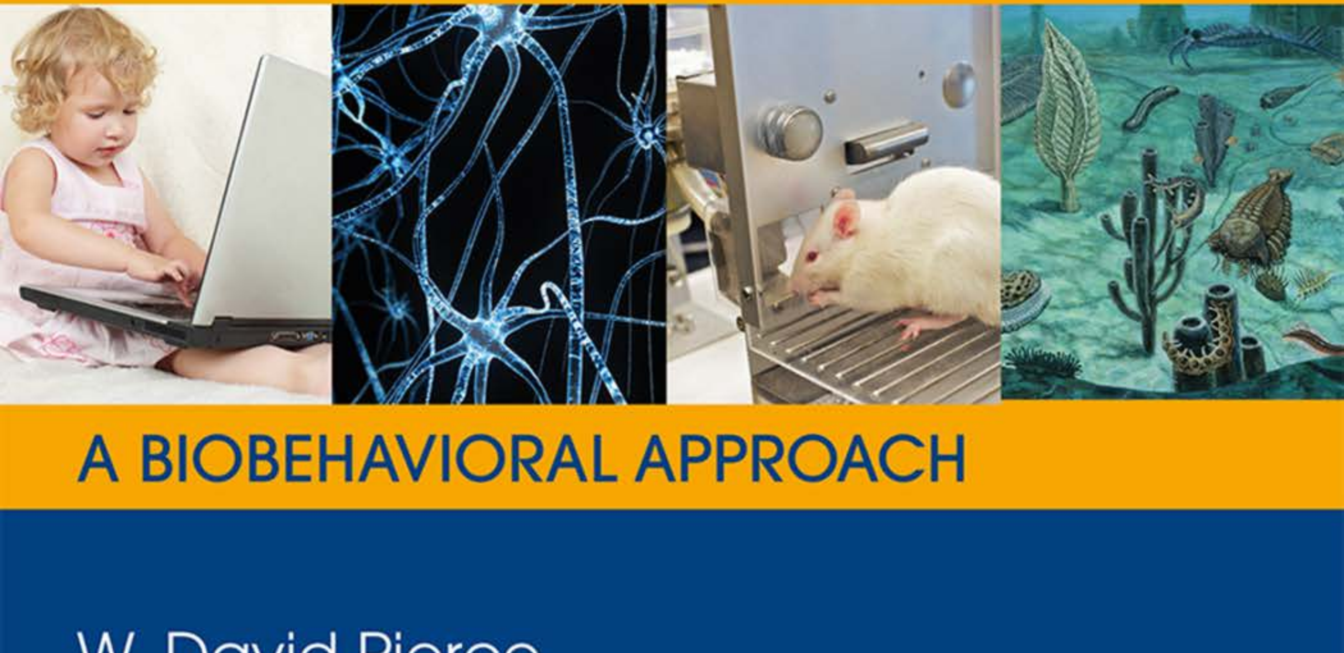
6th edition

Behavior Analysis and Learning



A BIOBEHAVIORAL APPROACH

W. David Pierce
and Carl D. Cheney

A Psychology Press Book

ROUTLEDGE

Behavior Analysis and Learning

Using a consistent Skinnerian perspective, *Behavior Analysis and Learning: A Biobehavioral Approach, Sixth Edition* provides an advanced introduction to the principles of behavior analysis and learned behaviors, covering a full range of principles from basic respondent and operant conditioning through applied behavior analysis into cultural design. The textbook uses Darwinian, neurophysiological, and biological theories and research to inform B.F. Skinner's philosophy of radical behaviorism.

The sixth edition expands focus on neurophysiological mechanisms and their relation to the experimental analysis of behavior, providing updated studies and references to reflect current expansions and changes in the field of behavior analysis. By bringing together ideas from behavior analysis, neuroscience, and epigenetics under a selectionist framework, this textbook facilitates understanding of behavior at environmental, genetic, and neurophysiological levels. This "grand synthesis" of behavior, neuroscience, and neurobiology roots behavior firmly in biology. The book includes special sections, "New Directions," "Focus On," "Note On," "On the Applied Side," and "Advanced Section," which enhance student learning and provide greater insight on specific topics.

This book is a valuable resource for advanced undergraduate and graduate students in psychology or other behavior-based disciplines, especially behavioral neuroscience. For additional resources to use alongside the textbook, consult the Companion Website at www.routledge.com/cw/Pierce.

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Behavior Analysis and Learning

A Biobehavioral Approach

Sixth Edition

W. David Pierce and
Carl D. Cheney

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To B. F. Skinner

When an organism acts upon the environment in which it lives, it changes that environment in ways that often affect the organism itself. Some of these changes are what the layman calls rewards, or what are generally referred to technically as reinforcers: when they follow behavior in this way they increase the likelihood that the organism will behave in the same way again.

(Ferster & Skinner, 1957, p. 1)

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Foreword

In my Foreword to the fifth edition of *Behavior Analysis and Learning* by David Pierce and Carl Cheney, I suggested that five editions of the book reflected the vitality and longevity of behavior analysis. The publication of the sixth edition goes even further to reflect the current breadth and depth of the discipline and its evolution as a member of the family of biological sciences by including research and concepts from the related sciences of neurophysiology and epigenetics, all in the context of an evolutionary framework. Because of this increased emphasis on how these other biological sciences intersect with the science of behavior analysis, Pierce and Cheney have added the subtitle, *A Biobehavioral Approach*. Throughout all of its incarnations, however, *Behavior Analysis and Learning* has dealt fundamentally with learning and behavior. To understand how Pierce and Cheney arrived at the sixth edition of *Behavior Analysis and Learning*, it is important to understand a few of the basic concepts of behavior analysis—behavior, environment, and learning—that the book has elucidated since it was first published.

Behavior—anything an organism does in response to a particular situation or stimulus—is defined by its reciprocal interaction with the environment, which itself is defined in terms of all of the stimuli that affect an organism's behavior at a given moment. Behavior is the means by which animals find food and shelter and escape predation. Evolutionarily, it is largely an organism's behavior that determines whether it will survive, that is, live long enough to pass on its genes. Physiologically, these environment–behavior interactions are mediated by a nervous system that has evolved two broad and basic functions—sensory and motor—that are supported by different and specialized areas in the brain and their corresponding nerves.

Learning refers to relatively permanent changes in environment–behavior relationships as a result of certain types of experiences. Thus, what changes when learning is said to occur is not simply behavior, but rather relationships between environmental events (stimuli) and behavior. The "certain types of experiences" that produce learning are Pavlovian and operant conditioning. Just as behavior and stimuli are mediated by the nervous system, so too is learning. What we might refer to as behavioral plasticity, that is, behavior's capacity to be modified, is mediated by what neuroscientists refer to as neural plasticity, that is, the capacity of neuronal connections to be modified.

