid * Melbourne * Mexico City
New York * Paris * San Francisco * Singapore * Tokyo * Toronto * Washington

Printed in the United States of America

For more information, contact Brooks/Cole Publishing Company, 511 Forest Lodge Road, Pacific Grove, CA 93950, or electronically at http://www.thomson.com/brookscole.html

International Thomson Publishing Europe
Berkshire House 168-173
High Holborn
London, WC1V 7AA, England

International Thomson Editores
Campos Eliseos 385, Piso 7
Col. Polanco
11560 México D.F. México

Thomas Nelson Australia
102 Dodds Street
South Melbourne 3205
Victoria, Australia

International Thomson Publishing Asia
221 Henderson Road
#05-10 Henderson Building
Singapore 0315

Nelson Canada
1120 Birchmount Road
Scarborough, Ontario
Canada M1K 5G4

International Thomson Publishing Japan
Hirakawacho Kyowa Building, 3F
2-2-1 Hirakawacho
Chiyoda-ku, Tokyo 102, Japan

International Thomson Publishing GmbH
Königswinterer Strasse 418
53227 Bonn, Germany

International Thomson Publishing Southern Africa
Building 18, Constantia Park
240 Old Pretoria Road
Halfway House, 1685 South Africa

ISBN 0-534-50392-6

The Adaptable Courseware Program consists of products and additions to existing Brooks/Cole Publishing Company products that are produced from camera-ready copy. Peer review, class testing, and accuracy are primarily the responsibility of the author(s).

Custom Contents

CHAPTER

1 INTRODUCTION

THE goal of Chapter 1 is to introduce the reader to the study of learning and behavior. I will begin by discussing key concepts in the study of learning from a historical viewpoint and will describe the origins of experimental research in the area. These origins lie in studies of the evolution of intelligence, of functional neurology, and of animal models of human behavior. The defining characteristics of learning will be described next, followed by a discussion of methodological approaches to the study of learning. Because numerous experiments on learning have been performed with nonhuman animals, I will conclude the chapter by discussing the rationale for the use of animals in research.

You are probably already interested in understanding behavior, be it your own or the behavior of others. This interest is more than idle curiosity. Your quality of life is governed by your actions and the actions of others. Whether you receive a job offer depends on your prior education and record of employment, as well as the decisions of your prospective employer. Whether you get along well with your roommate depends on how he reacts to the things you do and how you react to the things he does. Whether you get to school on time depends on whether you get up early enough and on how crowded the roads are.

Any systematic effort to understand behavior must include consideration of what we learn and how we learn it. Numerous aspects of both human and animal behavior are the results of learning. We learn to read, to write, and to count. We learn how to walk down stairs without falling, how to open doors, how to ride a bicycle, and how to swim. We also learn when to relax and when to become anxious. We learn what foods are good for us and what will make us sick. We learn who is fun to visit and whose company is to be avoided. We learn how to tell when someone is unhappy and how to know when that person feels fine. We learn when to carry an umbrella and when to take an extra scarf. Life is filled with activities and experiences that are shaped by what we have learned.

Learning is one of the biological processes that promotes survival. The integrity of life depends on a variety of biological functions, including respiration, digestion, and the excretion of metabolic waste. Physiological systems have evolved to accomplish these tasks. However, finely tuned physiological processes are not enough to maintain the integrity of life. People and nonhuman animals are faced with climatic changes, changes in food resources, the coming and going of predators, and other environmental disruptions. Adverse effects of environmental change often have to be minimized by behavioral adjustments.

Animals have to learn to find new food sources as old ones become used up; they have to learn to avoid predators as new ones enter their territory; and they have to find new shelter when storms destroy their old one. Accomplishing these tasks obviously requires motor behavior such as walking and manipulating objects. These tasks also require the ability to predict important facts about the environment such as the availability of food in a particular location and at a particular time. Acquisition of new motor behavior and new anticipatory reactions involves learning. Animals learn to go to a new water hole when their old one dries up and learn to anticipate new sources of danger. These learned adjustments to the environment are as important as physiological processes such as respiration and digestion.

