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Eighth Edition | Active Learning Edition

Learning and Behavior

Paul Chance
Ellen Furlong

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***Learning and Behavior*, Eighth Edition**

Paul Chance/Ellen Furlong

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Art Director and Cover Designer: Felicia Bennett

Cover Image: FatCamera/E+/Getty Images

Library of Congress Control Number: 2021923934

ISBN: 978-0-357-65811-6

Cengage
200 Pier 4 Boulevard
Boston, MA 02210
USA

Printed in the United States of America
Print Number: 01 Print Year: 2022

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Preface

A textbook is like a city: It is never finished. Go into any city and you see old buildings being torn down and new ones being built, people planting trees in vacant lots, jackhammers tearing up streets to install phone lines underground. The same holds true of textbooks: Some topics disappear, new ones get added, chapters or sections move from here to there. Here are some of the changes you'll find in *Learning and Behavior*, Eighth Edition:

- The addition of Learning Objectives for each chapter and each section within each chapter.
- Revisions to promote inclusion and diversity, including both language updates and an increase in coverage of research by underrepresented scholars and those outside of the United States.
- Updated scholarship. The reference list includes over 100 new items.
- Removed Recommended Readings at the end of the chapter, and instead, incorporated more thorough explanations or more relevant examples within the narrative reading itself.
- An increase in the number and variety of illustrations, including photographs and sketches.
- Additional boxes to provide context, highlight underrepresented scholars, and address the replication crisis.
- Enhanced explanations and examples for some of the more difficult topics.
- Revisions throughout to transition from passive to active voice to follow the APA style guide.

Although cities are constantly being "revised," some things remain the same for decades. The same is true of texts. The following key features of *Learning and Behavior* remain essentially unchanged:

- A readable style and a cordial tone that help make reading the text a welcome activity rather than a tedious chore, so that students get more out of their class sessions.
- Certain themes continue to run through the text: that learning is a biological mechanism (we call it evolved modifiability) by which individuals cope with change; that changes in behavior arise from biological and environmental events; and that the natural science approach offers the best way to study behavior.

- An abundance of examples and applications to help students "get" the principles, not merely memorize them.
- Though many of the experiments involve animal subjects, we emphasize what that research tells us about *human* behavior.
- Chapter 2 reviews the basic research methods used to study learning, including the single-subject designs that are unfamiliar to many students.
- Concept Checks appear at irregular intervals throughout the narrative to help keep students alert and to help them monitor their progress.
- Review Questions appear at the end of each chapter *without* answers. We believe the absence of answers prompts students to think about and discuss the questions and may result in interesting class discussions.
- A Practice Quiz (answers for the practice quiz can be found in the instructor's manual) at the end of each chapter allows students to check their comprehension and gauge their mastery of the concepts.
- Data graphs represent findings in an easy-to-grasp form.

We hope you will find that this is the best edition yet of *Learning and Behavior*, but we're already making notes for the next edition. As we said, textbooks, like cities, are never really finished.

Instructor Resources

Additional instructor resources for this product are available online. Instructor assets include an Instructor's Manual, PowerPoint® slides, and a test bank powered by Cognero®. Sign up or sign in at **www.cengage.com** to search for and access this product and its online resources.

Acknowledgments

As always, many people contributed to the "renovation" of this book throughout the years. We are grateful to the team at Cengage Learning, Lumina Datamatics, and other vendor partners who had a hand in producing the eighth edition of *Learning and Behavior*. We'd also like to thank several instructors who reviewed prior editions and suggested changes that were, as always, a great help. Thanks to:

Kim Andersen, Brigham Young University—Idaho
Shawn R. Charlton, University of Central Arkansas
W. Matthew Collins, Nova Southeastern University
Joanne Hash Converse, Rutgers, the State University of New Jersey
Runae Edwards-Wilson, Kean University
Yoshito Kawahara, San Diego Mesa College
Dennis K. Miller, University of Missouri
H. D. Schlinger, California State University—Los Angeles
David Widman, Juniata College

Other instructors and researchers who offered helpful comments or provided articles, images, or raw data throughout editions include Willem-Paul Brinkman, Delft University of Technology; Adam Doughty, College of Charleston; Robert Epstein, American Institute for Behavioral Research and Technology; Susan Friedman, Utah State University; Chad Galuska, College of Charleston; Bryan Gibson, Central Michigan University; Reese Halter, Global Forest Science; David Harrison, Bay Cove Human Services in Boston; William Heward, Ohio State University; Lydia Hopper, Georgia State University; Todd Huspeni, University of Wisconsin at Stevens Point; Marianne Jackson, California State University in Fresno; Kent Johnson, Morningside Academy, Seattle; Munsoo Kim, Chonnam National University, South Korea; Nobuo Masataka, Kyoto University, Japan; Koichi Ono, Komazawa University, Japan; David Palmer, Smith College; Thomas Parish, formerly of Kansas State University; James Pfister, Poisonous Plant Research Lab, Utah; Alan Poling, Western Michigan University; Albert Rizzo, University of Southern California; Erica Bree Rosenblum, now at the University of California at Berkeley; Barbara Rothbaum, Emory University; Carolyn Rovee-Collier, Rutgers University; Kurt Salzinger, Hofstra University; Stephen Scherer, San Diego Community College; Susan Schneider, University of the Pacific , Stockton; Satoru Shimamune, Hosei University, Japan; Edwin Taub, University of Alabama; and Andrew Whiten, University of St. Andrews, Scotland. We owe a special thanks to H. D. ("Hank") Schlinger, long a fan of *Learning and Behavior*. Finally, we want to thank the students who have taken the time to share their thoughts, positive or negative, about *Learning and Behavior*.

As you can see, we are indebted to a lot of people, and we're sure there are still more who deserve to be on this list. Our apologies to you if you are among them. All of you, named and unnamed, have contributed in one way or another to *Learning and Behavior*, Eighth Edition.

Paul Chance and Ellen Furlong

About the Authors

Paul Chance

Dr. Paul Chance received his Ph.D. in psychology from Utah State University. In addition to teaching at Salisbury University in Maryland, Dr. Chance has served as an adjunct instructor at the California Polytechnic State University in San Luis Obispo. He started his career as a schoolteacher, teaching grades 7–9, before moving to the college level. Dr. Chance has also worked as Book Review Editor for *Psychology Today* magazine. He is a senior fellow of the Cambridge Center for Behavioral Studies and a member of the Association for Science in Autism Treatment advisory board.

Ellen Furlong

Dr. Ellen Furlong earned her Ph.D. in psychology at the Ohio State University. An animal cognition scholar and animal welfare advocate, Dr. Furlong is the author of several scholarly and popular press articles on animal cognition and behavior. Her research focuses on evolutionary origins of human and animal cognition, origins of decision-making, and number cognition. She joined the faculty at Illinois Wesleyan University (IWU) in 2013 where she teaches courses on animal behavior, perception, cognition, and research methods. She also directs the IWU Dog Scientists, a research group that explores cognition in dogs and zoo animals.

Dedication

We dedicate this book to our families, as well as our colleagues and students, who enrich the world.

Ellen, especially, dedicates this book to her beloved dog and constant companion, Cleo, who taught Ellen more about behavior change (that is, how Cleo changed Ellen's behavior, not the other way around) than she learned from Skinner or Pavlov.

Note to the Student: How to Get the Most from This Book

There's a lot to learn about learning. Here are some suggestions on how to get the most from this book:

- First, turn to Chapter 12 and study the section called "Learning to Remember." This information will help you learn any course content.
- Second, be sure to read the "Preview" and "In This Chapter . . ." sections at the start of each chapter. This material will help you understand where the chapter is headed.
- Third, as you read through the text, answer the Concept Checks that appear. Write your answer on a slip of paper or say it aloud, then check your answer by reviewing the text preceding it.
- Fourth, after you've read a chapter, read the Review Questions and consider how you would answer them if you were asked those questions in class or on an exam. This is a great thing to do in a study group, since many of these questions can be answered in various ways.
- Fifth, take the Practice Quiz provided at the end of the chapter. Be sure to *write* your answers as you would if you were taking a quiz in class, or say them to a study partner. These quizzes will help you learn the content and give you a rough idea of how well you have mastered it.

If you really want to get the most from a text or a course, you have to be an active learner. If you want to get the most out of a class, you can't just sit back and listen to the instructor. You have to actively involve yourself—ask questions, make comments, take notes. The same thing holds when learning from a text: Ask questions, answer concept checks, make notes, think about the implications and applications of what you read, discuss what you read with other students, and review, review, review. If you are an active learner, you will not only have a far better chance of acing the exams, you will be able to put more of what you learn to practical use for years to come.

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Chapter 1 Introduction: Learning to Change

In this chapter . . .

"Change is the only constant."

—Lucretius

Preview

This chapter raises basic questions about the adaptation of humans and other living things—at the individual and the species level—to a changing environment. You'll notice that this chapter devotes a good deal of space to topics usually covered in biology texts. Why? Because *learning is a biological mechanism*. Your ability to learn did not evolve so that you could learn to solve algebra problems or program a computer. Learning is first and foremost a survival mechanism, a means of meeting ever-present challenges that threaten our ability to survive and thrive. I hope you will consider as you read this book whether human learning ability is up to the challenges that we face today.

Learning Objectives

After studying this chapter, you will be able to . . .

- **1-1** Explain how natural selection helps species cope with change.
- **1-2** Explain how natural selection produces adaptive behavior in the form of reflexes, modal action patterns, and general behavioral traits.
- **1-3** Describe the limits of natural selection.
- **1-4** Explain why learning can be defined in relation to behavior change.
- **1-5** Describe how habituation is an example of learning.
- **1-6** Explain why the nature–nurture debate oversimplifies the origins of behavior.

1-1 Natural Selection

Learning Objectives

To explain how natural selection helps species cope with change, you can . . .

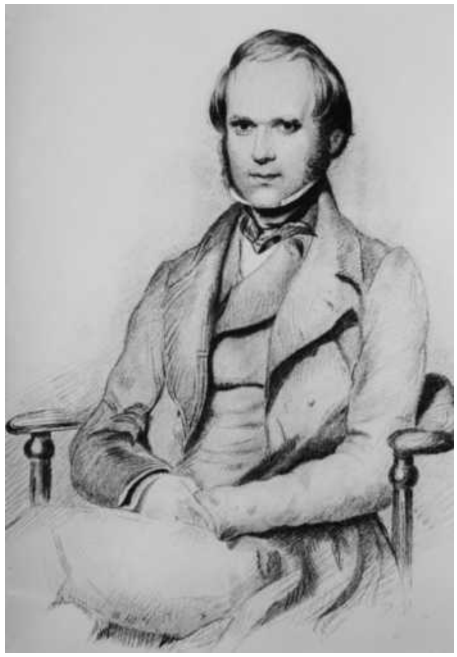
- **1-1-1** Describe how Darwin came to study natural history.
- **1-1-2** Explain how Darwin's experience with breeding animals contributed to his theory of evolution.
- **1-1-3** Explain how Malthus's work influenced Darwin's theory of evolution.
- **1-1-4** Compare natural and artificial selection.
- **1-1-5** Explain the importance of inheritance and variability for natural selection.
- **1-1-6** Describe how natural selection can account for complex structures such as the human eye and brain.
- **1-1-7** Give three examples as to how natural selection has helped animals (including humans) cope with environmental changes.
- **1-1-8** Explain how disease can drive natural selection.
- **1-1-9** Give an example of how natural selection can change behavior.