Learning and behavior as it relates to any particular species is a function of that species' evolutionary history. If human beings represent the pinnacle of anything evolutionarily, it is their evolved capacity for seemingly infinite behavioral and neural plasticity, that is, their capacity to learn. Although it is possible to scientifically study and understand the environment's role in selecting and maintaining behavior (i.e., learning) without any knowledge of genes and physiology—and, indeed, such a science, behavior analysis, already exists—a complete understanding of learning requires scientific inquiry at three levels: environment, genes, and neurophysiology.

There are textbooks on learning and behavior that do a fine job of explicating the laws of environment–behavior relations and their accompanying theories, but to date, only one textbook, *Behavior Analysis and Learning* by David Pierce and Carl Cheney, broadens the perspective. Since it was first published in 1995 (with W. Frank Epling), Pierce and Cheney's textbook has changed to reflect the evolution of the field of behavior analysis into a science that incorporates both neurophysiological and epigenetic concepts all within a selectionist framework. In so doing, Pierce and Cheney present behavior analysis as a member of the family of biological sciences, which, as a selectionist science, emphasizes Skinner's concept of selection by consequences at three levels: genes (i.e., natural selection), the behavior of individual organisms (i.e., operant conditioning), and cultural practices (i.e., cultural selection). In fact, the authors acknowledge that the capacity for learning itself is an evolved trait and that the behavior of scientists who study it is, in part, a function of cultural contingencies.

For each new edition, Pierce and Cheney have not only met the minimal requirements for a revision, they have updated the content (and references) to reflect changes in research and scholarship in the field. But Pierce and Cheney have also pushed the envelope in each new edition and have expanded the scope of learning and behavior to include the broader context of evolution, genes, and physiology. In the fifth edition, the authors added a section called "New Directions" that related the topic of each chapter to recent developments in behavioral neuroscience. The sixth edition goes even further with an increased focus on behavior analysis and neuroscience, neurophysiology, neurobiology, and epigenetics, creating what Pierce and Cheney refer to as a "grand synthesis" of behavioral science.

The phrase "grand synthesis" is derived from the Modern Synthesis in biology in which ideas and concepts from several separate fields of biology (e.g., natural selection theory, genetics, ecology, paleontology, etc.) were synthesized to form a stronger and more unified account of evolution. The term "grand synthesis" implies an even broader account of evolution to include nothing short of the universe itself. Thus, a grand synthesis of behavior science, while still perhaps a somewhat lofty goal, brings together ideas from three general areas of inquiry—behavior analysis, neuroscience, and epigenetics—all in the context of selectionism (i.e., natural selection and operant learning), to create a more complete picture of behavior. Thus, to fully understand behavior, scientists must now take a *biobehavioral approach*. As the authors write, "Our goal in this textbook also is to further the integration of applied and basic areas of behavior analysis and to encourage closer ties to other biological sciences."

As with the previous editions, the sixth covers not just learning and behavior, but behavior analysis as "a comprehensive, natural-science approach to the study of the behavior of organisms." To wit, Pierce and Cheney address not only the experimental foundations of the science, but its conceptual framework, philosophical implications, and applications to real-world behavioral problems. As with the fifth edition, each chapter still includes a section—"On the Applied Side"—in which the authors illustrate how the basic concepts or principles presented in the chapter have been used to ameliorate some socially significant behavior. Many chapters in the sixth edition include a "New Directions" section, which, consistent with the new emphasis and title, highlight some research topic in neuroscience that relates to the topic of the chapter. Other special sections include "Focus On," "Note On," and "Advanced Section," which cover a range of experimental, theoretical, and applied issues related to the content of each chapter.

Finally, a feature of *Behavior Analysis and Learning* that makes it stand out as a superior textbook is that, in addition to presenting the experimental foundations of behavior analysis in a broad biological context and showing how they can be used to improve socially significant behaviors, Pierce and Cheney demonstrate how the basic principles of behavior detailed in the book can be used to interpret behavior that is either novel, too complex to be studied in the lab, or seemingly mentalistic or cognitive. Interpretation is fundamental to all of the experimental sciences, and behavior analysis is no different. By demonstrating how laboratory-derived principles of behavior can be used to understand behaviors that go by such names as language, memory, consciousness, and perception, Pierce and Cheney broaden the reach of behavior-analytic theory and provide a parsimonious account of behaviors that have tempted dualistic thinking among psychologists and philosophers for centuries.

Beginning with the first edition, *Behavior Analysis and Learning* has been dedicated to B.F. Skinner, and I can think of no better tribute to him than a book which not only details the basic principles of the science he helped to establish, but also does so in the context of the selectionist principles he championed, and which demonstrates how, to paraphrase Skinner, we may be able to use those principles to act to save the world.

Henry D. Schlinger, Jr.
California State University, Los Angeles
16 September 2016

Preface

Behavior Analysis and Learning has come a long way since 1995. The experimental analysis of behavior has also come a long way. Many things have changed and some have not—behavior is still a function of its consequences; reinforcement still works; resurgence still happens in extinction; differential reinforcement of successive approximations still shapes new responses; and the Skinner Box is still a major component for exploring environment–behavior interactions. As things change they also remain the same. Students still have to be taught by skilled, attentive teachers; labeling and inferences about behavior are still just that and the behavior of the organism itself remains an important subject for scientific investigation; people still act as if non-physical, invented cognitive constructs such as mental maps, mindlessness, or other explanatory fictions provide a scientific account of human behavior.

In this sixth edition of our textbook, we have continued to expand the presentation of neurophysiological mechanisms as context for the experimental analysis of behavior, believing that the contributions of neuroscience and neurobiology will substantially improve our ultimate explanation of where behavior comes from and how it can be controlled. The "grand synthesis" is growing exponentially. One might say that the scientific study of behavior is working its way back into biology from whence it should never have left.

We maintain the world view or paradigm of selection by consequences at the biological, behavioral, and cultural levels and are impressed by the growing number of evidenced-based studies that support this position. We continue to promote the broad practice of applied behavior analysis and the growing literature illustrating diverse applications of behavior science. Several professional organizations have come into existence whose members express, either in research or application, Skinner's philosophy of radical behaviorism in the analysis of behavior. The discovery of the way behavior works upon the world is illuminated by the experimental analysis of behavior in learning and genetics laboratories, free-ranging animal environments, programmed instruction for classrooms, training centers for explosive sniffing dogs, care and treatment of zoo animals, early intensive behavioral intervention for children with autism and developmental disabilities, computer labs and human learning environments, applications to business and organizations, and university behavior laboratories investigating control by contingencies of reinforcement with a variety of organisms.

To ensure we stay current with the scientific analysis of behavior–environment relationships, we have added approximately 300 new references to the sixth edition, some from traditional sources like the *Journal of the Experimental Analysis of Behavior* and other citations from generalist and biological journals, including *Science* and *Nature*. Refinements of technology, research design, and data treatment together with an increased number of active investigators has vastly expanded the field of behavior analysis and therefore the topics and sources to present to students and readers. We have been driven by the breadth of related and contributing findings that appear from a huge scientific literature and media coverage to peruse and select only some of the relevant, emerging material. We suggest teachers recommend their students access original sources to more fully appreciate the new lines of research and evolution of specific topics.