Most people tend to think about learning as involving the acquisition of new behavior. Indeed, learning is required before a child can read, ride a bicycle, or play a musical instrument. However, learning can just as well consist of the decrease or loss of some behavior in the organism's repertoire. A child, for example, may learn not to cross the street when the traffic light is red, not to grab food from someone else's plate, and not to yell and scream when her mother is trying to take a nap. Learning to withhold responses is just as important as learning to make responses, if not more so.

When considering learning, people commonly focus on the kinds of learning that require special training—the kinds of learning that take place in public schools and colleges, for example. Solving problems in calculus or making a triple somersault when diving does require special instruction. However, we learn all kinds of things without an expert teacher or coach during the course of routine interactions with our social and physical environment. Children, for example, learn how to open doors and windows, how to respond to a ringing telephone, when to avoid a hot stove, and when to duck so as not to get hit by a thrown ball. College students learn how to find their way around campus, how to avoid heartburn from cafeteria food, and how to predict when a roommate will stay out late at night—all without special instruction.

In the coming chapters, I will survey the research on basic principles of learning and behavior. I will discuss the types of learning and behavior that are fundamental to life but that, like breathing, are often ignored. The focus will be on pervasive and basic forms of learning that are a normal—though usually unnoticed—part of living. I will discuss the learning of simple relationships among events in the environment, the learning of simple motor movements, and the learning of emotional reactions to stimuli. These forms of learning are investigated in experiments that involve "training" procedures of various sorts. However, these forms of learning occur in the lives of people and animals without explicit or organized instruction or schooling.

HISTORICAL ANTECEDENTS

Theoretical approaches to the study of learning have their roots in the philosophy of René Descartes (see Figure 1.1). Before Descartes, most people thought of human behavior as entirely determined by conscious intent and free will. People's actions were not considered to be controlled by external stimuli or mechanistic natural laws. What a person did was presumed to be the result of his or her will or deliberate intent. Descartes took exception to this view of human nature because he recognized that many things people do are automatic reactions to external stimuli. However, he was not prepared to abandon entirely the idea of free will and the conscious control of actions. He therefore formulated a dualistic view of human behavior known as Cartesian **dualism.**

According to Cartesian dualism, there are two classes of human behavior: involuntary and voluntary. Some actions are involuntary and occur in response to external stimuli. These actions are called **reflexes.** Other aspects of human behavior involve voluntary actions that do not have to be triggered by external stimuli; rather, they occur because of the person's conscious choice to act in that manner.

The details of Descartes' dualistic view of human behavior are diagrammed in Figure 1.2. Let us first consider the mechanisms of involuntary, or reflexive, behavior. Stimuli in the environment are detected by the person's sense organs. The sensory information is then relayed to the brain through nerves. From the brain, the impetus for action is sent through nerves to the muscles that create the involuntary response. Thus, sensory input is *reflected* in response output. Hence, involuntary behavior is called *reflexive.*

Several aspects of this system are noteworthy. Stimuli in the external environment are seen as the cause of all involuntary behavior. These stimuli produce involuntary responses by way of a neural circuit that includes the brain. However, Descartes assumed that only one set of nerves was involved—that the same nerves transmitted information from the sense organs to the brain and from the brain down to the muscles. This circuit, he believed, permitted rapid reactions to external stimuli—for example, a person's quick withdrawal of his finger from a hot stove.

Descartes assumed that the involuntary mechanism of behavior was the only one available to animals other than humans. According to this view, all of nonhuman animal behavior occurs as reflex responses to external stimuli. Thus, Descartes believed that nonhuman animals lacked free will and were incapable of voluntary, conscious

Figure 1.1
René Descartes
(1596–1650).

behavior. He considered free will and voluntary behavior to be uniquely human attributes. This superiority of humans over other animals existed because only human beings were thought to have a mind, or soul.

The mind was assumed to be a nonphysical entity. Descartes believed that the mind is connected to the physical body by way of the pineal gland, which is near the brain. Because of this connection, the mind could be aware of and keep track of involuntary behavior. Through this mechanism, the mind could also initiate voluntary actions. Because he thought voluntary behavior is initiated in the mind, Descartes assumed that it could occur independently of external stimulation.

The mind-body dualism introduced by Descartes stimulated two intellectual traditions. One, *mentalism,* was concerned with the contents and workings of the mind; the other, *reflexology,* with the mechanisms of reflexive behavior. Let us turn to these next.

