UNIT 5 Evolution

Kingfisher male with courtship gift

Insect of the newly named order Mantophasmatodea

Poison dart frogs

DISCOVERIES IN SCIENCE

Evolution and Life on Earth

1753

Carolus Linnaeus publishes the first of two volumes containing the classification of all known species. In doing so, Linnaeus establishes a consistent system for naming and classifying species. The system is widely used thereafter.

1859

Charles Darwin suggests that natural selection is the mechanism of evolution. Within months, public debates regarding the truth and significance of his theory ensue.

Galápagos tortoises

1907

In his book, *Plant Breeding,* Hugo de Vries, Dutch botanist, joins Mendel's laws of heredity with the newer theory of mutation. De Vries asserts that inheritable mutations are the mechanism by which species change and new species form.

1960

Mary and Jonathan Leakey discover fossil bones of a human ancestor, *Homo habilis,* in Olduvai Gorge, Tanzania.

Mary Leakey, paleoanthropologist

1974

Donald Johansen discovers a fossilized skeleton of one of the first hominids, *Australopithecus afarensis*. This specimen was nicknamed "Lucy."

Skull of *A. afarensis*

1980

Walter and Luis Alvarez, Frank Asaro, and Helen Michel publish a paper providing evidence that 65 million years ago, an asteroid collided with Earth and caused severe environmental changes. The changes may have led to the extinction of the majority of species that lived during that time.

1994

Reinhardt Kristensen and Peter Funch discover a tiny animal living on the lips of lobsters. They name the new species *Symbion pandora*. This species is so different from other animals that scientists classify it within a new phylum, Cycliophora, within kingdom Animalia.

2006

A team of biologists announces a study of Camiguin Island, the smallest island of the Philippines. They find 54 species of birds and 24 of species of mammals.

As-yet-unnamed parrot species

Beetles—one of the most diverse groups of animals on Earth

BIOLOGY CAREER

Museum Curator

Rob DeSalle

Rob DeSalle is a curator in the Division of Invertebrate Zoology at the American Museum of Natural History in New York City. He is an adjunct professor at Columbia University and City University of New York and is a Distinguished Research Professor at New York University. His current research focuses on molecular evolution in various organisms, including pathogenic bacteria and insects.

DeSalle enjoys being a scientist because he can investigate the diversity of life every day. He also enjoys the opportunity to serve as a mentor to students. Most of all, he enjoys the thrill of discovering something that no one else on the planet has found.

He considers his most significant accomplishment in science to be his work communicating scientific ideas through his writing and museum exhibitions.

Besides his work, DeSalle loves baseball and is a passionate fan of the Chicago Cubs.

Fossil and eggs of dinosaur called *oviraptor*

UNIT 5

Chapter Planner 16

Evolutionary Theory

	Time	Standards	Teach Key Ideas
CHAPTER OPENER, pp. 372–373	15 min.	*National Science Education Standards*	
SECTION 1 Developing a Theory, pp. 375–379 › A Theory to Explain Change over Time › Darwin's Ideas from Experience › Darwin's Ideas from Others	45 min.	LSEvol 1, LSEvol 2, LSEvol 3, LSInter 4, UCP2, SI2, SPSP2, HNS1, HNS2, HNS3	**Bellringer Transparency** **Transparencies** D10 Darwin's Finches **Visual Concepts** Darwin's Theories • Lamarck's Theory of Evolution • Population
SECTION 2 Applying Darwin's Ideas, pp. 380–385 › Evolution by Natural Selection › What Darwin Explained › Evaluating Darwin's Ideas	90 min.	LSGene 1, LSEvol 1, LSEvol 2, LSEvol 3, LSInter 4, UCP2, SI1, SI2	**Bellringer Transparency** **Transparencies** D13 Evidence of Whale Evolution • D14 Forelimbs of Vertebrates • D16 Hemoglobin Comparison **Visual Concepts** Natural Selection • Adaption • Biology • Similarities in Macromolecules • Homologous Feature • Similarities in Embryology
SECTION 3 Beyond Darwinian Theory, pp. 386–391 › Darwin's Theory Updated › Studying Evolution at All Scales	45 min.	LSGene 3, LSEvol 2, LSEvol 4, LSBeh 3, UCP2, SI2, HNS2, HNS3	**Bellringer Transparency** **Visual Concepts** Gradualism • Comparing Punctuated Equilibrium and Gradualism • Reproductive Isolation

See also PowerPoint® Resources

Chapter Review and Assessment Resources

- SE Super Summary, p. 392
- SE Chapter Review, p. 393
- SE Standardized Test Prep, p. 395
- Review Resources
- Chapter Tests A and B
- Holt Online Assessment

CHAPTER Fast Track

Thorough instruction will require the times shown.