As the Roman philosopher Lucretius said 2,000 years ago, "Change is the only constant." Change is not the exception to the rule; it *is* the rule. Throughout nature, the struggle to survive boils down to an effort to cope with change: The climate changes; prey animals become harder to see; predators become faster; diseases strike without warning; and population increases put added stress on the availability of food, water, habitable space, and other resources. Some changes, such as the movement of continents, take place over eons; others, such as the advance or retreat of glaciers, normally take hundreds or thousands of years; some, such as the changes in climate due to human use of fossil fuels, take decades; still others, such as the rise and fall of the sun or the abrupt lane change of an aggressive driver, occur on a daily basis. Change remains the one constant in our lives. Any individual or species must cope with change to survive. But how? By what mechanisms can we and other animals deal with such a fickle world? Charles Darwin offers one answer.

Charles Darwin was born in England in 1809. The son of a physician, Darwin attended the University of Edinburgh in 1825 to study medicine. He did not love medicine, however, and when the blood and screams of a patient undergoing surgery without anesthesia sent him scurrying to the exit, Darwin decided to pursue a degree in theology at Cambridge University. He didn't love theology either, and he spent much of his time pursuing his true love: natural history.

Shortly after graduating from Cambridge, Darwin accepted an offer to join an expedition on the British naval vessel HMS *Beagle* as the ship's naturalist. The leader of the *Beagle*, Captain Robert FitzRoy, a 23-year-old aristocrat, sought a naturalist who would also serve as a suitable dinner companion. The voyage's chief purpose, to map the shorelines of land areas around the world, proved a great success. However, its current fame arises from the fact that it gave Darwin the opportunity to gather hundreds of specimens of plants and animals in his effort to understand "that mystery of mysteries," the origin of species.

Darwin took a copy of Charles Lyell's *Principles of Geology* with him on the *Beagle*. Lyell, considered by many the father of geology, got many things wrong (he rejected the idea of ice ages, for example), but his view that the earth changes gradually over eons gave Darwin a new perspective on where species came from. If the earth had been around for millions of years and changed slowly, as Lyell argued, why think that the vast variety of life forms had appeared overnight in their current form?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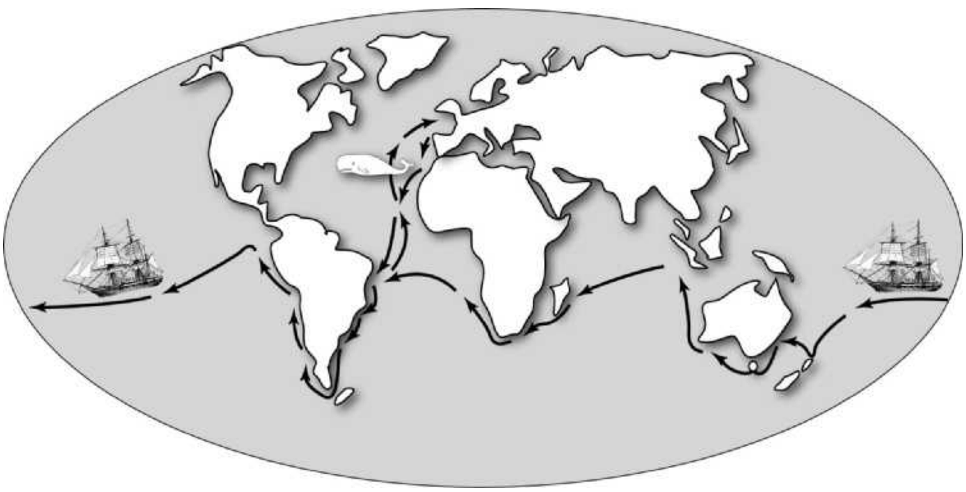
Portrait of Charles Darwin in the late 1830s when he was about 30 years old.

Once back in England, Darwin focused his attention on animal breeding as a source of insights into the variations in living things. He bred doves and knew that breeders like him had long changed the characteristics of cows, horses, pigs, sheep, chickens, dogs, cats, and other domestic animals by selectively cross-breeding individuals with desirable characteristics. Such breeding seemed to provide a model for changes in species in the wild, but unlike species changes in the wild, it resulted from deliberate, thoughtful intervention by the breeder. Who was nature's breeder?



The course of HMS *Beagle*. The *Beagle* left Plymouth, England, on December 27, 1831, and returned on October 2, 1836.

Work on selective breeding in foxes over a period of several decades shows that selective breeding can result in changes to behavioral characteristics such that the descendants behave more like a different species—domestic dogs—than like their own ancestors. Refer to Dugatkin and Trut (2017) for a nontechnical summary.

The answer occurred to Darwin when he read a book by a fellow Englishman, Thomas Malthus (1798): *An Essay on the Principle of Population*. Malthus, a clergyman, did not accept the then-popular idea that human population growth led to utopia. On the contrary, Malthus argued that such population growth would lead to ruin. With limited resources, an expanding population eventually spells disaster. As populations increase, these resources prove inadequate to supply all individuals. "The power of population," he wrote, "is indefinitely greater than the power in the earth to produce subsistence for man."

Malthus focused on the effects of human population growth, but Darwin realized that all species of animals and plants produce far more offspring than the environment can possibly support, inevitably leading to competition for resources. Some survive and reproduce, but most do not. What determines which individuals and species will win out? Clearly the "winners" must have features that provide an advantage. Those of their offspring that share their parents' advantage will tend to survive and reproduce. Over generations, these advantages, some of them very subtle, may accumulate, resulting in very different species. Darwin saw a parallel between the mechanism for this change and the breeder's practice of selectively mating animals with desirable characteristics. However, in the wild, *nature is the breeder*:

> Owing to this struggle for life, any variation, however slight and from whatever cause proceeding, if it be in any degree profitable to an individual of any species, . . . will tend to the preservation of that individual, and will generally be inherited by its offspring. The offspring, also, will thus have a better chance of surviving. . . . I have called this principle, by which each slight variation, if useful, is preserved, by the term of Natural Selection, in order to mark its relation to man's power of selection.

In writing "its relation to man's power of selection," Darwin draws attention to the analogy of **natural selection** to the **artificial selection** of breeders. "There is no obvious reason," he wrote, "why the principles which have acted so efficiently under domestication should not have acted under nature."

In Darwin's day, scholars knew little about how characteristics transmitted from one generation to the next. As Darwin noted, "The laws governing inheritance are quite unknown. . . ." The Austrian friar and founder of genetics, Gregor Mendel, did not publish his work on inheritance in peas until 1866, 17 years after Darwin published his famous book *On the Origin of Species*. Mendel's work did not become widely known among scientists until after Darwin's death. Nevertheless, Darwin argued that characteristics—whether beneficial, detrimental, or neutral in a particular environment—somehow passed from one generation to another.

Importantly, natural selection depends on variations among the members of a species. If all members of a species shared identical genes, natural selection would have nothing to act on. As Darwin wrote, "Unless profitable variations do occur, natural selection can do nothing."

Very few biologists question natural selection today, and many people throughout Europe accept it as well. However, a Gallup poll found that four in ten Americans still believe that God created all forms of life in their present form about 10,000 years ago (Brenan, 2019).

To see how the increasing complexity of the eye improves vision, go to youtube.com and search "Dawkins eye."

Darwin's critics have often said that even with variation, natural selection cannot possibly account for the sudden appearance of complex organs such as the human eye. Darwin agreed. But he went on to say that complex organs do not normally appear suddenly. Far from it.

Evidence suggests that the human eye, for example, had its origin millions of years ago with the appearance of a few light-sensitive cells on the skin of some primitive animals. These light-sensitive cells would have proved helpful because anything that cast a shadow on them could, for example, warn of an approaching predator. Through additional variations and natural selection, more light cells appeared, and the light-detecting organ became more and more complicated until it gradually reached the sophisticated light-sensitive organ found in many animals, including humans (Lamb, 2011; Schwab, 2011).

This may appear as pure speculation, because we have no videotape of the evolution of the eye. However, in general, evidence suggests increasing sophistication of organs, including the eye, as we go through the animal kingdom from the simplest to the more complex species. Consider, for example, the trematode *cercaria*, a parasitic flatworm that invades killifish brains (Lafferty & Morris, 1996). Cercaria has two spots that, though they may look a bit like eyes, share nothing at all with any mammalian eye (refer to Figure 1-1). The eye contains no iris, no retina, no vitreous humor, nothing, really, except light-sensitive cells that appear something like the cells forming the retina of your more sophisticated eyes. The cercaria's eyespots help it to find its way to a higher water level where the killifish on which it depends spend time. As you explore more complex creatures, you can see increasingly complex visual equipment. You may expect the human eye to represent the most complexity, but you would be mistaken. The eye of a mantis shrimp, for example, has 16 color receptors to our 3. It also responds to polarized light, which helps the shrimp locate empty burrows to call home (Gagnon et al., 2015).

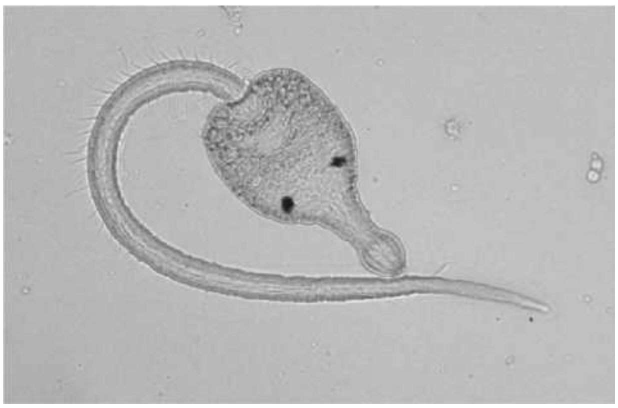


Figure 1-1 The flatworm cercaria with two light-sensitive eye spots. (Image courtesy of Todd C. Huspeni, Curator of Parasites, Department of Biology and Museum of Natural History, University of Wisconsin—Stevens Point.)

The human brain also did not appear overnight. The jellyfish has a simple network of neurons, but this primitive nervous system, which serves to coordinate its swimming movements, has no brain at all. The first true brains appear in worms. Earthworms have brains about the size of a mustard seed, but they provide an advance over the jellyfish. And primates—monkeys and apes (including humans!)—have developed yet more complex brains with greater capacity for dealing with environmental changes.