Chapter titles and their order have remained virtually the same as the fifth edition. The addition of more recent citations, however, has necessitated the removal of a substantial number of references, in many cases older papers. However, we consider many early papers in the experimental analysis of behavior to remain as relevant today as ever. It may be that we assume most readers or instructors to be somewhat familiar with older terms and findings when they are not. In which case, we recommend perusing the references of cited papers in the sixth edition to locate original sources.

The appropriate application of behavior principles in society at large is progressing. The basic behavior principles such as reinforcement, discrimination, and generalization have always been in operation, but many times these principles are used poorly, inaccurately, or under a different name. Committed students of behavior science are growing in number and even President Obama ordered agencies of the US government to be informed by the findings of behavior science. Nonetheless, as epigenetic transmission of the knowledge of behavior science does not seem viable in the foreseeable future, more traditional forms of education appear necessary. Enter Edition 6 of *Behavior Analysis and Learning*.

For this edition we began with the desire to include aspects of neuroscience as it contributes to a more comprehensive understanding of the behavior of organisms. Epigenetic research, optical excitement of neurons, computer/neural interfacing, and gut bacteria influences may seem a far cry from schedules of reinforcement or errorless learning, but as a biological organism all such elements contribute to the whole. We might recall that B. F. Skinner did his major research work in the physiological labs at Harvard. The point is, however, that BFS could see that behavior in and of itself was a separate field of biology and it deserved a special level of analysis. So, no matter how thoroughly we understand the neurobiological operations of the organism, principles of selection by consequences remain at work at the level of behavior. We may become more sophisticated about the overlap of frontal lobe circuitry and the nuanced action of synaptic neurotransmitters, but it will remain functional to distinguish between behavior under the influence of fixed-ratio or variable-interval schedules when accounting for specific instances of behavior on a given occasion. Recently, Skinner's functional approach for the analysis of language as verbal behavior has received empirical support by the wider scientific community, findings at odds with Chomsky's nativist, linguistic perspective.

A final issue that has not changed is our deep appreciation to the memory of W. Frank Epling, PhD, an original author. Our friend and colleague was instrumental in generating what we consider the best available source for behavior analysis and learning based on a consistent philosophy, research program, principles and examples of application. It should also go without saying that we acknowledge the origination of a science of behavior to B. F. Skinner. He discovered and articulated the basic principles of how the world works through selection by consequences as the operating process.

W. David Pierce
Carl D. Cheney

A Science of Behavior: Perspective, History, and Assumptions

1

1. Inquire about *learning*, a science of behavior and behavior analysis.
2. Discover how *selection by consequences* extends to evolution and behavior.
3. Explore new directions in behavior analysis and behavioral neuroscience.
4. See how early learning is retained by *epigenetic* mechanisms.
5. Investigate the early beginnings of behavior analysis and learning.
6. Analyze feeling and thinking as complex behavior.

Learning refers to the acquisition, maintenance, and change of an organism's *behavior* as a result of lifetime events. The **behavior** of an organism is everything it does, including private and covert actions like thinking and feeling (see "Science and Behavior: Some Assumptions" section of this chapter). Learning also involves **neuroplasticity**—alterations in the brain that accompany behavior change and participate in the regulation of behavior. While our focus in this book is centered on the study of behavior for its own sake, the links to the brain and neural processes are increasingly important to the field of learning and behavior analysis as we discuss throughout the book.

An important aspect of human learning concerns the experiences arranged by other people. From earliest history, people have acted to influence the behavior of other individuals. Rational argument, rewards, bribes, threats, and force are used in attempts to promote learning or change the behavior of people. In civilized societies, people are required to learn socially appropriate behaviors. As long as a person conforms, no one pays much attention. As soon as conduct substantially departs from cultural norms, people get upset and socially reject the non-conformist—ensuring that most of us comply (Williams & Nida, 2011). All societies have codes of conduct and laws that their people have to learn; people who break moral codes or civil laws face penalties ranging from minor fines to capital punishment. Clearly, all cultures are concerned with human learning and the regulation of human conduct. Without regulation, anarchy and confusion eventually destroy the civil order of society.

Theories of learning and behavior have ranged from philosophy to natural science. When Socrates was told that new discoveries in anatomy proved that bodily movement was caused by the arrangement of muscles, bones, and joints, he replied, "That hardly explains why I am sitting here in a curved position talking to you" (Millenson, 1967, p. 3). About 2300 years later, in 1934, the great philosopher Alfred North Whitehead and the famous behaviorist B. F. Skinner were seated together at dinner involved in a discussion about the behaviorist approach to psychology. After listening to Skinner's interpretations of human behavior based on principles discovered in the laboratory, Whitehead challenged the behaviorist to account for the generative nature of human language. He said, "Let me see you account for my behavior as I sit here saying, 'No black scorpion is falling upon this table'" (Skinner, 1957, p. 457). Whitehead's point was that no theoretical or empirical system existed to account for the spontaneous and generative nature of human language. Although there was no satisfactory behavioral account of complex human behavior and language in the 1930s, the science of behavior is currently addressing such puzzling questions.

Human behavior has been attributed to a great variety of causes. The causes of behavior have been located both within and outside of people. Internal causes have ranged from metaphysical entities like the soul to hypothetical structures of the nervous system. Suggested external causes of behavior have included the effect of the moon and tides, the arrangement of stars, and the whims of gods. Unfortunately, some of these bizarre, prescientific attempts to explain human behavior remain popular today. For example, the use of astrological forecasts is even found in modern corporations, as demonstrated in the following passage taken from *The Economist*:

> Is astrology the ultimate key to competitive advantage? That is what Divinitel, a French company specializing in celestial consulting, claims. For FFr350 ($70) a session, the firm's astrologers offer advice on anything from the timing of takeovers to exorcisms. . . . So who is daft enough to pay for such mystical mumbo-jumbo? About 10% of French businesses are, according to a study by HEC, a French business school.
>
> ("Twinkle, Twinkle," *The Economist*, 22 December 1990, p. 95)

In an interview with Ashley Lutz for *Business Insider* (2012), Susan Miller, a successful astrologer with a business degree from NYU, said, "What I do is scientific. Astrology involves careful methods learned over the years and years of training and experience." Her website has six million visitors every month and she has built an empire based on her "scarily accurate" predictions, said the *Insider*. Miller states "one unlikely group of customers . . . are professional men from 25 to 45-years-old. In these uncertain economic times, astrology is more important than ever!" Many people faced with the unpredictability of daily existence turn to the theory of celestial alignment (astrology) to inform and guide their actions in business, life, and personal relationships.