Historical Developments in the Study of the Mind

Philosophers concerned with the mind were interested in what is in the mind and how the mind works. Descartes had something to say about both these issues. Because Descartes thought the mind is connected to the brain by way of the pineal gland, he believed that some of the contents of the mind come from sense experiences. However, he also believed that the mind contains ideas that are innate and that exist in all human beings independent of personal experience. For example, he be-

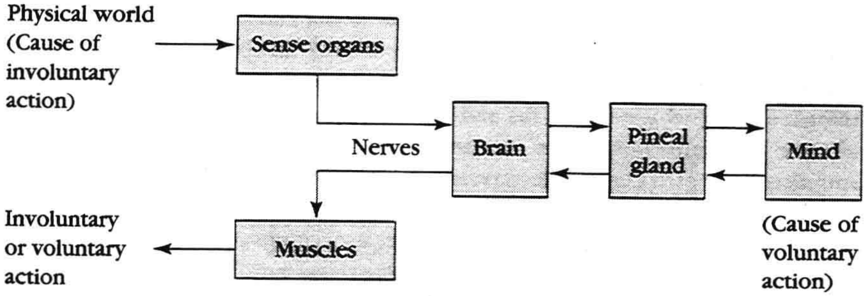


Figure 1.2 Diagram of Cartesian dualism. Events in the physical world are detected by sense organs. From here the information is passed along to the brain. The brain is connected to the mind by way of the pineal gland. Involuntary action is produced by a reflex arc that involves messages sent first from the sense organs to the brain and then from the brain to the muscles. Voluntary action is initiated by the mind, with messages sent to the brain and then the muscles.

lieved that all humans are born having a concept of God, a concept of self, and certain fundamental axioms of geometry (such as the fact that the shortest distance between two points is a straight line). The philosophical approach that assumes humans are born with innate ideas about certain things is called **nativism.**

Some philosophers after Descartes took issue with the nativist position. In particular, the British philosopher John Locke (1632–1704) believed that all the ideas people have are acquired directly or indirectly through experiences after birth. He believed that human beings are born without any preconceptions about the world. According to Locke, the mind starts out as a clean slate (*tabula rasa,* in Latin), to be gradually filled with ideas and information as the person has various sense experiences. This philosophical approach to the contents of the mind is called **empiricism.** Empiricism was accepted by a group of British philosophers who lived during the seventeenth, eighteenth, and nineteenth centuries and who came to be known as the *British empiricists.*

The nativist and empiricist philosophies differed not only on what the mind was assumed to contain but also on how the mind was assumed to operate. Descartes believed that the mind does not function in a predictable and orderly manner, according to discoverable rules or laws. One of the first to propose an alternative to this position was the British philosopher Thomas Hobbes (1588–1679). Hobbes accepted the distinction between voluntary and involuntary behavior stated by Descartes and also accepted the notion that voluntary behavior is controlled by the mind. However, unlike Descartes, he believed that the mind operates just as predictably and lawfully as reflex mechanisms. More specifically, he proposed that voluntary behavior is governed by the principle of **hedonism.** According to this principle, people do things in the pursuit of pleasure and the avoidance of pain. Hobbes was not concerned with whether the pursuit of pleasure and the avoidance of pain are laudable or desirable. For Hobbes, hedonism was simply a fact of life. As we will see, this conception of behavior has remained with us in one form or another to the present day.

According to the British empiricists, another important aspect of how the mind works involved the concept of **association.** Recall that empiricism assumes that all ideas originate from sense experiences. But how do the experiences of various colors, shapes, odors, and sounds allow the formation of more complex ideas? Consider, for example, the concept of a car. If you hear the word "car," you have an idea of what the thing looks like, what it is used for, and how you might feel if you sat in it. Where do all these ideas come from, given just the sound of the letters *c, a,* and *r*? The British empiricists proposed that simple sensations are combined into more complex ideas by associations. Because you had heard the word "car" when you saw a car, had considered using one to get to work, or had sat in one, associations may have become established between the word "car" and various aspects of cars. The British empiricists considered such associations very important in their explanation of how the mind works; hence, they devoted considerable effort to detailing the rules of associations.