Basic Learners

- TE Evolution Examples, p. 376
- TE Anatomical Comparisons, p. 382
- TE Organizing Concepts, p. 383
- TE What Can Evolve?, p. 387
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Advanced Learners

- TE Lamarckian Inheritance, p. 378
- TE What Would You Say?, p. 381
- TE Cytochrome c Evidence, p. 384
- Critical Thinking Worksheets*
- Concept Mapping Worksheets*
- Science Skills Worksheets*
- Lab Datasheets, Level C*

Key
SE Student Edition
TE Teacher's Edition
Chapter Resource File
Workbook
Transparency
CD or CD-ROM
* Datasheet or blackline master available
■ Also available in Spanish

All resources listed below are also available on the Teacher's One-Stop Planner.

Why It Matters	Hands-On	Skills Development	Assessment
Build student motivation with resources about high-interest applications.	SE **Inquiry Lab** Scientific Inference, p. 373* ■	TE **Reading Toolbox** Assessing Prior Knowledge, p. 372 SE **Reading Toolbox,** p. 374	
TE **Demonstration** They're All Related, p. 375 TE **How the Tortoise Got Its Name,** p. 376 SE **Breeding,** p. 377	SE **Quick Lab** Two Kinds of Growth, p. 378* ■	SE **Reading Toolbox** Key-Term Fold, p. 376 TE **Reading Toolbox** Key-Term Fold, p. 376	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*** ■ **Section Quiz** ■
TE **Extinct Organisms,** p. 382	SE **Skills Practice Lab** Natural Selection Simulation, p. 390* ■ **Quick Lab** Comparing Limb Structure and Function* **Skills Practice Lab** Melanism in Insects*	SE **Reading Toolbox** Hypothesis or Theory, p. 381 TE **Reading Toolbox** Hypothesis or Theory, p. 381 TE **Reading Toolbox** Visual Literacy, p. 383 TE **Reading Toolbox** Visual Literacy, p. 384	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*** ■ **Section Quiz** ■
TE **Antibiotic-Resistant Bacteria,** p. 386	SE **Quick Lab** Selection Model, p. 387* ■	SE **Reading Toolbox** Taking Notes, p. 389 TE **Reading Toolbox** Taking Notes, p. 389	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*** ■ **Section Quiz** ■
	See also Lab Generator		**See also Holt Online Assessment Resources**

Resources for Differentiated Instruction

English Learners

- TE Steps in Darwin's Theory, p. 380
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Multilingual Glossary

Struggling Readers

- TE Everyday Words, p. 387
- TE Key-Term Fold, p. 388
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide*
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Special Education Students

- TE Darwin's Theory, p. 381
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Alternative Assessment

- TE Evidence Brochure, p. 384
- Science Skills Worksheets*
- Section Quizzes* ■
- Chapter Tests A, B, and C* ■

Chapter 16

Overview

The purpose of this chapter is to introduce scientific ideas about evolution and natural selection. Students will develop an understanding of the basic elements of evolutionary theory and will evaluate supporting evidence from fossils, molecules, anatomy, and embryonic development.

READING TOOLBOX

Assessing Prior Knowledge Students should understand the following concepts:

- cellular nature of life
- basic genetics concepts

Visual Literacy Have students study the photographs of the pygmy seahorse. Ask students to think of the advantages of looking like coral. (Seahorses that look like coral may avoid being eaten by predators.) Ask students to predict what would happen to this seahorse's chances of survival if it were living in an environment it did not closely resemble. (It would not blend in as well and would be more likely to be captured by predators.)