The trouble with astrology and other primitive accounts of human behavior is that they are not scientifically valid. These theories do not hold up to objective testing, replication, and close scrutinizing by researchers who follow the scientific method. Over the last century, a science-based model of learning and behavior has developed. Behavior theory states that all behavior is due to a complex interaction between genetic influence and environmental experience. The theory is based on observation and controlled experimentation, and it provides a natural-science account of the learning and behavior of organisms, including humans. This book is concerned with such an account.

SCIENCE OF BEHAVIOR

The **experimental analysis of behavior** is a natural-science approach to understanding behavior regulation. Experimental analysis is concerned with controlling and changing the factors that affect the behavior of humans and other animals. For example, a behavioral researcher in a classroom may use a computer to arrange corrective feedback for a student's mathematical performance. The relevant condition manipulated or changed by the experimenter may involve presenting corrective feedback on some days and withholding it on others. In this case, the researcher would probably observe more accurate mathematical performance on days with programmed feedback. This simple experiment illustrates one of the most basic principles of behavior—the principle of **reinforcement**.

The principle of reinforcement (and other behavior principles) provides a scientific account of how people and animals learn complex actions. When a researcher identifies a basic principle that governs behavior, this is called an analysis of behavior. Thus, the experimental analysis of behavior involves specifying the basic processes and principles that regulate the behavior of organisms. Experiments are then used to test the adequacy of the analysis.

NOTE ON: Experimental Analysis of Behavior

Experimental analysis occurs when, for example, a researcher notices that more seagulls fly and congregate along a shoreline when people are on the beach than when the beach is deserted. After checking that changes in climate, temperature, time of day, and other conditions do not affect the behavior of the seagulls, the researcher offers the following analysis: People feed the birds and this reinforces flocking to the beach. When the beach is abandoned, the seagulls are no longer fed for congregating on the shoreline. This is a reasonable guess, but it can only be tested by an experiment. Pretend that the behavior analyst owns the beach and has complete control over it. The experiment involves changing the usual relationship between the presence of people and food. Simply stated, people are not allowed to feed the birds, and food is placed on the beach when people are not around. Over time and repeated days of food with no people, and no food plus people days, the behavior analyst notes that there are fewer and fewer seagulls on the beach when people are present, and more and more gulls when the shoreline is deserted. The behaviorist concludes that people regulated coming to the beach because the birds were fed, or reinforced, for this behavior only when people were present. This is one example of an experimental analysis of behavior.

Behavior Analysis: A Science of Behavior

Experimental analysis is the fundamental method used to establish the principles for a **science of behavior**. Contemporary researchers no longer refer to their science as behavioral psychology, recognizing that psychology is focused on mental or cognitive events rather than on the behavior of organisms. Today, a science of behavior informed by a philosophy of naturalism is called *behavior analysis*. This term implies a more general scientific approach that includes assumptions about how to study behavior, techniques for carrying out the analysis, a systematic body of knowledge, and practical implications for society and culture.

Behavior analysis is a comprehensive, natural-science approach to the study of the behavior of organisms. Primary objectives are the discovery of principles and laws that govern behavior, the extension of these principles across species, and the development of an applied technology for the management of behavior. One behavior principle is called discrimination. The principle of discrimination states that an organism will respond differently to two situations (e.g., predator vs. no predator) if its behavior has been reinforced in one setting but not in the other (*differential reinforcement*). Two assumptions should be noted here. First, behavior is a product of the organism's past and current interactions with the environment, as well as its biological or evolutionary history (primarily coded by the genes). Secondly, the principles (e.g., discrimination) discovered by an experimental analysis have wide generality, applying to all animal life.

The principle of discrimination may be extended to human behavior and social reinforcement. You may discuss dating with Carmen, but not Tracey, because Carmen has shown interest in such conversation while Tracey has not (*differential reinforcement*). In a classroom, the principle of discrimination can be used to improve teaching and learning. A child is given a series of multiplication problems from the 2-times table such as 2 × 4 =_?_. Correct answers result in the next question, while incorrect responses lead to corrective feedback from the teacher, and repetition of the question. In this way, most children learn their 2-times table. The use of behavior principles to solve practical problems is called **applied behavior analysis** and is discussed at some length in Chapter 13.

As you can see, behavior analysis has a strong focus on behavior–environment relationships. The focus is on how organisms alter their behavior to meet the ever-changing demands of the environment. When an organism learns new ways of behaving in reaction to the changes in its environment, this is called *conditioning*. The two basic kinds of conditioning are called respondent and operant.

Two Types of Conditioning

A **reflex** involves **respondent** behavior *elicited* by a biologically relevant stimulus. When a stimulus (S) automatically elicits (→) a stereotypical response (R) or *respondent*, the S → R *relationship* is called a reflex. The reflex is inherited in the sense that those animals that quickly and reliably responded to particular stimuli were more likely than other organisms to survive and reproduce. For instance, animals that startle and run in response to a sudden noise may escape a predator, hence the startle reflex may have provided an adaptive advantage over organisms that did not run, or that ran less quickly in response to the noise. Thus, reflexes are selected across the history of the species. Of course, different species of organisms exhibit different sets of reflexes.

Respondent Conditioning

Respondent conditioning occurs when a feature (or event) of the environment without a known effect on behavior is correlated with an *unconditioned stimulus* (US). The US is a stimulus that *elicits* a response based on an organism's biological history—thus, a puff of air (US) in the eyes elicits blinking (UR or *unconditioned response*) as an inherited response without apparent learning on the part of the organism. Presentation of a light does not elicit eye blinking, and has no stimulus function with respect to the eye-blinking response before conditioning (a non-functional stimulus). However, if the light comes to predict the air puff (US) and control the blink response, we say the light has acquired a *conditioned-stimulus* (CS) function. One method to ensure that a feature of the environment predicts the US is called pairing or *temporal contiguity*; the US closely follows the feature in time. For example, respondent conditioning occurs when the buzz of bees is paired with painful stings (US), but other insect sounds are not. After this conditioning, a buzzing bee (CS) usually causes people to behave so as to escape it; this is the conditioned response (CR) or *respondent*. The Russian physiologist *Ivan Petrovich Pavlov* made explicit this form of conditioning at the turn of the 20th century. He observed that dogs salivated when food was placed in their mouths. This relation between the food stimulus and salivation is an *unconditioned reflex*, and it occurs because of the animals' biological history. However, when Pavlov rang a bell just before feeding the dogs and not on other occasions (discrimination), the animals began to salivate at the sound of the bell. In this way, a new feature (the sound of the bell) that predicted the presentation of food came to control the respondent behavior of salivation. As shown in Figure 1.1, the respondent (CR) is now elicited by the new *conditioned stimulus* (CS).