Rules of Associations. The British empiricists accepted two sets of rules for the establishment of associations, one primary and the other secondary. The primary rules were originally set forth by the ancient Greek philosopher Aristotle. He proposed three principles for the establishment of associations: (1) contiguity, (2) similarity, and (3) contrast. Of these, the contiguity principle has been the most prominent in studies of associations. It states that, if two events repeatedly occur together in space or time, they will become associated. Once an association has been established, the occurrence of one of the events will activate the memory of the other event. For example, if you encounter the smell of tomato sauce with spaghetti often enough, the smell of tomato sauce will become sufficient to get you to think about spaghetti. The similarity and contrast principles state that two things will become associated if they are similar in some respect (both are red, for example) or have some contrasting characteristics (one might be strikingly tall and the other strikingly short, for example).

Various secondary laws of associations were set forth by a number of empiricist philosophers—among them the Scotsman Thomas Brown (1778–1820). Brown proposed that a number of factors influence the formation of associations between two sensations. These include the intensity of the sensations and how frequently or recently the sensations occurred together. In addition, the formation of an association between two events was considered to depend on the number of other associations in which each event was already involved and the similarity of these past associations to the current one being formed.

The British empiricists discussed rules of association as a part of their philosophical discourse. They did not perform experiments to determine whether or not the rules were valid. Nor did they attempt to determine the circumstances in which one rule was more important than another. Empirical investigation of the mechanisms of associations did not begin until the pioneering work of the nineteenth-century German psychologist Hermann Ebbinghaus (1850–1909).

To study how associations are formed, Ebbinghaus invented **nonsense syllables.** These were three-letter combinations ("bap," for example), devoid of any meaning that might influence how a person might react to them. Ebbinghaus used himself as the experimental participant. He studied lists of nonsense syllables and measured his ability to remember the syllables under various experimental conditions. This general method enabled him to answer such questions as how the strength of an association improved with increased training, whether nonsense syllables that appeared close together in a list were associated more strongly than syllables that were farther apart, and whether a syllable became more strongly associated with the next one on the list than with the preceding one.

Historical Developments in the Study of Reflexes

The concept of reflex action, that was introduced by Descartes greatly advanced the understanding of behavior. However, Descartes was mistaken in many of his beliefs about reflexes. He believed that sensory messages going from sense organs to the brain and motor messages going from the brain to the muscles travel along the same nerves. He thought that nerves are hollow tubes and that neural transmission involves gases called *animal spirits.* The animal spirits, released by the pineal gland, were assumed to flow through the neural tubes and enter the muscles, causing them to swell and create movement. Finally, Descartes considered all reflexive movements to be innate and to be fixed by the anatomy of the nervous system.

Later experimental work on animals by Charles Bell (1774–1842) in England and François Magendie (1783–1855) in France showed that separate nerves transmit sensory information from sense organs to the central nervous system and motor information from the central nervous system to muscles. If a sensory nerve is cut, an animal remains capable of muscle movements; if a motor nerve is cut, the animal remains capable of registering sensory information.

The idea that animal spirits are involved in neural transmission was also disproved after the death of Descartes. In 1669 John Swammerdam (1637–1680) showed that mechanical irritation of a nerve was sufficient to produce a muscle contraction. Thus, infusion of animal spirits from the pineal gland was not necessary. In other studies, Francis Glisson (1597–1677) demonstrated that muscle contractions are not produced by swelling due to the infusion of a gas, as Descartes had postulated. Glisson measured the swelling of the muscles of the arm by having people submerge their arm in water and then contract their arm muscle. If muscle contraction were resulting from the infusion of a gas, the muscle should have displaced more water when contracted than when relaxed. Contrary to this prediction, the amount of water displaced by the muscle did not change when the muscle was contracted. Such experiments indicate that neural conduction does not occur by the mechanisms Descartes had proposed.

Descartes and most philosophers after him assumed that reflexes are responsible only for simple reactions to stimuli. The energy in a stimulus was thought to be translated directly into the energy of the elicited response by the neural connections. The more intense the stimulus was, the more vigorous the resulting response would be. This view of reflexes is consistent with many casual observations. If you touch a stove, for example, the hotter the stove, the more quickly you withdraw your finger. However, reflexes can also be more complicated.