The devices resulting from natural selection are rarely, if ever, as simple and efficient as possible, but they generally work well enough to aid survival and reproduction (Marcus, 2009; Olshansky, 2009). Natural selection does not have a goal, and it typically takes countless generations for sophisticated features to develop. Nevertheless, natural selection helps species meet the challenges of a changing environment.

All kinds of changes in the environment can affect the characteristics of a species. Climate change perhaps serves as the most important of these environmental changes, a point made by Darwin (1859). The west coast of Scotland has famously cold winters, and its native Soay sheep have notoriously warm wool. Until recently the Soay sheep tended toward the large side, as smaller sheep often succumbed to the cold before reaching reproductive age. Over the past few decades, however, the sheep of this area have shrunk: They have become increasingly smaller and lighter (Maloney, Fuller, & Mitchell, 2010; Ozgul et al., 2009). This reduction in size parallels a change in climate due to global warming: Winters in Scotland have become shorter and milder in recent decades, so smaller sheep can now survive and reproduce.

Changes in terrain (due to a change in the course of a river or volcanic eruption, for example) can also induce changes in species through natural selection. Evolutionary biologist Erica Rosenblum and her colleagues at the University of Idaho (Rosenblum et al., 2010) studied three species of lizards in White Sands, New Mexico. All three species have dark skins in other geographic areas, but those in White Sands, an area with dunes composed of white gypsum, have developed lighter skins (Figure 1-2). The lizards evolved in areas where their dark skin made them difficult for predators to see, but when they moved into the white dunes, those dark skins made them vulnerable to predators. Lizards with lighter skins survived and reproduced, while lizards with darker skin succumbed to predators. This selection process continued over generations until the lizards in the dunes had turned far lighter than their ancestors.

Pollution provides another example of how changes in the environment affect species characteristics. The peppered moth, one of many large moths found in the British Isles, provides the classic example. The peppered moth feeds at night and rests during the day on the trunks and limbs of trees. Its survival depends in large part on its ability to escape detection by the birds that find it appetizing. At one time, nearly all these moths had a mottled light gray color, closely resembling the lichen-covered trees on which they rested. A rare black variation of the moth, first observed in 1848, stood out

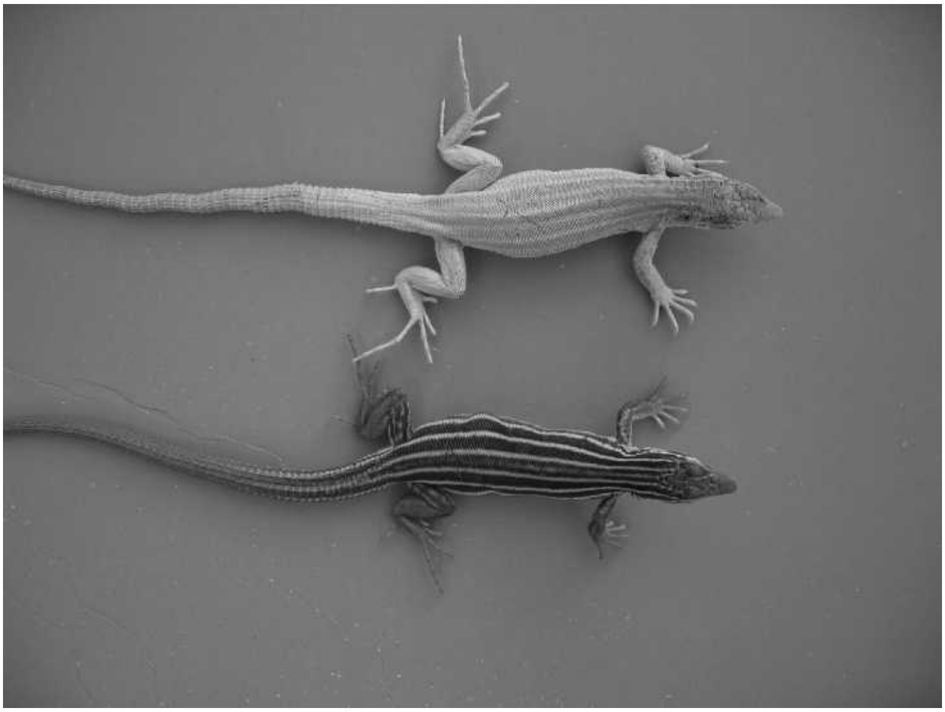


Figure 1-2 The natural selection of skin color. Descendants of lizards that were dark skinned elsewhere (bottom photo) became light in color when living among white sand dunes in New Mexico. (Photo courtesy of Erica Bree Rosenblum, Department of Biological Sciences, University of Idaho at Moscow.)

against this background like coal against snow, making it highly vulnerable to predation. But when pollutants from burning coal killed the lichen and darkened the bark of trees, the light-colored moths increasingly fell prey to birds, whereas the dark moths tended to survive and reproduce. In forests with higher pollution rates (those near industrial centers), the black moths increased in number, and the light-colored variety declined. In some areas, 90% of the moths now had the once-rare black coloration (Kettlewell, 1959; refer to Figure 1-3). Improvement in local air quality has reversed this trend so that the lighter variety of moth once again dominates the population.

Predators also serve as an important part of most animals' surroundings, and changes in predators play an important role in natural selection. Swanne Gordon of the University of California at Riverside and her colleagues (Gordon et al., 2009) demonstrated this with guppies. Gordon and her team moved wild guppies in Trinidad from a stream with no predators to a stream with guppy-eating fish. Eight years later, Gordon transferred more guppies from the safer stream and compared the survival rate of their young with the young of guppies that had lived among the predators for many generations. The evolved guppies had a survival rate more than 50% higher than that of the newcomers.

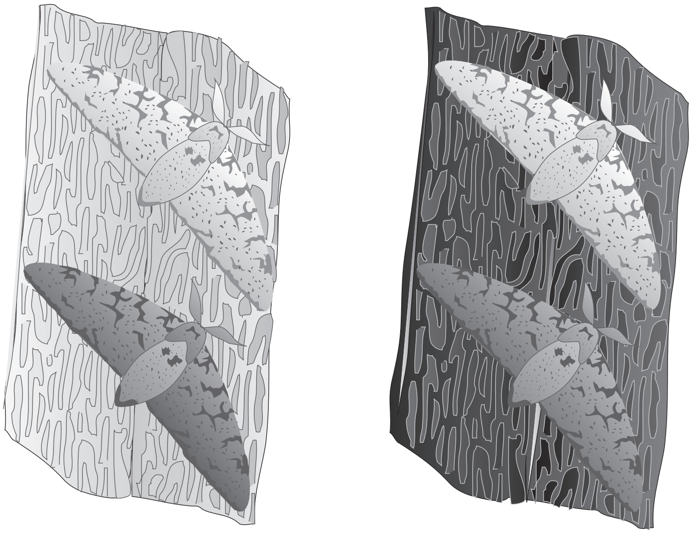


Figure 1-3 The peppered moth and pollution. Prior to 1850, the gray peppered moth was hard to detect against the light trees on which it rested. After soot darkened the trees, the once-rare black variety became dominant. (Drawings by Diane Chance.)

Changes in the environment also affect human characteristics. The amount of melanin, a substance found in the skin that screens out the sun's harmful rays, largely determines human skin color. The more melanin, the darker the skin and the more sunlight it screens out. People native to Scandinavia and northern Europe, locations with scarce sunlight, typically have fair skin, a trait that allows them to absorb the sunlight they need to produce vitamin D. People native to locations near the equator, with abundant sunlight, typically have dark skin, a trait that protects them against the hazards of too much sun. Through natural selection, the human species acquires the coloration required for survival in a given environment.

Many surprising changes occur due to natural selection as well. New diseases can result in widespread deaths, as happened with the bubonic plague that killed a third or more of the people living in Europe in the 14th century. A bacterium causes the disease, but garbage caused the epidemic: People routinely threw garbage into the streets, rats fed on the garbage, and the fleas on the rats infected people with the plague bacteria. Despite the high mortality rate of bubonic disease, some people proved genetically resistant or immune to the disease. Those who carried this trait passed some form of resistance on to their children. Future generations no doubt found such traits helpful in subsequent epidemics of the same disease, which killed significantly fewer people. Interestingly, some argue this same genetic variation protects some people from the HIV virus that causes AIDS.

Today health professionals worry a great deal about global epidemics. The bacterium that causes bubonic plague still lives and thrives, as do any number of other microorganisms that pose a threat of pandemics. As we witnessed with the COVID-19 pandemic, increases in international travel and trade bring vectors (carriers of disease-causing organisms) into ports around the world (Khanh et al., 2020). When pandemics occur, those individuals who have genetic features that convey resistance or immunity will survive and pass on their advantage to their offspring. The descendants of survivors may appear no different from those who died, but they will have slight differences, thanks to natural selection.

These examples illustrate how changes in the environment induce changes in species through natural selection. They also suggest that if a species' surroundings do not change dramatically, the species itself may not change its characteristics. We can observe this, for example, in the American alligator, a creature that has scarcely changed in 200 million years. The alligator is ideally suited to its habitat, the ponds and wetlands of the American Southeast, particularly the states of Louisiana and Florida, where approximately 5 million of them thrive today. The alligator's territory has shrunk drastically over the millennia, but otherwise changed little. Once a species adapts well to a consistent environment, a rule seems to develop: *no change in the environment, no change in the species*.

When we think of the changes produced by natural selection, we usually think of physical characteristics, such as size, shape, and color. In fact, the same pressures that select a physical feature, such as wings, can also select a behavior, such as wing flapping. For example, partridge tend to spend the bulk of their time on the ground, flying into trees only when in danger. In many instances, they actually run up trees while flapping their wings. Biologist Kenneth Dial (reported in Wong, 2002) found that wing flapping while running up trees assists the partridge in escaping predators. Even partridge chicks with immature wings have an easier time reaching the branches as a result of flapping their stubby wings. Chicks that flap their wings when attempting to climb trees escape predators more than those that don't, so natural selection will likely select this behavioral tendency just as it will select the form of the wings.

Natural selection generally results in three kinds of behaviors. What are these kinds of behavior? Let's find out.

Section **Review**

Charles Darwin was obsessed over the origin of the various life forms. People had changed the characteristics of domestic animals for thousands of years through selective breeding, and it occurred to Darwin that nature might do much the same thing. Natural selection, he argued, helps species adapt to change over generations. Sophisticated organs do not appear abruptly but over countless generations; evidence suggests that the human eye, for example, began as light-sensitive cells in primitive organisms. Natural selection changes not only physical characteristics but certain kinds of behavior as well.

1-2 Evolved Behavior

Learning Objectives

To explain how natural selection produces adaptive behavior in the form of reflexes, modal action patterns, and general behavioral traits, you can . . .