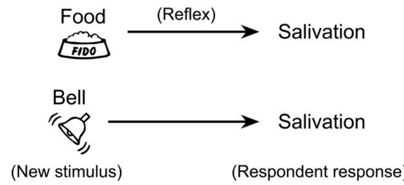

FIG. 1.1 Simple respondent conditioning: In a reflex for a dog, food in the mouth produces salivation as respondent behavior. Next, a bell rings (new stimulus) just before feeding the dog; after several pairings of bell and food the dog begins to salivate at the sound of the bell.

Respondent (classical or Pavlovian) conditioning is one way in which organisms meet the challenge of change in their environments. A grazing animal that conditions to the sound of rustling grass before a predator's attack, but not to grass blowing in the wind, gains a survival advantage. The animal is able to efficiently consume food, running away only when its life is threatened. All species that have been tested, including humans, show this kind of conditioning. In terms of human behavior, many of what we call our likes and dislikes are based on evaluative conditioning. Evaluative conditioning of humans replicates many of the respondent-conditioning effects found in animals, although some differences have been noted (De Houwer, Thomas, & Baeyens, 2001). Generally, when good or bad things happen to us we usually have an emotional reaction. These emotional responses can be conditioned to other people who are present when the positive or negative events occur. Thus, respondent conditioning plays an important role in our social relationships—determining, to a great extent, how we evaluate and come to "feel" about our friends as well as our enemies. Respondent conditioning is covered in more detail in Chapter 3.

Operant Conditioning

Operant conditioning involves the *regulation of behavior by its consequences*. B.F. Skinner called this kind of behavior regulation **operant conditioning** because, in a given situation or setting (S^D), behavior (R) *operates* on the environment to produce effects or consequences (S^r). An **operant** is any behavior that operates on the environment to produce an effect. The effect or consequence in turn changes the likelihood that the operant will occur again in a similar situation. During operant conditioning, an organism emits operant behavior based upon its genetic endowment; the operant produces an effect that increases (or decreases) the frequency of the response in a given situation (Skinner, 1938, p. 20). In the laboratory, a hungry rat in a chamber may receive food if it presses a lever when a light is on. If lever pressing increases in the presence of the light, then operant conditioning has occurred and food functions as *reinforcement* (S^r) for this operant response (Figure 1.2).

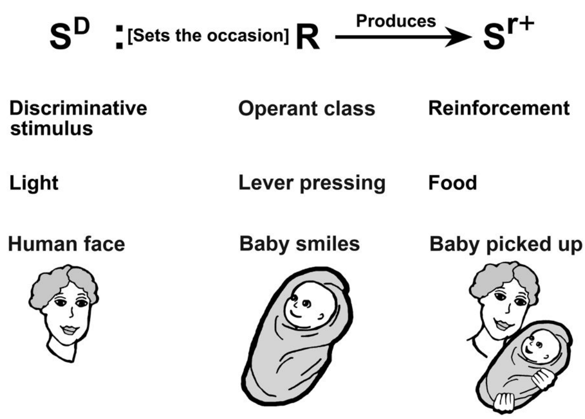

FIG. 1.2 Simple operant conditioning: In an operant chamber, lever pressing produces food for a hungry rat. The consequences of lever pressing (presentation of food) increase its frequency in that setting. In another example, a baby smiles to a human face and is picked up. The consequence of smiling (social attention) increases the frequency of this behavior in the presence of human faces.

In this example, the light (S^D) eventually *sets the occasion for* lever pressing in the sense that *the operant is likely to occur* when the light is on and is unlikely to occur when it is off. Basically, the frequency of lever pressing increases in the presence of the light (S^D). Turning the light on, however, does not force or elicit lever pressing as with a respondent conditioned stimulus; it simply increases the probability of the lever-pressing response when the light is on. The control by the light stimulus is based on the past history of reinforcement for lever pressing in the presence of the light and no reinforcement when it is off.

Most of what we commonly call voluntary, willful, or purposive action is analyzed as operant behavior. *Operant conditioning* occurs, for example, when a baby smiles to a human face and is then picked up. If smiling to faces increases in frequency because of such social attention, then smiling is an operant and the effect is a result of conditioning. The presentation of a human face (S^D) *sets the occasion for* infant smiling only after a history of operant conditioning. When a face appears, the frequency of smiling increases; also, smiling has a low frequency of occurrence when no one is around. In a more complex example using video games, the presence of targets on the screen (S^D) *sets the occasion for* pressing a sequence of buttons (operant) that result in hitting a target (S^r) and increasing the probability of the response sequence. Other examples of operant behavior include driving a car to work to get paid, talking on the phone for fun, taking lecture notes to pass a test, walking to the store to buy groceries, reading a book for pleasure, writing a term paper for grades, or conducting an experiment to resolve a scientific question. In each case, we say the operant is *selected by its consequences*.

Selection as a Causal Process

B. F. Skinner (1938) viewed psychology as the study of the behavior of organisms. From this point of view, psychology is a subfield of biology. The main organizing principle of contemporary biology is evolution through natural selection. Skinner generalized this concept to a broader principle of **selection by consequences**. Selection by consequences applies at three levels: (1) the selection over generations for genes related to survival and reproduction (natural or Darwinian selection); (2) the selection for behavior within the lifetime of an individual organism (selection by operant conditioning); and (3) the selection for behavior patterns (practices, traditions, or rituals) of groups of human beings that endure beyond the lifetime of a single individual (cultural selection). In all three cases, it is the consequences arranged by the environment that select for (or against) the frequency of genetic, behavioral, and cultural forms (see Chapter 14).

Selection by consequences is a form of causal explanation. In science we talk about two kinds of causation: immediate and remote. **Immediate causation** is the kind of mechanism studied by physics and chemistry—the “billiard ball” type of process where we try to isolate a chain of events that directly result in some effect. For example, chemical reactions are explained by describing molecular interactions. In the study of behavior, an immediate causal explanation might refer to the physiology, biochemistry, and genetics of the organism. For example, the bar pressing of a rat for food or a gambler playing roulette could each involve the release of endogenous opiates and dopamine in the hypothalamus (Shizgal & Arvanitogiannis, 2003).

In contrast, **remote causation** is typical of sciences like evolutionary biology, geology, and astronomy. In this case, we explain some phenomenon by pointing to remote events that made it likely. Thus, the causal explanation of a species characteristic (e.g., size, coloration, or exceptional vision) involves the working of natural selection on the gene pool of the parent population. An evolutionary account of species coloration, for example, would involve showing how this characteristic improved the reproductive success of organisms in a given ecological environment. Thus, natural selection for coloration explains the current frequency of the characteristic in the population.

On the behavioral level, the principle of selection by consequences is a form of explanation by remote causation called *functional analysis*. When a rat learns to press a lever for food, we explain the rat's behavior by pointing to its past consequences (the function of behavior). Thus, the current frequency of bar pressing is explained by the **contingency** between bar pressing and food in the past. The rat's behavior has been *selected by its history of reinforcement*. Thus, the history of reinforcement is what explains why the rat presses the lever.