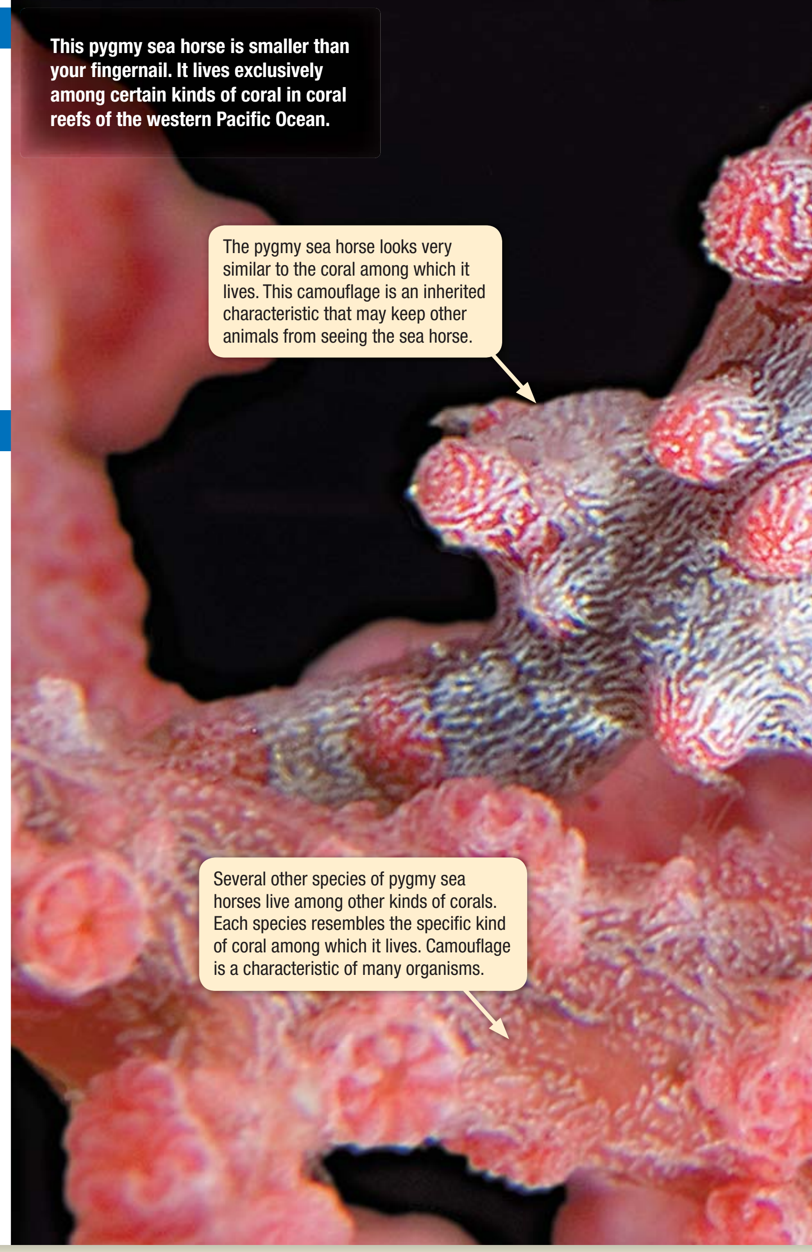
Chapter 16

Evolutionary Theory

Preview

Why It Matters

Modern evolutionary theory provides strong and detailed explanations for many aspects of biology, such as anatomy and behavior.



Chapter Correlations — *National Science Education Standards*

LSGene 1 In all organisms, the instructions for specifying the characteristics of the organisms are carried in DNA.

LSGene 3 Changes in DNA (mutations) occur spontaneously at low rates.

LSEvol 1 Species evolve over time.

LSEvol 2 The great diversity of organisms is the result of more than 3.5 billion years of evolution.

LSEvol 3 Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms as well as for the striking molecular similarities observed among the diverse species of living organisms.

LSEvol 4 The millions of difference species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors.

LSInter 4 Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite.

LSBeh 3 Like other aspects of an organism's biology, behaviors have evolved through natural selection.