- **1-2-1** Compare and contrast characteristics of reflexes, modal action patterns, and general behavioral traits.
- **1-2-2** Describe the role of reflexes, modal action patterns, and general behavioral traits in aiding survival.
- **1-2-3** Provide three examples each of reflexes, modal action patterns, and general behavioral traits.
- **1-2-4** Explain why it is difficult to know whether humans exhibit modal action patterns.
- **1-2-5** Explain how natural selection can produce general behavioral traits.

Natural selection produces a repertoire of largely innate, adaptive forms of behavior that help organisms cope with the demands of their particular environment. The behavior falls into three categories: reflexes, modal action patterns, and general behavior traits.

Reflexes

A **reflex** is a relationship between a specific event (a stimulus) and a simple response to that event. A reflex is not, as many often think, only behavior. Rather, it includes a *relationship* between certain kinds of events, usually events in the immediate surroundings, and relatively simple forms of behavior (refer to Figure 1-4). For example, you tend to blink when a speck of dirt hits your eye. The eyeblink alone is not the reflex; the reflex requires the relation between the speck of dirt and the movement of your eyelid.

Some reflexes can occur immediately after birth, while others appear at predictable stages in development. Virtually all members of a species share their reflexes, as reflexes come packaged as part of the adaptive equipment of the animal. All animals, from protozoa to college professors, have reflexes.

Many reflexes serve to protect the individual from injury. The amoeba, an irregularly shaped, single-celled animal that travels by extending a part of its perimeter forward and then pulling the rest along after, provides a good example. When the amoeba encounters a noxious substance, it immediately withdraws from it; this reflex minimizes the harmful effects of the substance. Larger animals do much the same thing when they withdraw a limb from a painful object. The chef who picks up a very hot skillet will immediately release it and withdraw the injured hand. Other protective reflexes in humans include the pupillary reflex, in which the iris contracts or relaxes in response to changes in light; the sneeze, by which the nose and lungs expel irritants such as dust and pollen; and the vomit reflex, which removes toxic substances from the stomach in an efficient, if indelicate, manner.

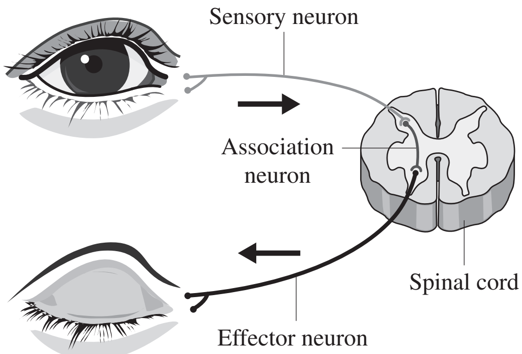


Figure 1-4 The reflex arc. In a typical reflex, an event excites sensory neurons that carry an impulse to the spinal cord, where the impulse is transmitted to an interneuron, which in turn transmits the impulse to effector neurons. The effector neurons carry the impulse to muscle tissues or glands, which then produce a simple response. (Drawing by Gary Dale Davis.)

Concept Check 1: Why would you be incorrect if you said that a reflex is behavior alone?

Other reflexes aid food consumption. When an amoeba encounters some edible object, such as a dead bacterium, it immediately responds to the object by engulfing it and making a meal of it. Humans have a number of such consummatory reflexes: Touch a baby's face, and they will turn toward what touched them; this rooting reflex helps the baby find the mother's nipple. When the nipple touches the baby's lips, this evokes the sucking reflex, which brings milk into the baby's mouth. Food in the mouth elicits the salivary reflex, the flow of saliva that begins the process of digestion. The presence of saliva and food in the mouth triggers swallowing. Swallowing triggers peristalsis, the rhythmic motion of the lining of the esophagus that carries food to the stomach. Thus, you can think of the simple act of eating as, in large measure, a chain of reflexes.

We tend not to notice useful reflexes until they fail to function properly. People who have consumed excessive amounts of alcohol or other drugs that depress the central nervous system may experience reflex failure. Death from alcoholic intoxication can occur, for example, when the alcohol interferes with the respiratory reflex (inhaling and exhaling) or when the intoxicated person vomits inadequately and chokes to death on the vomit. Fortunately, most of us remain blissfully unaware that we even have reflexes until one of them malfunctions.

Reflexes manifest in highly stereotypic ways; in other words, they remain remarkably consistent in form, frequency, strength, and time of appearance during development. However, they do still vary in a number of ways. The rooting reflex mentioned previously may first appear in one infant at the age of seven days but may not show up in a second infant for another week. A tap below the knee may produce a barely detectable knee jerk in one person, whereas in another person of the same age and similar health, the same light blow may result in a kick that looks like an attempt to make a field goal. Reflexes also change across the life span. Motor reflexes tend to slow with age, which may partially explain why people in their seventies fall more often than people in their thirties.

Modal Action Patterns

Modal action pattern (MAP), a series of related acts found in all or nearly all members of a species (Tinbergen, 1951), provides another kind of naturally selected behavior. Scholars used to term these behaviors *instincts*, but this term fell out of favor, partly because it came to refer to any more or less automatic act (as in, "Angel *instinctively* slammed on the brakes"). Other terms seen in the literature include *fixed action patterns* and *species-specific behavior*.

MAPs resemble reflexes in that they have a strong genetic basis; display relatively little variability from individual to individual or from day to day in the same individual; and often become activated by a particular kind of event, called a **releaser**. MAPs differ from reflexes in three ways: First, they involve the entire organism rather than a few muscles or glands; second, they often consist of long series of reflex-like acts; and third, they demonstrate more variability than reflexes, though still remaining rather stereotypic.

Because of their complexity and their utility, many MAPs appear at first glance as thoughtful acts. However, in fact, they probably require no more thought than a person who responds to a tap on the knee by jerking their leg. If you have spent much time around dogs, you may be familiar with one form of MAP: Dogs often spin around and around in a circle before lying down to take a nap (Rapoport, 2014).

The tropical army ant provides an illustration of the unthinking nature of MAPs. Entire colonies of these ants charge across the forests in what appears as a highly organized, intelligently directed campaign. However, the ants merely follow a chemical trail laid down by the ants ahead of them. T. C. Schneirla (1944) demonstrated that on a flat surface, such as a road, where no obstacles direct the course of the march, the lead ants tend to move toward the ants beside them. The column then turns in on itself, and the ants soon march round and round in a circle. This is not very intelligent behavior.

Concept Check 2: How do MAPs differ from reflexes?

Various scholars (e.g., Carr, 1967; Dawkins, 1995; Skinner, 1966, 1975, 1984) have suggested that gradual changes in the environment have selected some MAPs. Consider, for example, salmon that migrate upstream to breed. This act often requires the fish to ascend steep cliffs and swim against rushing currents. At one time, returning to the breeding area might have constituted a relatively easy swim up a gently rising stream. As geological changes gradually increased the steepness of the slope, those fish with the ability to make the trip bred successfully and reproduced their kind, whereas those not up to the challenge failed to reproduce. It seems likely that other environmental pressures have shaped MAPs (such as migration and mating rituals) in much the same way.

MAPs evolve through natural selection because they contribute to the survival of the species. They do this chiefly by helping the individual find food, deal with threats to their safety, or pass their genes on to the next generation. The pine bark beetle burrows into pine trees to find a meal. Some spiders spin webs with which they capture prey, while others conceal themselves, wait for an unsuspecting meal to pass by, and pounce on it. The buck moth caterpillar climbs deciduous trees, particularly oaks, to feed on the leaves. Pigs root for worms, larvae, and truffles beneath the ground. Woodpeckers peck on trees to get at the insects that feed there, while the yellow-billed cuckoo and other birds feed on the caterpillars that feed on leaves.

Food gathering can account for some apparently pointless aggressive behavior. For example, the cuckoo lays its eggs in the nest of a smaller species, a wren. The cuckoo chick hatches a little earlier than the wren chicks do, and it uses that time to push the wren eggs out of the nest. If the wren eggs hatch first, the cuckoo will push the smaller wren chicks from the nest. The wren parents end up providing meals to a single chick more than twice their own size.

Many MAPs serve to protect the individual from environmental threats, such as predators. The rattlesnake shakes its rattle when approached by an animal, such as a hiker, that may harm it. When confronted by a threatening dog, the house cat arches its back, hisses, growls, and flicks its tail. These acts make the cat appear larger and more formidable than reality and may therefore serve to put off an attacker. The opossum responds quite differently to predators: It plays dead. Some of the opossum's predators eat only animals that they themselves have killed; others will cover a dead animal they find and return to eat it later, so a "dead" opossum has a chance of surviving. The beaver avoids predators by building a dam and then a lodge with an underwater entrance. It packs mud on top of the lodge, which adds to the difficulty of getting at the beaver: Predators must tear at the roof of the lodge if they hope to catch the beaver.

Seasonal changes pose another kind of threat. Bears eat voraciously from spring to fall, thereby adding layers of fat. Then they seek shelter in a cave or in a cavity under a rock or fallen trees. There they spend most of the winter in a state of torpor. They do not eat, drink, or eliminate wastes. A study of black bears in Alaska found that their metabolic rate fell by 75%, thus drastically reducing their consumption of calories (Tøien et al., 2011). This enables the bears to live off the calories they stored as fat during the warmer months. Many birds and some mammals deal with cold by migrating to a warmer area in the fall. The Canada goose flies from its nesting grounds in the north to the much more temperate climate in the mid-Atlantic region.

Some of the most interesting MAPs have to do with reproduction. The male bowerbird attracts a female by creating elaborate artistic structures. The male bighorn sheep wins a partner by bashing its head against that of its rival. The genital area of certain female primates becomes swollen and red when she can become impregnated, and through MAPs, she displays these features to a potential partner, nonverbally saying, "I'm available!"

MAPs also govern the care and rearing of the young. After mating, the female of a certain species of wasp builds a nest, places a paralyzed spider in it, lays an egg on top of the spider, closes the nest, and goes on its way, leaving the young wasp to fend for itself after it eats its first meal. The newborn of many complex species of animals require nurturing, for which task natural selection has genetically equipped their parents. Most birds feed their young at least until they leave the nest. When the adult robin arrives at the nest, the chicks chirp loudly and then open their beaks wide; the parent responds to the gaping mouths by regurgitating a mix of worms and insects it has eaten. As the chicks get older, the parent shoves undigested bits of prey between their gaping beaks.

Do human beings have MAPs? The answer proves complex. Darwin (1874) wrote of the instincts of self-preservation, lust, and vengeance, among others, in humans. Over a century ago, textbooks listed dozens of human instincts, including the sex instinct, the social instinct, the maternal instinct, and the territorial instinct (refer to, e.g., McDougall, 1908). But the list of human instincts has grown shorter over the years because the strict definition of MAPs does not apply neatly to human behavior. Today, many researchers maintain that people show no true MAPs and that the "instincts" previously attributed to them lack the monotonous character of web spinning in spiders and nest building in birds. For instance, for thousands of years, people around the planet obtained food mainly by hunting and gathering. Many people think that men typically did the hunting and women typically did the gathering. But the hunting and gathering took different forms in different regions and at different times, and the gender roles displayed a great deal of variability. And today people obtain their food from a store more often than they do by shooting deer or digging up roots.