The physiological processes responsible for reflex behavior became better understood in the nineteenth century, and reflexes came to be used as an explanation for a greater range of behaviors. Two Russian physiologists, I. M. Sechenov (1829–1905) (see Figure 1.3) and Ivan Pavlov (1849–1936), were primarily responsible for these developments. Sechenov proposed that stimuli do not elicit reflex responses directly in all cases. Rather, in some cases a stimulus can release a response from inhibition. Where a stimulus released a response from inhibition, the vigor of the response would not depend on the intensity of the stimulus. This simple idea opened up all sorts of new possibilities.

Since the vigor of an elicited response does not invariably depend on the intensity of its triggering stimulus, it is possible for a very faint stimulus to produce a large response. Small pieces of dust in the nose, for example, can cause a vigorous sneeze. Sechenov took advantage of this type of mechanism to provide a reflex analysis of vol-

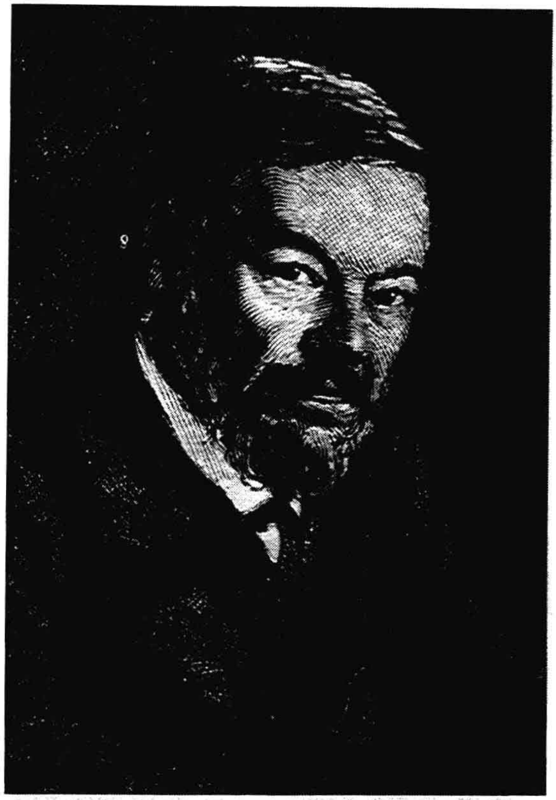


Figure 1.3
I. M. Sechenov
(1829–1905)

untary behavior. He suggested that complex forms of behavior (actions or thoughts) that occur in the absence of an obvious eliciting stimulus are in fact reflexive responses. In these cases, the eliciting stimuli are so faint as to be unnoticeable. Thus, according to Sechenov, voluntary behavior and thoughts are actually elicited by inconspicuous, faint stimuli.

Sechenov's ideas about voluntary behavior greatly extended the use of reflex mechanisms to explain a variety of aspects of behavior. However, his ideas were philosophical extrapolations from the research results he obtained. In addition, Sechenov did not address the question of how reflex mechanisms can account for the fact that the behavior of organisms is not fixed and invariant throughout an organism's lifetime but can be altered by experience. From the time of Descartes, reflex responses were considered to be innate and fixed by the anatomy of the nervous system. Reflexes were thought to depend on a pre-wired neural circuit connecting the sense organs to the relevant muscles. According to this view, a given stimulus could be expected to elicit the same response throughout an organism's life. Although this is true in some cases, there are also many examples in which responses to stimuli change as a result of experience. Explanation of such cases by reflex processes had to await the experimental and theoretical work of Ivan Pavlov.

Pavlov showed experimentally that not all reflexes are innate. New reflexes to stimuli can be established through mechanisms of association. Thus, Pavlov's role in the history of the study of reflexes is comparable to the role of Ebbinghaus in the study of the mind. Both were concerned with establishing the laws of associations through empirical research.

8

Experimental studies of basic principles of learning often are conducted with nonhuman animals and in the tradition of reflexology. Research in animal learning came to be pursued with great vigor starting a little more than 100 years ago. Impetus for the research came from three primary sources (see Domjan, 1987). The first of these was interest in comparative cognition and the evolution of the mind. The second was interest in how the nervous system works (functional neurology), and the third was interest in developing animal models to study certain aspects of human behavior. As we will see in ensuing chapters, comparative cognition, functional neurology, and animal models of human behavior continue to dominate contemporary research in learning processes.