Both immediate and remote causal explanations are acceptable in science. Behavior analysts have emphasized functional analysis and selection by consequences (remote causation), but are also interested in direct analysis of physiological and neurochemical processes (immediate causation). Ultimately, both types of causal explanation will provide a more complete account of learning and behavior.

FOCUS ON: Behavior Analysis and Neuroscience

Behavior analysis is becoming more involved with the scientific analysis of the brain and nervous system or neuroscience (Schlinger, 2015). Researchers who primarily study the behavior of organisms and learning are often interested in the brain processes that participate in the regulation of behavior (Schaal, 2013; see also special issue on "Relation of Behavior and Neuroscience" (2005) in *Journal of the Experimental Analysis of Behavior*, *84*, pp. 305–667). The word *participate* is used because the brain shows **neuroplasticity**, or changes in the interconnections of neurons or nerve cells (Kandel, 2006) and glia or non-neuronal cells (Fields, 2009) as an organism interacts with the world in which it lives—altering gene transmission, gene expression, and neural pathways related to learning and memory (McClung & Nestler, 2008; also see "New Directions: Epigenetics and Retention of Early Learning" in this chapter). The brain is not a static structure that determines behavior, but a malleable organ constantly adjusting to the behavioral requirements of everyday life or the laboratory (Draganski et al., 2004; Schlinger, 2004). For example, brain mechanisms (neurons or groups of neurons) obviously participate in the regulation of behavior (bar pressing) by its consequences (food). Describing how neurons assemble, code for, and respond to stimulation and reinforcement is an important and exciting addition to a behavior analysis (Fiorillo, Tobler, & Schultz, 2003).

Currently, neuroscientists are mapping neurons to behavior in simple organisms like the fruit fly, *Drosophila* (Vogelstein et al., 2014). Flies are genetically engineered to selectively express a light-sensitive protein in defined sets of neurons (1054 neuron lines), which researchers activate with the presentation of light (optogenetic stimulation). Larvae are placed in plastic dishes and light stimulation is applied to the genetically engineered neurons, allowing observation and control of defined behavioral sequences (e.g., "wiggle escape" or "turn-turn-turn"). One finding is that the relation between a specific line of neurons and evoked behavior is probabilistic—repeatedly activating the same neurons did not always produce the identical behavioral sequence; thus, the *topography of response* varies even though the identical brain pathway is activated. The researchers note that optogenetic mapping of neurons to behavior would allow for an atlas of connectivity–activity maps to further investigate how neurons participate in the regulation of complex behavior.

At the practical level, knowing the reinforcement contingencies for lever pressing is sufficient by itself to allow us to predict and control the rat's behavior. We can get the rat to increase or decrease its lever pressing by providing or denying food reinforcement for this behavior—there is no need to look at neural systems. However, we gain a more complete account of how a rat's behavior increases when the action of neurons (and neural systems) is combined with the analysis of behavior. For example, in some cases it may be possible to "sensitize" or "desensitize" a rat to the behavioral contingencies by drugs that activate or block the action of specialized neurons (e.g., Bratcher, Farmer-Dougan, Dougan, Heidenreich, & Garris, 2005). Research at the neural level could, in this way, add to the practical control or regulation of behavior by its consequences.

Neural processes also may participate as immediate consequences (local contingencies) for behavior that had long-range benefits for organisms—remote contingencies, as in evolution and natural selection (Tobler, Fiorillo, & Schultz, 2005). The so-called *neural basis of reward* involves the interrelationship of the endogenous opiate and dopamine systems (as well as other neural processes) in the regulation of behavior and learning (Fiorillo, Tobler, & Schultz, 2003; Puig, Rose, Schmidt, & Freund, 2014). For example, rats that are food restricted and allowed to run in activity wheels increase running over days—up to 20,000 wheel turns. Wheel running leads to the release of neural opiates that reinforce this behavior (Pierce, 2001; Smith & Rasmussen, 2010). If wheel running is viewed as food-related travel, one function of neural reinforcement is to promote locomotion under conditions of food scarcity. The long-range or remote contingency (travel produces food: travel → food) is supported proximally by the release of endogenous opiates (physical activity → release of endogenous opiates) that "keep the rat going" under conditions of food scarcity (e.g., famine or drought).

The integration of the science of behavior with neuroscience (**behavioral neuroscience**) is a growing field of inquiry. Areas of interest include the effects of drugs on behavior (behavioral pharmacology), neural imaging and complex stimulus relations, choice and neural activity, and the brain circuitry of learning and addiction. We shall examine some of this research in subsequent chapters in sections that focus on behavior analysis and neuroscience ("Focus On" sections) or in sections that emphasize applications ("On the Applied Side" sections).

The Evolution of Learning

When organisms were faced with unpredictable and changing environments in their evolutionary past, natural selection favored those individuals whose behavior could be conditioned. Organisms that condition are more flexible, in the sense that they can learn new requirements and relationships in the environment (see section on "Behavioral Flexibility" in Chapter 14 for evidence by Mery and Kawecki (2002) on the link between learning ability and improved fitness in the fruit fly, *Drosophila melanogaster*). Such behavioral flexibility must reflect underlying structural changes of the organism. During embryonic development, genes are sequenced to form the anatomical and physiological characteristics of the individual, allowing for different degrees of functional flexibility (Mukherjee, 2016, pp. 185–199). Thus, differences in the structure of organisms based on genetic control give rise to differences in the regulation of behavior. Processes of learning, like operant and respondent conditioning, lead to greater (or lesser) reproductive success. Presumably, those organisms that changed their behavior as a result of experiences during their lifetimes survived and had offspring (passing on the genome), while those that were less flexible did not. Simply stated, this means that *the capacity for learning is inherited*.

The evolution of learning processes had an important consequence. Behavior that was closely tied to survival and reproduction could be influenced by experience. Specific physiological processes, orchestrated by genes and proteins at the cellular level, typically regulate behavior related to survival and reproduction. However, for behaviorally flexible organisms, this control by physiology may be modified by experiences during the lifetime of the individual. The extent of such modification depends on the amount and scope of behavioral flexibility. For example, sexual behavior is closely tied to reproductive success and is regulated by distinct physiological processes. For many species, sexual behavior is rigidly controlled by genetically driven mechanisms. In humans, however, sexual behavior is also influenced by socially mediated experiences. It is these experiences, not genes, which come to dictate when sexual intercourse occurs, how it is performed, and who can be a sexual partner. Powerful religious or social controls can make people abstain from sex. This example demonstrates that even the biologically relevant behavior of humans is partly determined by life experience.