Similarly, among humans, the method of finding a sexual partner varies tremendously from culture to culture, from individual to individual, and even within the same individual from time to time. Humans have invented marriage, dating apps, singles bars, speed dating, and all sorts of rules and customs for defining how, when, where, and with whom sexual acts may be performed. The complexity and variability of mating rituals among humans differ dramatically from the stereotypic mating behavior of many other animals.

We can make the same sort of case against the so-called parental instinct. True, many people do desire to have children and to protect and nurture them. But parents show great variation in performing these tasks. In some societies, parents hold and coddle young children constantly, meeting their slightest need immediately; in others, parents encourage more independence, leaving children largely to their own resources. Moreover, parents in Western societies increasingly delay or forgo the traditional parental role altogether. We cannot so readily discard true MAPs.

We observe evidence, then, of few, if any, MAPs in humans. We can identify the role of genetics in behavior, however, in both nonhumans and humans in the form of general behavior traits.

General Behavior Traits

Over the past few decades, a great deal of research has focused on the role of genes in determining what I will refer to here as **general behavior traits**. By this I mean the tendency to engage in a certain kind of behavior. Examples include the tendency toward shyness (or boldness), aggression (or passivity), adventurousness (or cautiousness), anxiety (or relaxedness), and thoughtfulness (or impulsiveness).

Scholars once classified some behavioral traits as MAPs, but they differ from the latter in important ways. As noted previously, MAPs activate in response to fairly specific kinds of environmental events, called releasers. The gaping mouth of a fledgling induces the parent bird to provide food; a closed beak does not have this effect. Behavior traits, on the other hand, occur in a wide variety of situations. For instance, under certain circumstances, unpleasant experiences will reliably produce aggressive behavior in many animals, including people (Berkowitz, 1983; Ulrich & Azrin, 1962). But *unpleasant experience* covers a lot of territory. It can include, among other things, an electric shock, a pinprick, a spray of cold water, a threatening stare, an insult, an air temperature above 90 degrees, and so on. All can increase the likelihood of aggressive behavior. MAPs do not respond to so many different kinds of events.

Another difference between MAPs and behavior traits concerns the plasticity (flexibility) of the behavior. Compare the MAP of the web-spinning spider with the aggressiveness of a shocked rat. Each web-spinning spider spins a web with a specific pattern, and it goes about the task with a remarkable sameness. Moreover, the web spinning of one spider looks remarkably like that of other members of the same species (Savory, 1974). But the rat that attacks its neighbor does so in a far less stereotypic manner, and there may be considerable difference between the attack of one rat and that of another of the same species.

Behavior traits display more variability than MAPs, but heredity certainly plays an important role in them. Selective breeding has, for example, produced strains of animals differing in fearfulness (Hall, 1951; Marks, 1986; refer to Figure 1-5); excitability (Viggiano et al., 2002); aggressiveness (Dierick & Greenspan, 2006); activity level (Garland et al., 2011); drug abuse (Matson & Grahame, 2011); and risk-taking (Jonas et al., 2010), among others.

Today, researchers can use genetic engineering to demonstrate the role of genes in behavior traits. Gleb Shumyatsky, a geneticist at Rutgers University, and his colleagues (Shumyatsky et al., 2005) bred a line of mice without a

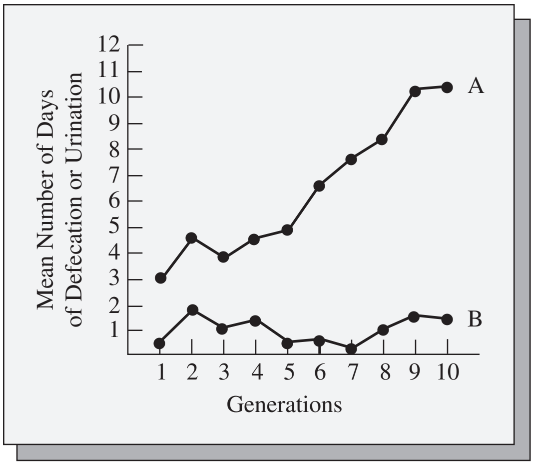


Figure 1-5 Fearfulness and heredity. A researcher put rats in an open enclosure and then bred the most fearful (as measured by urination and defecation) with one another (A) and the least fearful with one another (B). The graph shows the changes over ten generations. (Compiled from data in Hall, 1951.)

particular gene. Although these mice looked and generally behaved normally, the missing gene had a profound effect on one kind of behavior. Typically mice placed on an unfamiliar white surface display caution. The engineered mice, however, displayed boldness: They spent twice as much time exploring the area as the ordinary mice.

Genes also play a significant role in the behavior traits of people. We cannot ethically use selective breeding and genetic engineering with humans, but twin studies and studies of specific genes serve researchers well. Researchers have shown that, as in other animals, genes play an important role in fearfulness (Hettema et al., 2003); excitability (Pellicciari et al., 2009); aggressiveness (Rhee & Waldman, 2002); activity level (Perusse et al., 1989); drug abuse (Li & Burmeister, 2009; Nielsen et al., 2008); and risk-taking (Kuhnen & Chiao, 2009). If this list of traits sounds familiar, it is because you encountered them mentioned earlier as characteristics that researchers have bred in animals. Genes influence all sorts of other human characteristics (e.g., Knafo et al., 2008; Kreek et al., 2005).

You can easily tell how some behavior traits can contribute to survival. The rabbit that flees a fox may escape and go on to create more rabbits, whereas the rabbit that stands its ground becomes fox food. But if rabbits must compete with other rabbits for food, the more aggressive ones likely fare better. So the desirable level of aggressive tendencies in rabbits will depend on the kind of threat they face. In an area with many foxes, the running rabbits will prevail; in an area with few foxes but lots of rabbits competing for food, the more aggressive rabbits will dominate.

We can undoubtedly say the same of people. For example, some people tend to act bold and adventurous, while others act cautious and reserved.

Hunting gazelle with a spear requires walking into the grassy area where the gazelle feed and lions prowl. Those people who lead the way will most likely secure food for themselves and their group, but they put themselves most at risk of falling victim to lions. The more cautious people risk going hungry, but hungry people have more chances to reproduce than people whom lions have eaten. Even today we need people who "boldly go where no one has gone before," but we also need people who agree that there is "no place like home."

Thanks to genetic variation and natural selection, then, adaptive forms of behavior (reflexes, MAPs, and general behavior traits) spread throughout a species and help it survive. As the environment changes, new adaptive forms of behavior appear and old ones that no longer serve an adaptive purpose often fade. Natural selection produces both physical and behavioral characteristics suited to a changing environment, but it has its limits.

Section Review

Natural selection produces three categories of behavior:

1. Reflexive behaviors show simple responses to a specific event. Examples include eye blinking in response to a puff of air in the eye and withdrawing a hand when it touches something hot.
2. MAPs, formerly called instincts, offer more complexity than reflexes, but like reflexes, they remain very stereotypical. Examples include the nest building of birds and the torpor of bears.
3. General behavior traits have a strong genetic component. Examples include shyness, general anxiety, and compulsivity. Natural selection produces physical and behavioral characteristics that can help a species survive. However, it has its limitations.

1-3 Limits of Natural Selection

Learning Objectives

To describe the limits of natural selection, you can . . .

- **1-3-1** Give two examples of how rapid changes in the environment led to extinction in animals.
- **1-3-2** Describe why natural selection will likely not effectively protect people from the effects of pandemics.
- **1-3-3** Give two examples of how past environments have shaped behavior that is no longer adaptive.
- **1-3-4** Describe the role of mutations and hybridization in natural selection.

Natural selection has a chief problem when it comes to coping with change: time. It takes generations for significant change to occur.

Consider Gordon's study of guppies put into a stream with new predators. The guppies adapted, but it took between 13 and 26 generations. Guppies reproduce quickly, reaching sexual maturity between two and five months and gestating their young for a few weeks, so those generations occurred over only eight years. Other species take longer to reach sexual maturity and have longer gestational periods, which makes adaptation through natural selection even slower. Humans, for example, reach sexual maturity in their teens, and gestation takes nine months. The typical generation time for humans is about 20 to 30 years. For us to get the kind of adaptive changes seen in Gordon's guppies would likely take, at a minimum, somewhere between 200 and 400 years.

Natural selection, therefore, has limits in coping with abrupt changes. Hawaii, "the extinction capital of the world," provides an apt example. When Captain Cook stumbled onto the Hawaiian Islands in 1778, they teemed with a great variety of wildlife. Unfortunately, Cook's arrival and that of other early visitors brought rats. Other invasive species followed, including cats, dogs, and snakes. Some indigenous animals on the islands had little or no defenses against these new predators. In the approximately 250 years since Cook's arrival, close to 200 species of animals that once thrived on the islands have become extinct.

The passenger pigeon provides another example of how rapid changes in the environment can lead to extinction. These North American birds, which resembled their cousin, the mourning dove, once numbered in the millions. Sometimes their flocks included so many animals that they blocked the sun and turned day into twilight. But natural selection could not help the passenger pigeon against the shotgun and unregulated hunting. The last passenger pigeon died in 1914.

Concept Check 3: Why can it be a problem for a species that natural selection is slow to act?

Infectious disease represents one rapid change that threatens humans. As mentioned earlier, the bubonic plague killed millions of Europeans in the 14th century, the flu pandemic of 1918 killed 27 million worldwide, and more recently, the COVID-19 pandemic killed over 2.5 million people in its first year. Pandemics of similar magnitude will likely occur again (IPBES, 2020). The Ebola virus, for instance, has no effective treatment; almost inevitably ends in a horrible death; and proves highly contagious. The disease originated in and is currently limited to Africa, but during a major outbreak in 2014, several people infected with the disease arrived in the United States. In the age of the jet plane, tourism, and imports and exports, chances increase that viruses such as Ebola and novel coronaviruses will continue to threaten people on every continent during this century. Natural selection likely will not work quickly enough to prevent massive casualties from highly infectious and deadly diseases.

In 2009, an influenza virus spread around the globe. We did not have vaccines in time to block its spread. Had the virus been more lethal, the result would have been catastrophic (Peiris, Poon, & Guan, 2012).

Further, adaptations that served a species for thousands or even millions of years can turn useless almost overnight. Lee Cronk (1992) provides several examples of this phenomenon in a delightful article called "Old Dogs, Old Tricks." "Behavioral and physical adaptations that seem to make no sense in an organism's current environment," Cronk writes, "can be traced to the legacy of an earlier, different environment in which those traits were favored" (p. 13). He cites the example of the rabbit that dodges back and forth when pursued by foxes, bobcats, and coyotes. This practice still helps them elude these predators but proves less effective when the rabbit finds itself on a highway "pursued" by a truck. Similarly, Cronk notes, armadillos befuddled approaching predators for thousands of years by springing into the air. Once again, however, this behavior no longer serves an adaptive purpose on modern highways. As Cronk puts it, "Leap two feet high in front of a Buick, and you're buzzard bait" (p. 13).