Comparative Cognition and the Evolution of Intelligence

Interest in comparative cognition and the evolution of the mind was sparked by the writings of Charles Darwin (see Figure 1.4), who took Descartes' ideas about human nature one step further. Descartes had started chipping away at the age-old notion that human beings have a unique and privileged position in the animal kingdom by proposing that at least some aspects of human behavior (their reflexes) are animal-like. However, Descartes had preserved some privilege for human beings by assuming that humans (and only humans) have a mind.

Darwin attacked this last vestige of privilege. In his second major work, *The Descent of Man, and Selection in Relation to Sex,* Darwin argued that "man is descended from some lower form, notwithstanding that connecting-links have not hitherto been discovered" (Darwin, 1897, p. 146). In claiming a continuity from animals to humans, Darwin attempted to characterize not only the evolution of physical traits but also the evolution of psychological or mental abilities. Thus, he suggested that the human mind is a product of evolution. In making this claim, Darwin did not deny that human beings have such special mental abilities as the capacity for wonder, curiosity, imitation, attention, memory, reasoning, and aesthetic sensibility. Rather, he suggested that nonhuman animals also have these abilities. Moreover, he maintained that nonhuman animals are capable even of belief in spiritual agencies (Darwin, 1897, p. 95).

Darwin collected anecdotal evidence of various forms of intelligent behavior in animals in an effort to support his claims. Although the evidence was not compelling by modern standards, the research question was. Investigators ever since have been captivated by the possibility of tracing the evolution of intelligence by studying the abilities of various species of animals.

Before investigating the evolution of intelligence in a systematic fashion, a researcher must have a criterion for identifying intelligent behavior in animals. A highly influential proposal for a criterion was offered by George Romanes in his book *Animal Intelligence* (Romanes, 1884). Romanes suggested that intelligence can be identified by determining whether an animal learns "to make new adjustments, or to modify old ones, in accordance with the results of its own individual experience" (p. 4). Thus, Romanes defined intelligence in terms of the ability to learn. This definition was widely accepted by comparative psychologists at the end of the nineteenth and the start of the twentieth century and served to make the study of animal learning the key to obtaining information about the evolution of intelligence.

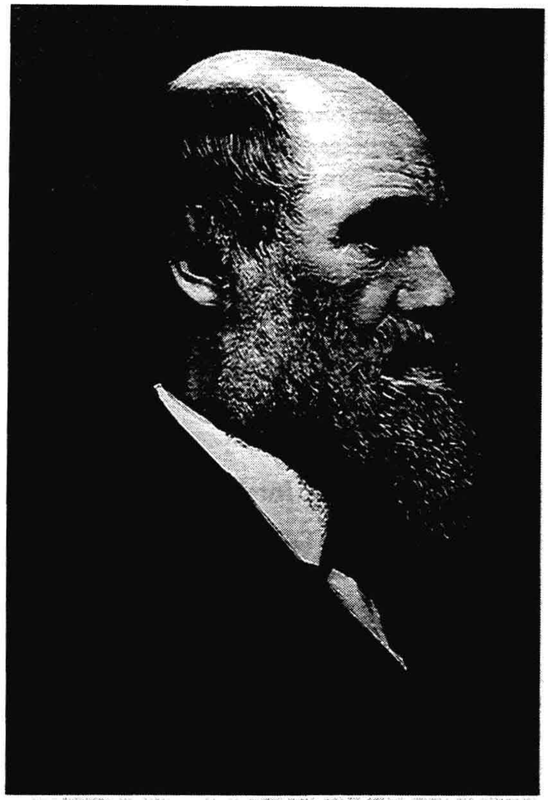


Figure 1.4
Charles Darwin (1809–1882).

As we will see in the upcoming chapters, much research on the mechanisms of animal learning has not been concerned with trying to obtain evidence of the evolution of intelligence. Nevertheless, this issue remains of considerable contemporary interest (for example, Wasserman, 1993). I will describe some of the fruits of this contemporary research on animal cognition in Chapters 11 and 12.

Functional Neurology

As I previously mentioned, the modern era in the study of learning processes was also greatly stimulated by efforts to use studies of animal learning to gain insights into how the nervous system works. This line of research was led by the Russian physiologist Ivan Pavlov, quite independently of the work of Darwin, Romanes, and others interested in comparative cognition.