The Biological Context of Behavior

As we have emphasized, behavior analysts recognize and promote the importance of biology, genes, and evolution, but focus more on the interplay of behavior and environment. To maintain this focus, the evolutionary history and biological status of an organism are examined as part of the *context of behavior* (see Morris, 1988). This contextualist view is seen in B. F. Skinner's analysis of imprinting in a duckling:

> Operant conditioning and natural selection are combined in the so-called imprinting of a newly hatched duckling. In its natural environment the young duckling moves towards its mother and follows her as she moves about. The behavior has obvious survival value. When no duck is present, the duckling behaves in much the same way with respect to other objects. Recently it has been shown that a young duckling will come to approach and follow any moving object, particularly if it is the same size as a duck—for example, a shoebox. Evidently survival is sufficiently well served even if the behavior is not under the control of the specific visual features of a duck. Merely approaching and following is enough.
>
> Even so, that is not a correct statement of what happens. What the duckling inherits is the *capacity to be reinforced by maintaining or reducing the distance between itself and a moving object*. In the natural environment, and in the laboratory in which imprinting is studied, approaching and following have these consequences, but the contingencies can be changed. A mechanical system can be constructed in which movement *toward* an object causes the object to move rapidly away, while movement *away from* the object causes it to come closer. Under these conditions, the duckling will move away from the object rather than approach or follow it. A duckling will learn to peck a spot on the wall if pecking brings the object closer. Only by knowing what and how the duckling learns during its lifetime can we be sure of what it is equipped to do at birth.
>
> (Skinner, 1974, pp. 40–41)

The duckling's biological history, in terms of providing the *capacity for reinforcement* by proximity to a duck-sized object, is the context for the regulation of its behavior. Of course, the anatomy and neurophysiology of the duckling allow for this capacity. The way the environment is arranged during its lifetime, however, determines the behavior of the individual organism on a specific occasion. Laboratory experiments in behavior analysis identify the general principles that govern the behavior of organisms, the specific events that regulate the behavior of different species, and the arrangement of these events during the lifetime of an individual.

NEW DIRECTIONS: Epigenetics and Retention of Early Learning

One discovery that has rocked the scientific world in recent years is that learning experiences (and other environmental factors) can affect gene expression (transcription and translation), resulting in structural and functional changes to the brain and behavior, which may be long lasting (Roth & Sweatt, 2011).

Epigenetics is a branch of biology concerned with heritable, functional changes to the genome that do not involve alterations of the gene itself (sequence of deoxyribonucleic acid, or DNA code). All cells in the body have a nucleus which includes chromatin, a combination of DNA and histone protein in a spool-like structure (see illustration at https://en.wikipedia.org/wiki/Epigenetics#/media/File:Epigenetic_mechanisms.jpg). Biochemical markings of the chromatin control accessibility to genes and gene expression, allowing cells to adapt to an ever-changing environment, beginning with cell differentiation and fetal development in utero and continuing throughout the organism's lifetime. The molecular biology of epigenetic (outside of genetic) processes is beyond the scope of this textbook (see Tammen, Friso, & Choi, 2013 for overview), but the basics can be outlined briefly. There are two primary epigenetic mechanisms called DNA methylation (adding mythyl groups to DNA) and histone modification (e.g., acetylation, adding acetyl groups to histone tails), both of which determine whether "packaged" cellular DNA is available for gene transcription by messenger RNA (mRNA) and subsequent translation by mRNA into proteins. DNA methylation increases the affinity between DNA and histone (alkaline proteins of eukaryotic cell nuclei) "spools," limiting accessibility to the genetic code and silencing the gene transcription machinery; therefore, DNA methylation provides an epigenetic mark (signal) for *gene silencing*. Histone acetylation, in contrast, usually decreases the affinity between histone and DNA, allowing for mRNA transcription and subsequent translation into proteins; thus, histone acetylation is an epigenetic mark for *gene activation*. Thus, an active chromatin structure ("packaged" genes available for activation) allows mRNA access to the genetic material for transcription and subsequent translation into proteins, which in turn control the cell structure and function of the organism—including the cells or neurons in its brain (Day & Sweatt, 2011).

Evidence in rats indicates that epigenetic changes underlie the effects of maternal caretaking of pups on the adult behavior of these offspring (see Roth, 2012). Rodent mothers (dames) differ in the amount of grooming and licking they provide to pups within the first 10 days after birth. Compared to low nurturing mothers, dames that provided high levels of grooming and licking produced adult offspring with lower indicators of physiological stress and less fear responses to a novel environment.

Subsequent research showed that maternal care influenced DNA transcription of the glucocorticoid receptor gene (GR) in the hippocampus (see Roth, 2012). Notably, increased GR gene transcription helps to moderate the animal's neural and behavioral responses to stressful (aversive) situations with higher GR expression linked to less severe stress responses. Thus, adult male rats from high-caregiving dames were shown to have less DNA-methlylation markers (lower silencing of GR gene) and greater histone-acetylation markers (higher transcription of GR gene) in the hippocampus than dames providing lower amounts of grooming and licking of pups after birth. Further research subsequently established causal connections among postnatal maternal caretaking, epigenetic alterations of gene expression, and differences in adult offspring responses to stressful situations.

Non-genetic factors including learning experiences (e.g., conditioning) can result in epigenetic changes by histone acetylation and DNA methylation, which in turn affect brain and behavior via mRNA transcription and mRNA translation to proteins; although still controversial (Francis, 2014), it appears that cell division passes on epigenetic markings over one's lifetime and even from one generation to the next via noncoding mRNAs of sex cells or gametes (Dias & Ressler, 2014; Gapp et al., 2014; see Jablonka & Raz, 2009 for a complete discussion of transgenerational epigenetic inheritance). One implication is that learning sometimes can be transmitted epigenetically from one generation to the next with no change in the genes themselves. Also, in the future, it may be possible to produce lasting reversal of epigenetic changes by targeted early behavioral interventions (as in autism; see Chapter 13) or reverse epigenetic effects in later life by arranging new (re)programmed learning experiences (Tammen et al., 2013). Generally, evolution has provided animals with epigenetic mechanisms that allow for retention of learning experiences (changes in behavior due to the prevailing environmental contingencies) over an organism's lifetime and perhaps beyond.

The Selection of Operant Behavior

Early behaviorists like John B. Watson (1903) used the terminology of stimulus–response (S–R) psychology. From this perspective, stimuli force responses much like meat in a dog's mouth elicits (or forces) salivation. In fact, Watson based his stimulus–response theory of behavior on Pavlov's conditioning experiments. Stimulus–response theories are mechanistic in the sense that an organism is compelled to respond when a stimulus is presented. This is similar to a physical account of the motion of billiard balls. The impact of the cue ball (stimulus) determines the motion and trajectory (response) of the target ball. Although stimulus–response conceptions are useful for analyzing reflexive behavior and other rigid response patterns, the push–pull model is not as useful when applied to voluntary actions or *operants*. To be fair, Watson talked about "habits" in a way that sounds like operant behavior, but he lacked the experimental evidence and vocabulary to distinguish between respondent and operant conditioning.