Concept Check **4:**

Natural selection may not help an individual to survive environmental changes; who or what does it help to adapt to change?

Human beings also have become hostages to their genetic history. B. F. Skinner (1984) notes that humans evolved in a world scarce in salt and sugar. Those individuals who had a natural preference for these foods likely sought out the sodium and the calories needed for survival. We have, as a consequence, evolved into a species with strong preferences for both salty and sweet foods. But our world has changed: Industrialized societies have salt and sugar in abundance, and many of us consume far too much of them, endangering our health in the process. Now, heart disease, stroke, and diabetes, the diseases of civilization, kill many. In fact, we could consider these diseases of natural selection.

Sometimes abrupt changes in genes, known as **mutations**, appear, and although most of them do not help in the struggle for survival, occasionally they prove useful. When the mutation provides a significant advantage, it may "sweep" through the population and could conceivably ensure the survival of the species. However, we definitely cannot count on having desirable mutations sweep through the population (Hernandez et al., 2011).

Hybridization, the cross-breeding of closely related species, can sometimes aid species adaptation—but only if the species are closely related enough to produce viable offspring. For example, coyotes and gray wolves have interbred to create a hybrid—the coywolf—that shares characteristics of both a coyote and a wolf (Mech et al., 2014). Your ancestors (and hence, you) may have profited from such hybridization: From 1% to 4% of the genes of people of European and Asian descent are those of *Homo neanderthalensis*, a species distinct from *Homo sapiens* (Carroll, 2010; Finlayson, 2010; Wong, 2000). Matings across species should increase the variability of genes in the next generation and thereby lead to useful adaptations, but hybrid animals often cannot reproduce, so it remains uncertain whether hybridization could speed up the adaptive process.

Some genes even "jump" from one area of a chromosome to another, changing the influence the genes would otherwise have (Gage & Muotri, 2012). Like mutations and hybridization, this might increase the variability of features, including behavioral characteristics. Often these "jumps" do not lead to beneficial changes, but even if they do, it takes multiple generations for natural selection to take advantage of them.

It seems clear that natural selection does not respond well to rapid change. We need a characteristic that allows organisms to change, not over many generations but *within the lifetime of the individual*. Fortunately, such a mechanism has evolved. I like to think of it as evolved modifiability, but most people call it learning.

Section **Review**

The chief problem with natural selection is speed: Natural selection typically takes place over many generations, risking that the species will become extinct before adaptive changes appear. Abrupt changes in the environment, such as invasive species, new diseases, pollution, and changes in terrain, may not allow time for natural selection to work. Mutations and naturally occurring hybridization may help, but organisms really need a mechanism for coping with change during the lifetime of the individual.

1-4 Learning: Evolved Modifiability

Learning Objectives

To explain why learning can be defined in relation to behavior change, you can . . .

- **1-4-1** Explain why learning is simply defined as a change in behavior.
- **1-4-2** Define behavior.
- **1-4-3** Compare behavior, thinking, and feelings.
- **1-4-4** Explain why equating learning with neurological changes in the brain that arise from experience proves problematic.
- **1-4-5** Give three examples of stimuli.
- **1-4-6** Explain why not all changes in behavior arise from learning.

Learning has been defined in countless ways, but learning researchers often define it as *a change in behavior due to experience*. As you will soon learn, this means *a change in behavior due to a change in the environment*. This deceptively simple definition deserves careful examination.

Learning Means Change

Consider the word *change*. Why should we consider learning a change in behavior? Why not say, for example, that learning means the acquisition of behavior?

The word *change* proves more accurate than *acquisition* because learning does not always involve acquiring something, but it does always involve some sort of change. Ari would like to *quit* smoking; Idris wants to *stop* biting their nails; and Alex and Blake would like to quarrel *less often*. All these reductions in behavior, if they occur, provide examples of learning without acquiring something—at least, not in the ordinary sense of that word. Learning means a change in some aspect of behavior such as its frequency, intensity, speed, or form (refer to Chapter 2).

Some authorities (e.g., Kimble, 1961) insist that only *durable* changes qualify as learning, but as no one has reached consensus about what *durable* means (a few milliseconds? a second? a minute? a week? a year?), adding durability to the definition does not seem to help. Besides, why should we require durability? If you see your doctor because you had a severe pain in your chest that lasted six seconds, will your doctor say, "Six seconds? Oh, then it didn't happen."? They might say not to worry, but they aren't going to say it didn't happen. If an astronomer sees a star explode and disappear in three seconds, will other astronomers say, "Forget it. If it didn't last for at least a minute it didn't happen."? The key issue in learning is whether a change in behavior occurred, not how long it lasted. The fact that you no longer remember all the math you learned in high school doesn't mean that you didn't learn it.

Behavior Changes

Behavior changes when learning occurs. We can define **behavior** as *anything measurable a person or other animal does* (Moore, 2011; Reber, 1995; Skinner, 1938). Actually, anything an animal does might qualify as behavior, whether measurable or not, but for scientific analysis, we limit ourselves to those behaviors that we can measure (Baum, 2011).

The concept of behavior seems simple enough, but it can get fuzzy when you examine it closely (e.g., refer to Angier, 2009). Does a heartbeat count as behavior? What about a single neuron firing? How about the secretion of adrenaline into the bloodstream? Probably most people think of these as physiology, not behavior. But we can measure these actions, so they qualify as behavior. You may have heard that dogs can learn to salivate at the sound of a bell. Physiologists typically study salivation, the secretion of saliva by a gland, but the dog produces the saliva and researchers can measure the amount of saliva, so it qualifies as behavior.

People think, so does thinking qualify as behavior? Most people would probably say "No," arguing that behavior involves physical movement, whereas thoughts involve internal mental gymnastics. We usually define the word *mental* as *of the mind*, which implies that thoughts exist in a different dimension from the physical world (Descartes, 1637, 1641). That takes thoughts out of the reach of science. However, people (and presumably some animals) do think, so *if we can measure thinking*, it qualifies as behavior.

Psychologists devise many techniques for measuring thinking, and we will discuss several of them in the upcoming chapters.

The chief difference between thinking and other forms of behavior comes to this: One occurs privately, and the other occurs publicly. Evidence suggests that we can consider much of what we call thinking as simply covert behavior. In other words, what we do "in our head" is often merely a more subtle form of public behavior. For example, we can speak to others, or we can "think out loud" (express thoughts vocally), or we can engage in "inner speech" (Huang, Carr, & Cao, 2001; Schlinger, 2009; Watson, 1920). People with schizophrenia often hear voices, for example, but research suggests that these voices actually belong to them—they talk to themselves silently or softly (Lindsley, 1963; McGuigan, 1966; Slade, 1974; Stephane, Barton, & Boutros, 2001). Similarly, people who are deaf and who use sign language often seem to think with their fingers—signing subtly as they wrestle with a problem (Max, 1937; Watson, 1920).

Neurological evidence supports the idea that we can think of our covert speech as essentially a diminutive form of speech. In one experiment, researchers found that a kind of magnetic stimulation of an area of the brain involved in language interfered with both overt and covert speech (Aziz-Zadeh, Cattaneo, & Rizzolatti, 2005). If thinking and overt speech draw from entirely different systems, it seems unlikely that stimulation that interferes with one would interfere with the other. Similarly, when the neuroanatomist Jill Bolte Taylor (2008) had a severe stroke, she lost the ability to speak both to others *and to herself*. We unwittingly acknowledge the shared nature of overt and covert speech when someone asks us what we are mumbling and we reply, "Oh, I was just thinking out loud."

Will we one day be able to "listen in" on another person's thoughts by recording brain activity and translating it into words? We have good reason to believe so [refer to Martin et al., 2016]).

What about unconscious thoughts—do they count as behavior? No, but they do not count as thoughts either. The phrase *unconscious thoughts* presents an oxymoron. True, your brain routinely engages in activities outside of your awareness, and some of these activities may affect your behavior (your covert and overt speech, for example). But so do your salivary glands, stomach, liver, intestines, and bone marrow; would you call the unconscious activities of these organs thoughts?

Thoughts and overt behaviors differ. In particular, they often have different effects. If I'm in a stuffy room, I can open a window and let in fresh air; *thinking* about opening a window will not have that effect. (Neither will talking about it.) Similarly, thinking that someone is acting idiotically may not have the same consequences as calling someone an idiot. But these differences in effect do not justify assigning thoughts to a fundamentally different and mysterious realm. The effects of publicly performed behavior also can have different consequences. Angrily shouting names at someone, for example, will have different effects than laughingly saying the same words in good humor, and those laughing words will have different effects than inaudible speech—that is, thoughts.

People often erroneously assume that feelings, like thoughts, do not qualify as behavior. Emotions, after all, act as part of our response to events around us and sometimes in us—toothaches do not feel good, for example. Like thoughts, feelings pose special problems because much of what we call feelings are not normally publicly observable. However, feelings tend to "spill out" from the body in the form of readily observed behavior. When you feel happy, you often have a smile on your face; when you feel sad, you may frown and perhaps shed tears; when you have a toothache, you may moan and hold your jaw. We can also "look in on" a person's feelings by recording physiological activities reliably correlated with expressed feelings. A person who reports feeling angry likely has an increased heart rate and blood pressure; a person feeling fear likely has an increase in electrical conductivity of their skin; a person in love likely has an increase in activity in the reward system of their brain when they see their loved one.

Some people might argue that we should define learning as a change in the nervous system that makes a change in behavior possible. In this view, behavior change merely serves as an indicator of learning. Researchers have made great progress in recent years in our understanding of how learning experiences change the brain (e.g., Cohen et al., 2012; Holy, 2012; Kandel, 1970, 2007). No learning researcher denies that learning involves a change in the nervous system, but at least two problems occur with equating learning with neurological changes.

First, we still have much to learn about the biological mechanisms involved in learning. No one can point to changes in a rat's brain and say, "This animal can run a maze better today than it did yesterday." Nor can anyone point to features of a person's brain and say, "This person can play the piano." Advances in technology use the brain to predict learning, but such work remains very preliminary (Cetron et al., 2019). At present, change in behavior remains the only reliable measure of learning.

Second, defining learning as neurological change denies the importance of behavior. Understanding how experience changes the nervous system serves important functions. But even if we could say, solely on the basis of physiological measures, "This rat can run a maze better today than it did yesterday" or "This person can play the piano," the changes in behavior would remain paramount. When we go to a concert, we go to hear the pianist play, not to watch their neurons fire.

Thus, as it relates to learning, behavior is literally "where it's at." The changes in behavior do not *result* from learning; they *are* learning. They *result* from experience.