While still a medical student, Pavlov became committed to the principle of **nervism.** According to nervism, all key physiological functions are governed by the nervous system. Armed with this principle, Pavlov devoted his life to documenting how the nervous system controls various aspects of physiology. Much of his work was devoted to identifying the neural mechanisms of digestion.

For many years, Pavlov's research progressed according to plan. But in 1902, two British investigators (Bayliss and Starling) published results showing that the pancreas, an important digestive organ, was partially under hormonal rather than neural control. Writing some time later, Pavlov's friend and biographer noted that these novel findings produced a crisis in the laboratory because they "shook the very foun-

10

dation of the teachings of the exclusive nervous regulation of the secretory activity of the digestive glands" (Babkin, 1949, p. 228).

The evidence of hormonal control of the pancreas presented Pavlov with a dilemma. If he continued his investigations of digestion, he would have to abandon his interest in the nervous system. On the other hand, if he maintained his commitment to nervism, he would have to stop studying digestive physiology. Nervism won out. In an effort to continue studying the nervous system, Pavlov changed from studying digestive physiology to studying the conditioning of reflexes. Thus, Pavlov regarded his studies of conditioning (which is a form of learning) as a way to obtain information about the functions of the nervous system—how the nervous system works. Pavlov's claim that studies of learning reveal how the nervous system functions is well accepted by contemporary neuroscientists. Kandel, for example, has commented that "the central tenet of modern neural science is that all behavior is a reflection of brain function" (Kandel, Schwartz, & Jessell, 1991, p. 3).

The behavioral psychologist is like a driver who tries to find out about an experimental car by immediately taking it out for a test drive instead of first looking at how the car was put together. By driving the car, a person can learn a great deal about how it functions. He can discover its acceleration, its top speed, the quality of its ride, its turning radius, and how quickly it comes to a stop. Driving the car will not tell us how these various functions are accomplished, but it will reveal the major functional characteristics of the internal machinery of the car.

Knowledge of the functional characteristics of a car can, in turn, provide clues about its internal machinery. For example, if the car accelerates sluggishly and never reaches high speeds, chances are it is not powered by a rocket engine. If the car only goes forward when facing downhill, it may be propelled by gravity rather than by an engine. On the other hand, if the car cannot be made to come to a stop quickly, it may not have brakes.

In a similar manner, behavioral studies of learning can provide clues about the machinery of the nervous system. Such studies show the kinds of plasticity the nervous system can exhibit, the conditions under which learning can take place, how long learned responses persist, and the circumstances under which learned information is accessible or inaccessible. By detailing the functions of the nervous system, behavioral studies of learning define the features or functions that have to be explained by neurophysiological investigations.

Animal Models of Human Behavior

The third major impetus for the modern era in the study of animal learning was the suggestion that animal research can provide information that may advance the understanding of human behavior. Animal models of human behavior are of more recent origin than comparative cognition or functional neurology. The approach was systematized by Dollard and Miller and their collaborators (Dollard, Miller, Doob, Mowrer, & Sears, 1939; Miller & Dollard, 1941) and developed further by B. F. Skinner (1953).

Drawing inferences about human behavior on the basis of research with animal participants can be hazardous and controversial. The inferences are hazardous if they are unwarranted; they are controversial if the rationale for the model system approach is poorly understood. Although animal models of human behavior have been developed based on research with a variety of species, most of the models were developed with rats and pigeons.

In generalizing from research with rats and pigeons to human behavior, scientists do not make the assumption that rats and pigeons are like people. Animal models are like other types of models. Architects, pharmacologists, medical scientists, and designers of automobiles all rely on models, and the models are often strikingly different from the real thing. Architects, for example, make small-scale models of buildings they are designing. Obviously, such models are not the same as the real building. They are much smaller, made of cardboard and small pieces of wood instead of bricks and mortar, and support little weight.

Models are commonly used because they permit the investigation of certain aspects of what they represent under conditions that are *simpler, more easily controlled,* and *less expensive* than the real thing. For example, with the use of a model, an architect can study the design of the exterior of a planned building without the expense of actual construction. The model can be used to determine what the building will look like from various vantage points and how it will appear relative to nearby buildings. Studying a model in a design studio is much simpler than studying a building on a busy street corner. Factors that may get in the way of getting a good view (other buildings, traffic, and power lines, for example) can be controlled and minimized in a model.