It was B. F. Skinner (1935) who made the distinction between two types of conditioned reflex, corresponding to the difference between operant and respondent behavior. In 1938, he introduced the term "operant" in his classic book, *The Behavior of Organisms*. Eventually, Skinner rejected the mechanistic (S–R) model of Watson and based operant conditioning on Darwin's principle of selection. The basic idea is that an individual *emits behavior that produces effects or consequences*. Based on these consequences, those performances that are appropriate to the environmental requirements increase, becoming more frequent in the population or class of responses for the situation; at the same time, less appropriate forms of response decline or become extinct. Julie Vargas is the daughter of B. F. Skinner and was a professor of behavior analysis at West Virginia University. She has commented on her father's model of causation:

> Skinner's paradigm is a *selectionist* paradigm not unlike Darwin's selectionist theory of the evolution of species. Where Darwin found an explanation for the evolution of species, Skinner looked for variables functionally related to changes in behavior over the lifetime of an individual. Both explanations assumed variation; Darwin in inherited characteristics, Skinner in individual acts. Skinner, in other words, does not concern himself with why behavior varies, only with how patterns of behavior are drawn out from the variations that already exist. In looking at the functional relationships between acts and their effects on the world, Skinner broke with the S–R, input–output transformation model.
>
> (Vargas, 1990, p. 9)

Skinner recognized that operants are selected by their consequences (behavioral selection). He also noted that operant behavior naturally varies in form and frequency. Even the simple movement of opening the door to your house is not done exactly the same way each time, an observation consistent with recent optogenetic studies of variation of neuron firing in fruit flies (Vogelstein et al., 2014). Pressure on the doorknob, strength of pull, and the hand used change from one occasion to the next. If the door sticks and becomes difficult to open, a more forceful response may eventually occur. This energetic response may succeed in opening the door and become the most likely performance for the situation. Other forms of response may occur at different frequencies depending on how often they succeed in opening the door (reinforcement). Thus, *operants are selected by their consequences*.

Similarly, it is well known that babies produce a variety of sounds called "babbling." These natural variations in sound production are important for language learning. When sounds occur, parents usually react to them. If the infant produces a familiar sound, parents often repeat it more precisely. Unfamiliar sounds are usually ignored. Eventually, the baby begins to produce sounds (we say talk) like other people in their culture or verbal community. Selection of verbal behavior by its social consequences is an important process underlying human communication and language (Skinner, 1957).

Culture and Behavior Analysis

Although much of the basic research in the experimental analysis of behavior is based on laboratory animals, contemporary behavior analysts are increasingly concerned with human behavior. The behavior of people occurs in a social environment. Society and culture refer to aspects of the social environment, the social context, which regulates human conduct. One of the primary tasks of behavior analysis is to show how individual behavior is acquired, maintained, and changed through interaction with others. An additional task is to account for the practices of the group, community, or society that affect an individual's behavior (Lamal, 1997).

Culture is usually defined in terms of the ideas and values of a society. However, behavior analysts define **culture** as all the conditions, events, and stimuli arranged by other people that regulate human action (Glenn, 2004; Skinner, 1953). The principles and laws of behavior analysis provide an account of how culture regulates an individual's behavior. A person in an English-speaking culture learns to speak in accord with the verbal practices of that community. People in the community provide reinforcement for a certain way of speaking. In this manner, a person comes to talk like and share the language of other members of the public and, in doing so, contributes to the perpetuation of the culture. The customs or practices of a culture are therefore maintained through the social conditioning of individual behavior.

Another objective is to account for the evolution of cultural practices. Behavior analysts suggest that the principles of variation and selection by consequences occur at the biological, behavioral and cultural levels (Wilson, Hayes, Biglan, & Embry, 2014). Thus, cultural practices increase (or decrease) based on consequences produced in the past. A cultural practice of making containers to hold water is an advantage to the group because it allows for the transportation and storage of water. This practice may include using shells or hollow leaves, or making fired-clay containers. The cultural form selected (e.g., clay jars) is the one that proves most efficient and least costly. In other words, the community values and uses those containers that last the longest, hold the most, and are easily stored. People manufacture and use clay pots, while production and use of less efficient containers declines.

Behavior analysts are interested in cultural evolution because cultural changes alter the social conditioning of individual behavior. Analysis of cultural evolution suggests how the social environment is arranged and rearranged to support specific forms of human behavior. On a more practical level, behavior analysts suggest that the solution to many social problems requires a technology of cultural design. B.F. Skinner addressed this possibility in his utopian book, *Walden Two* (Skinner, 1948a). Although this idealistic novel was written more than six decades ago, contemporary behavior analysts have conducted small-scale social experiments based on Skinner's ideas (Komar, 1983). Behavioral technology also has been used to manage environmental pollution, encourage energy conservation, and regulate overpopulation (Bostow, 2011; Lehman & Geller, 2004; Wilson, Hayes, Biglan, & Embry, 2014).

FOCUS ON: Burrhus Frederic Skinner

B.F. Skinner (1904–1990) was the intellectual force behind behavior analysis. He was born and named Burrhus Frederic Skinner on 20 March 1904 in Susquehanna, Pennsylvania. When he was a boy, Skinner spent much of his time exploring the countryside with his younger brother. He had a passion for English literature and mechanical inventions. His hobbies included writing stories and designing perpetual-motion machines. He wanted to be a novelist, and went to Hamilton College in Clinton, New York, where he graduated with a degree in English. After graduation in 1926, Skinner reported that he was not a great writer because he had nothing to say. He began reading about behaviorism, a new intellectual movement at that time, and as a result went to Harvard in 1928 to learn more about a science of behavior. He earned his master's degree in 1930 and his PhD the following year.

Skinner (Figure 1.3) began writing about the behavior of organisms in the 1930s, when the discipline was in its infancy, and he continued to publish papers until his death in 1990. During his long career, he wrote about and researched topics ranging from utopian societies to the philosophy of science, teaching machines, pigeons that controlled the direction of missiles, air cribs for infants, and techniques for improving education. Some people considered him a genius, while others were critical of his theory of behavior.

Skinner was always a controversial figure. He proposed a natural-science approach to human behavior. According to Skinner, the behavior of organisms, including humans, was determined by observable and measurable processes. Although common sense suggests that we do things because of our feelings, thoughts, and intentions, Skinner stated that behavior resulted from genetic endowment and environment. This position bothered many people who believed that humans have some degree of self-determination and free will. Even though he was constantly confronted with arguments against his position, Skinner maintained that the scientific facts required the rejection of feelings, thoughts, and intentions as *causes* of behavior. He said that these internal (private) events were not explanations of behavior; rather these events were additional activities of people that needed to be explained:

FIG. 1.3 B. F. Skinner.
Source: Reprinted with permission from the B. F. Skinner Foundation.

> The practice of looking inside the organism for an explanation of behavior has tended to obscure the variables which are immediately available for a scientific analysis. These variables lie outside the organism in its immediate environment and in its environmental history. They have a physical status to which the usual techniques of science are adapted, and they make it possible to explain behavior as other subjects