Concept Check **5:** What is behavior?

Experience Changes Behavior

Our definition says that learning arises from experience. **Experience** means changes in the environment, so our definition of learning could modify to *a change in behavior due to changes in the environment*. These changes in the environment affect, or could affect, behavior. We call such events **stimuli**.

Stimuli are physical changes in an organism's environment: the changes in air pressure we call sound, the light waves we call sights, and the tactile pressures we call touch. The delicate fragrance of a rose derives from just so many molecules of "rose matter" arising from the flower. We can even describe the gentle caress and softly whispered words of a lover as, in scientific terms, merely physical events. Stimuli often have significance beyond their physical properties (the fragrance of a rose may remind us of a friend), but their physical properties define them.

Often researchers studying learning keep stimuli very simple such as a lightbulb coming on or going off or a buzzer sounding, but this does not mean that all experiences that change behavior remain simple. Researchers typically define experience in terms of simple events to untangle the problem under study.

In most studies of learning, the stimuli investigated occur outside the person or the animal. However, physical events occur inside the body as well, and they, too, can affect behavior. We tend to define these internal events in terms of sensations—the pain of a toothache or the nausea of an upset stomach—but these sensations, like those from stimuli outside the body, have a physical basis. The toothache may occur due to an inflamed root; the nausea may occur due to spoiled meat in the stomach.

This point raises an interesting philosophical question: Does the physical event affect behavior, or does the sensation produced by the physical event affect behavior? Some people cannot experience pain, so if they pick up a hot skillet, they may not immediately release it and consequently will burn their hand. Similarly, a person who is deaf does not respond to the sound of a telephone or the warning sound of a car horn. This question, like most philosophical issues, remains complicated and difficult to resolve. For practical reasons, however, scientists generally focus on readily observable physical features rather than perceptual features.

We saw earlier that changes due to natural selection generally arise from changes in the environment. As a rule, no change in the environment results in no change in the species. A parallel rule of thumb applies to learning: *no change in the environment, no change in behavior*.

Not all changes in behavior, even those resulting from changes in the environment, qualify as learning, however. A physician may give an emotionally distraught patient a tranquilizer, but we do not then say that the patient learned to behave calmly. A usually agreeable person may, following a head injury, become very argumentative. If this change in behavior occurs due to brain damage, we do not say that they *learned* to become quarrelsome. Changes in behavior due to drugs, injury, aging, or disease do not qualify as learning.

We might say much more about the meaning of learning, but perhaps you now have a better understanding of why here we define it as a change in behavior due to experience. To illustrate this definition, let's take a brief look at arguably the simplest example of learning, habituation.

Concept Check **6:** What is a stimulus?

Section **Review**

Learning, change in behavior due to experience, encompasses more than acquisition; it simply means that some feature of a given behavior changes. Behavior includes anything measurable that a person or other animal does. Experience produces these changes in behavior—in other words, changes in the environment lead to changes in behavior. As a general rule of thumb, no change in the environment means no change in behavior. So two forces contribute to behavior: natural selection, which modifies characteristics of the species, including behavior, and learning, which modifies the behavior of the individual.

1-5 Habituation: An Example of Learning

Learning Objectives

To describe how habituation is an example of learning, you can . . .

1-5-1 Define habituation.
1-5-2 Describe how habituation aids survival.

Habituation is a reduction in the intensity or probability of a reflex response as a result of repeatedly evoking the response. Researchers have demonstrated many versions of habituation. Seth Sharpless and Herbert Jasper (1956), for example, noted the effects of loud noises on cats by recording their brain waves on an electroencephalograph (EEG). The EEG showed strong reaction at first, but the reaction declined steadily with each repetition of a given sound until the noise had hardly any effect. Wagner Bridger (1961) studied habituation in infants and found that when babies first heard a noise, their heart rate increased. With repetition of the noise at regular intervals, however, the change in heart rate became less and less pronounced until, in some cases, the noise did not affect heart rate at all. Even human fetuses demonstrate habituation. A stimulus to the mother's abdomen during the last three months of pregnancy will produce movement in the fetus. If the stimulus occurs repeatedly in a regular way, the fetal response becomes steadily weaker (Leader, 1995). Plotting the course of

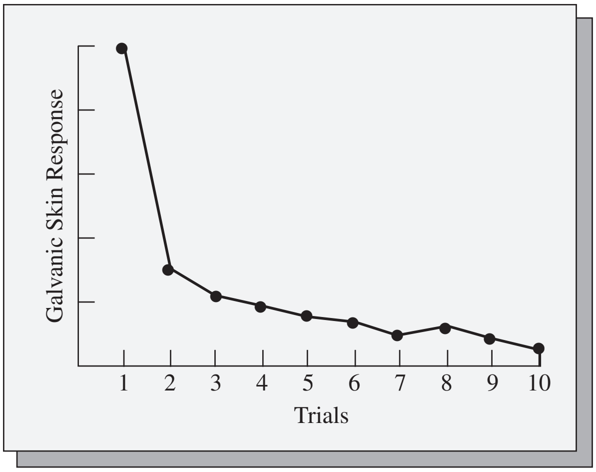


Figure 1-6 Habituation. Exposure to a novel stimulus produces a change in the electrical conductivity of the skin (the galvanic skin response [GSR]). Repeated exposure to the stimulus results in progressively weaker GSRs. (Hypothetical data.)

habituation on a graph usually reveals a fairly smooth, decelerating curve (refer to Figure 1-6).

Although habituation appears relatively simple, it is not as simple as this discussion implies. Variations in the stimulus used to elicit the response affect the rate of habituation. For example, a sudden loud noise will typically elicit the startle reflex—the "jump" you experience when, for example, the wind causes a door to slam shut. But the rate at which habituation occurs depends on the loudness of the sound, variations in the quality of the sound, the number of times the sound occurs, the time interval between repeated exposures to the sound, and other variables. (For more on this, refer to Thompson, 2000, 2009.)

Concept Check **7:** What is habituation?

You can probably guess how habituation aids survival. The world presents many dangers: predators, venomous reptiles, stinging insects and plants, lightning, forest fires, hurricanes, not to mention drunk drivers and people behaving in unpredictable ways. The world also presents us with opportunities: An unsuspecting prey animal may come our way, for example, providing an easy meal. We and other animals need to attend to events around us that might signal trouble or opportunity. However, events that occur repeatedly and do *not* signal trouble or opportunity can distract us from more important things, such as eating or sleeping. Habituation allows us to go on with life without interruption. If you live next to a train line, for example, at first the noise from passing trains prevents you from falling asleep, but with repeated exposure to the sounds, you sleep like a rock, thanks to habituation.

While most people do not think of habituation when they think of learning, it illustrates the essential nature of learning: a change in behavior due to experience. It also illustrates the survival value of learning. We have seen that changes in the environment produce both changes in the species (through natural selection) and changes in the individual (through learning). Which of those influences, nature or experience, has a greater impact on behavior? We will explore this question next.

Section **Review**

Habituation, perhaps the simplest form of learning, occurs when organisms experience a change in the frequency or strength of a reflex response due to repetition of an event. Like all forms of learning, it involves a change in behavior due to experience: in this case, the repeated presentation of a stimulus. Like all forms of learning, it evolved because it has survival value.

1-6 Nature vs. Nurture

Learning Objectives

To explain why the nature–nurture debate oversimplifies the origins of behavior, you can . . .

1-6-1 Describe the nature–nurture debate.

1-6-2 Explain how the nature–nurture debate creates an artificial division between the contributions of heredity and learning.

1-6-3 Give an example of a behavior that is the product of both nature and nurture.

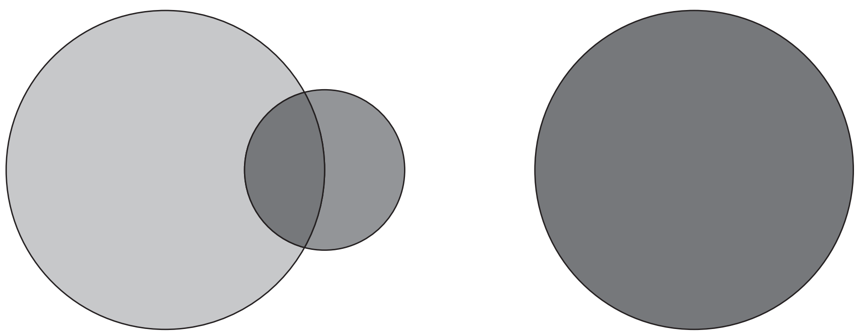
1-6-4 Explain how both nature and nurture affect the ability to learn.

One of the longest-running arguments in the study of behavior—indeed, in all of science—concerns the relative importance of nature and nurture (basically, heredity and learning) in determining behavior. Do we, as individuals, behave in a certain way because we were "born that way," or do we behave that way because our environment "taught" us to behave that way? We can observe the debate in sayings people use every day, often without thinking about their larger significance. Can a person "turn over a new leaf" (behave in a better or more responsible way), or is the leopard stuck with its spots (are people unable to change)? Are leaders born, or are they made?

Of course, no one denies the importance of learning, and no one completely ignores the role of heredity. Many have called the most influential behavior scientist of the 20th century, B. F. Skinner, an "extreme environmentalist," and some have even accused him of denying that biology plays any role in behavior. Yet he began his career in research by studying biology, and throughout his career, he wrote repeatedly of the role of biology in behavior (Morris, Lazo, & Smith, 2004; Skinner, 1969, 1975). In one passage, for example, Skinner (1953) writes that "behavior requires a behaving organism which is the product of a genetic process. Gross differences in the behavior of different species show that the genetic constitution . . . is important" (p. 26). Similarly, some have labeled biologists such as E. O. Wilson (1978), who emphasizes hereditary factors in behavior, "biological determinists," yet they acknowledge that experience plays an important role as well. Nevertheless, for centuries, people have lined up on one side or the other of the nature–nurture debate, arguing that one or the other, heredity or learning, truly determines behavior.

However, the nature–nurture debate creates an artificial division between the contributions of heredity and learning. The debate wrongly implies that the answer must be one or the other (Kuo, 1967; Midgley, 1987). In fact, nature and nurture interweave in a kind of Gordian knot; we cannot separate the two strands. As William Verplanck (1955) put it long ago, "Learned behavior is innate, and vice versa" (also refer to Moore, 2001; Ridley, 2003; Schneider, 2003; refer to Figure 1-7).