In a comparable fashion, a car designer can study the wind resistance of various design features of a new automobile with the use of a model in the form of a computer program. The program can be used to show how the addition of spoilers or changes in the shape of the car can cause changes in wind resistance. The computer model bears little resemblance to a real car. It has no tires or engine and cannot be driven. However, the model permits testing the wind resistance of a car design under conditions that are much simpler, better controlled, and less expensive than if the car were built and driven down the highway under various conditions in order to measure wind resistance.

What makes models valid for studying something, given all the differences between the model and the real thing? For a model to be valid, it must be comparable to the real thing in terms of the feature under study—the *relevant feature.* If the model of a building is used to study the building's exterior appearance, then all the exterior dimensions of the model must be proportional to the corresponding dimensions of the planned building. Other features of the model, such as its structural elements, are irrelevant. In contrast, if the model were used to study how well the building would withstand an earthquake, then its structural elements (beams and how they are connected) would be critical.

In a similar manner, the only thing relevant in a computer model of car wind resistance is that the computer program provide calculations for wind resistance that match the results obtained with real cars driven through real air. No other feature is relevant; therefore, the fact that the computer program lacks an engine or rubber tires is of no consequence.

The rationale and strategies associated with animal models of human behavior are similar to those pertaining to models in other areas of inquiry. Animal models permit the investigation of problems that are difficult, if not impossible, to investigate directly with people. A model permits the investigation to be carried out under circumstances that are simpler, better controlled, and less expensive. Furthermore, the validity of animal models is based on the same criterion as the validity of other types of models. The important thing is similarity between the animal model and human behavior in *relevant features* for the problem at hand. For example, similarities between rats and humans in the way they learn to avoid dangerous foods makes a rat model valid for the investigation of human food aversion learning. The fact that rats have long tails and walk on four legs rather than two is entirely irrelevant to food selection.

The critical task in constructing a successful animal model is to identify a relevant similarity between the animal model and the human behavior of interest. Because animal models are often used to push back the frontiers of knowledge, the correspondence between the animal findings and human behavior always must be carefully verified by empirical data.

The rationale and strategy for the development of animal models of human behavior were stated succinctly by Dollard and Miller (1950):

> In using the results from [research with rats] we are working on the hypothesis that people have all the learning capacities of rats. . . . Even though the facts must be verified at the human level, it is often easier to notice the operation of principles after they have been studied and isolated in simpler situations so that one knows exactly what to look for. Furthermore, in those cases in which it is impossible to use as rigorous experimental controls at the human level, our faith in what evidence can be gathered at that level will be increased if it is in line with the results of more carefully controlled experiments on other mammals. (p. 63)

Dollard and Miller advocated an interplay between animal and human research in which laboratory studies with animals are used to isolate and identify phenomena that can then be investigated in people more successfully. The animal research is also used to increase confidence in human data that are obtained with weaker research methods.

Animal models have been developed for a wide range of human problems and behaviors (see Overmier & Burke, 1992, for a bibliography). In the upcoming chapters I will discuss animal models of love and attachment, drug tolerance and addiction, food aversion learning, learning of fears and phobias, and stress and coping, among others. Animal models have also led to the development of numerous procedures now commonly employed with people, such as biofeedback, programmed instruction, systematic desensitization, token economies, and other techniques of behavior modification. I will provide examples of such applications throughout the text at relevant points.

THE DEFINITION OF LEARNING

Learning is such a common human experience that few people reflect on exactly what it means to say that something has been learned. A universally accepted definition of learning does not exist. However, many critical aspects of the concept are captured in the following statement:

> *Learning is an enduring change in the mechanisms of behavior involving specific stimuli and/or responses that results from prior experience with similar stimuli and responses.*

The Learning-Performance Distinction

Whenever we see evidence of learning, we see the emergence of a change in behavior—the performance of a new response or the suppression of a response that occurred previously. A child becomes skilled in snapping the buckles of her sandals or becomes more patient in waiting to eat dinner until everyone has been seated at the