Let's take, as an example, the question of aggression. Douglas Mock (2006), a zoologist at the University of Oklahoma, compared the aggression of great blue heron birds and great egret chicks toward their siblings. The egrets killed their siblings more than the herons did. At first glance, it appears that egrets demonstrate innately more aggression, but Mock performed an experiment to explore this question. He had egrets raise herons and herons



(A) (B)

Figure 1-7 Nature–nurture. The traditional view of the nature–nurture relationship (A) sees the two influences as overlapping but with one or the other dominating overall. The contemporary view (B) sees the two influences as inextricably intertwined in all areas, with neither dominating. (Drawing by Gary Dale Davis.)

raise egrets. If the genetics solely determined the difference in siblicide, this switch should have made no difference. Mock found, however, that while egrets showed the same amount of aggression to their siblings, the herons showed more. The difference arose due to parental behavior: The herons bring their young large fish they can share; the egrets bring small fish that the birds can swallow—*if* they get them before their nest mate does. The difference in environment—parental behavior—influences the aggressiveness of the chicks.

Cats provide another example. It seems obvious that cats have a natural attraction to rats—as food, not as playmates. Zing Yang Kuo (1930) of China reared kittens under different conditions. Some grew up with their mothers and had the opportunity to see them kill rats. Others grew up away from their mothers and never saw rats killed. When the kittens matured, Kuo put them together with rats. He found that 86% of the cats reared with their mothers killed rats, but only 45% of the others did. Thus, experience strongly influences even something as basic as killing "natural" prey.

A tangled mix of nature and nurture also produces aggression in humans. Some genetic variants, for example, increase the likelihood that a person may react to negative stressors in aggressive ways (Iofrida, Palumbo, & Pellegrini, 2014). People without those genetic variants rarely react to the same stressors aggressively.

Concept Check **8:** Kuo's experiment showed that whether cats killed rats depended on whether they saw what kind of behavior?

Heredity and experience even affect the ability to learn itself. Numerous studies suggest that genes play a role in determining learning ability, but many other studies have shown that we cannot ignore the role of prior learning experiences. For instance, children whose parents regularly read to them have, on average, heard 1.4 million more words than children whose parents never read to them (Logan et al., 2019). These early reading experiences can affect children's learning and IQ for many more years to come—at least through middle school (Mendelsohn & Klass, 2018).

Thus, while we are biological organisms, we are also environmental organisms. Someone has said that asking, "Which is more important in determining behavior, heredity or environment?" is like asking, "Which is more important in determining the area of a rectangle, width or length?" All behaviors reflect a blending of nature and nurture so complex and intricate that we cannot say where one begins and the other ends. You can think of heredity and learning as merely different aspects of the same process, the effort to cope with life's one constant—change.

Section Review

Scholars have engaged in the nature–nurture debate for hundreds of years, perhaps longer. Many people still lean strongly toward the idea that genes or experience pretty much dictate our behavior. Science consistently reveals, however, that the two are inextricably intertwined so that it becomes difficult if not impossible to separate them. Experience can, for example, alter inherited tendencies, but genes play a major role in our ability to benefit from experience.

A Final Word

The apparent stability of the world is an illusion; change represents the most constant feature of our environment.

Natural selection offers one way of coping with change, but such changes take place across generations, so natural selection provides limited value in helping us cope with new challenges or abrupt changes. These observations may seem of no immediate importance to you, but in fact, they are massively important, because our environment is currently undergoing very substantial and abrupt changes.

For example, in 2019, the average global atmospheric levels of carbon dioxide, a major source of global warming, reached 410 ppm (Lindsey, 2020), and sea levels have been rising at the rate of 3.4 mm per year, about two and a half times the rate as in most of the 20th century (Lindsey, 2021). These facts directly relate to changes in the climate worldwide. And the years 2013–2020 have been the warmest years ever recorded; 2020 tied with 2016 as the warmest years on record, averaging nearly 2 degrees Fahrenheit warmer than previous baseline years (NASA, 2021).

What does climate change have to do with learning? Everything! Learning is about changes in behavior due to experience, and experience occurs in our environment. As our environment changes, we will need to learn to survive in new conditions. Or we need to learn to move toward a more sustainable society, with less emphasis on consumption. Regardless, our changing environment will require some kind of behavior change.

Key Terms

Review **Questions**

Note: Many of the questions that appear here (and in subsequent chapters) cannot be answered merely by searching through the chapter and copying a line or two from the text. To answer the questions properly, you may have to apply information in the text in imaginative ways.

1. Are humans still evolving? How could you show that they are or are not?
2. Why has the field mouse not evolved into an animal as large and ferocious as the grizzly bear?
3. In what sense is natural selection a product of the environment?
4. In what sense is what we learn the product of natural selection?
5. Invent a new reflex, one that would be helpful to humans.
6. Why is natural selection "behind the times"? Is learning behind the times?
7. How are reflexes, modal action patterns, and general behavior traits alike? How do they differ?
8. Learning is a mechanism for adapting to change. Are the changes ever *non*adaptive?
9. Captive animals often behave very differently from animals in the wild. In which circumstance is their true nature revealed? Where should one look to see true human nature?

Practice **Quiz**

1. Learning is _______________.
2. Behavior that has survival value at one time may be harmful at another time. We can see this today in the human fondness for sugar and _______________.
3. The sight of a chick with an open mouth reliably results in an adult bird providing food. The chick's open mouth is an example of a _______________.
4. Evolution is the product of two kinds of selection, _____________________ and ________________.
5. A relationship between a simple stimulus and response is known as a _______________.
6. One example of a general behavior trait is ________________.

7. A reduction in the intensity or probability of a reflex response due to repeated exposure to a stimulus that elicits that response is known as ______________.
8. Learning can be thought of as evolved ___________________.
9. The chief limitation of natural selection as a mechanism for coping with change is that it is _______________.
10. Climate change requires learning because ______________.

Chapter

2 The Study of Learning and Behavior

In this chapter . . .

"Sit down before fact as a little child, be prepared to give up every preconceived notion, follow humbly wherever and to whatever abysses nature leads, or you will learn nothing."

—T. H. Huxley

Preview

To engage in the scientific study of behavior, you have to go out of your mind. Nearly everyone, it seems, looks for explanations of behavior inside the mind, a mysterious entity that, in popular thought, resides between our ears and snuggles with, but is separate from, the brain. The scientific study of behavior requires adopting a very different, some will say downright alien, way of accounting for behavior: the natural science approach.

Learning Objectives

After studying this chapter, you will be able to . . .

2-1 Describe the natural science approach to explaining behavior.

2-2 Explain how psychologists measure learning.

2-3 Compare the benefits and drawbacks of the four different sources of data.

2-4 Describe the role of animals in human learning research.

2-1 The Natural Science Approach

Learning Objectives

To describe the natural science approach to explaining behavior, you can . . .

2-1-1 Define the natural science approach.

2-1-2 Explain the four assumptions underpinning the natural science approach.

Poets, educators, and philosophers have long admired learning, sung its praises, and wondered at its power. But learning has only been the subject of *scientific* analysis for little more than a hundred years.

What does scientific analysis mean when it comes to learning? Answers vary, but many learning researchers take the natural science approach. This approach maintains that learning arises from a natural phenomenon and can and must be accounted for like any other natural phenomenon. The following four assumptions underpin the natural science approach:

1. **Something causes natural phenomena.** Things do not "just happen"; rather they result from other events. In the 1840s, Dr. Ignaz Semmelweis, a German-Hungarian physician, noticed that women who gave birth in a hospital died of childbed fever more than women who gave birth at home, or even on the street. His attempt to find out why rested firmly on the assumption that the difference in death rates wasn't a random phenomenon, that something about the hospitals made them more dangerous. This led to research that eventually changed medical practices and saved countless lives.

   We can never prove that all events have a cause, but science rests on the assumption that effects have causes, including the science of behavior.

2. **Causes precede their effects.** Dr. Semmelweis assumed that whatever caused patients in a hospital to get childbed fever had to occur before they became ill. In most areas of science, such a statement might appear painfully obvious, yet many people seem to assume that future events can change *behavior*—in other words, that behavior can precede whatever event causes it. For example, people commonly say that a student studies hard because by doing so they *will get* a good grade. People assume that the future good grade causes the current studying. Some will counter that students study now, not for the future good grade, but because they currently have an *expectation* that studying will result in a better grade. And that this expectation causes studying. However, this view fails to take into account that our thoughts often coincide with or follow, rather than precede, the overt act they supposedly cause (Bechara et al., 1997; Libet, 2005; Libet et al., 1983; Libet, Sinnott-Armstrong, & Nadel, 2010; Obhi & Haggard, 2004; Soon et al., 2008). Events (including thoughts) cannot reach into the past to cause changes in behavior. Our proverbial student probably studies because in the past they earned better grades after studying than after not studying.

3. **The causes of natural events include only natural phenomena.** Mind, spirits, psychic energy, and other mysterious forces have no place in the natural science approach. You cannot explain the movement of tectonic plates (and the earthquakes and tsunamis they cause) by attributing them to God's anger. Similarly, you cannot explain a person's overeating by attributing it to a lack of willpower or bad karma. Someone may come up with an original idea, but we do not explain this creativity by attributing it to "the unconscious mind."

   To explain behavior, which includes thoughts and feelings (refer to Chapter 1), we must identify the natural events that produce it. These include biological or environmental events. Because learning involves the study of the changes in behavior produced by experience, our main concern in scientifically exploring learning focuses on how events in the individual's environment change behavior.

4. **The simplest explanation that fits the data is best.** This fundamental tenet of all sciences, the law of parsimony, means, in part, that the fewer assumptions (unverified events) required by an explanation, the better.

   In the 2nd century A.D., the Egyptian astronomer Claudius Ptolemy proposed the dominant explanation of astronomical events that lasted for about 1,500 years: the geocentric theory. According to the geocentric theory, the earth sits at the center of the universe, and the sun creates day and night by revolving around the earth once every 24 hours. But as astronomers gathered facts about the stellar bodies, the geocentric theory required modification again and again to accommodate facts that didn't fit it. These modifications resulted in a complicated and inelegant theory. In 1543, the Polish astronomer Nicolaus Copernicus put forward a radically different explanation of astronomical events. His heliocentric theory proposed that the earth rotates on its axis (thereby creating periods of day and night every 24 hours) and revolves around the sun once every year. Both the geocentric and heliocentric theories attempted to explain the known facts about the universe, but astronomers quickly accepted the simpler and far more elegant heliocentric theory.

   Today, many people, including many psychologists, accept explanations of behavior that rely on hypothetical events that supposedly take place in the mind. One example, Freud's Thanatos, proposes that people have an unconscious drive toward self-destruction that causes people to engage in risky behavior, such as misusing drugs, picking fights, and driving recklessly. The law of parsimony suggests that if we can account for such behavior by observable natural phenomena, such as heredity and environmental events, then speculations about mysterious and unobservable forces in a conscious or unconscious mind do not improve our understanding of the behavior (Moore, 2010; Palmer, 2003; Schall, 2005).

For many people, applying the assumptions of natural science to behavior requires a major shift in their view of human nature. Fear not: The shift will not turn you into a robot.

The natural science approach rests on the four assumptions just described. However, studying learning requires more than those assumptions. It also includes methods consistent with those assumptions. Let us begin with ways of measuring learning.