UCP2 Evidence, models, and explanation

SI1 Abilities necessary to do scientific inquiry

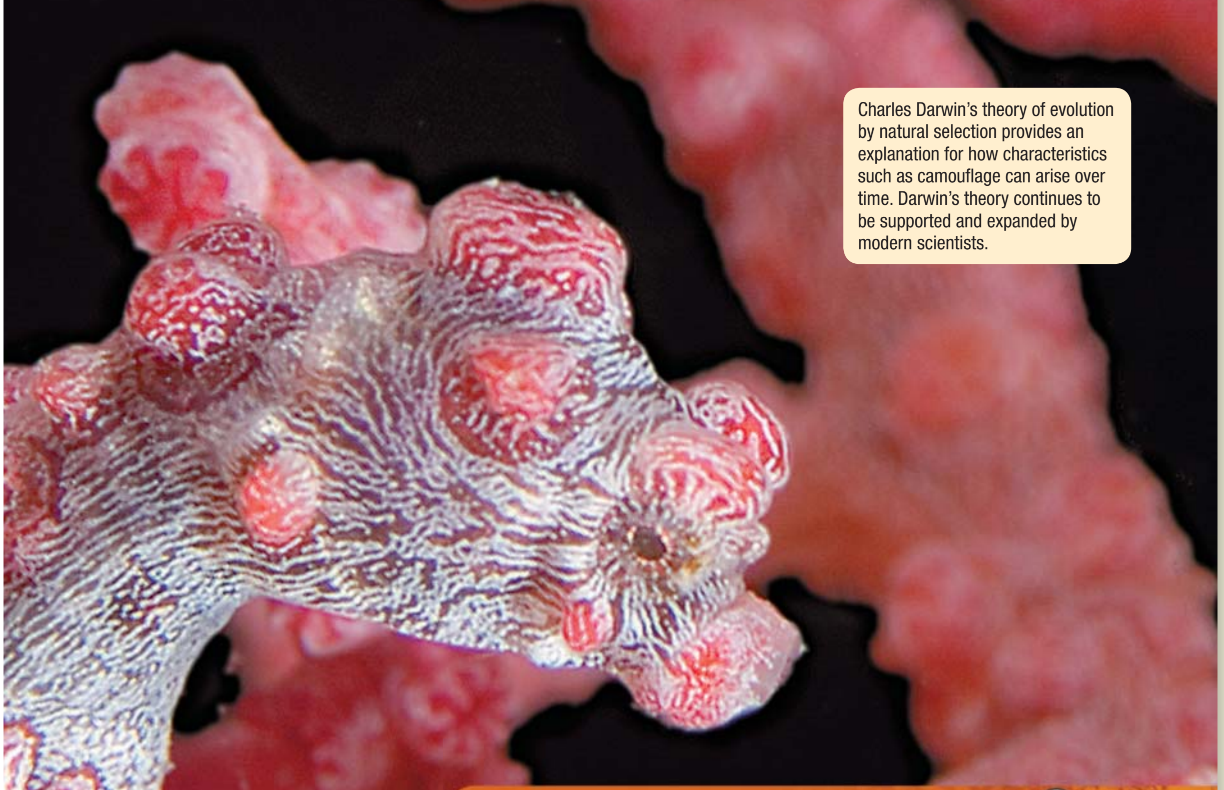
SI2 Understandings about scientific inquiry

SPSP2 Population growth

HNS1 Science as a human endeavor

HNS2 Nature of scientific knowledge

HNS3 Historical perspectives



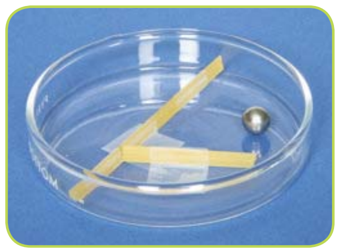
Charles Darwin's theory of evolution by natural selection provides an explanation for how characteristics such as camouflage can arise over time. Darwin's theory continues to be supported and expanded by modern scientists.

InquiryLab

15 min

Scientific Inference

Much of science is based on making inferences. Not all inferences can be supported by direct observation. Instead, many are tested by modeling, prediction, and experimentation. Doing so requires attention to detail and, sometimes, creative thinking.



Procedure

1. Break a **piece of flat-noodle pasta** into two smaller segments about 8 cm long and 3 cm long.
2. Erect two "walls" in the bottom of a **Petri dish** by securing the pasta pieces to the dish with **tape.**
3. Place a **ball bearing** in the dish.
4. Secure the lid onto the dish with tape. Keeping the dish upright, place it in a **brown paper bag.**
5. Exchange bags with another student. Without looking inside the bag, try to infer the arrangement of the pasta in the dish.

Analysis

1. **Describe** your inference, and explain how you formed it.
2. **Suggest** how your inference could be supported or confirmed.

InquiryLab

Teacher's Notes Emphasize that the purpose of this activity is not to guess the exact arrangement of pasta; instead, the purpose is to experience a recurring challenge in science, which is making inferences about things that cannot be directly observed. For example, tell students that we know about the composition of the sun, yet we've never traveled there.

Materials
- petri dish
- flat noodles
- tape
- metric ruler
- ball bearing
- brown paper bag

Safety Caution Review safety rules. Remind students not to eat or taste food items used in the lab and to wash their hands after completing this activity. Food items used in the lab should be treated as potentially pathogenic and should be disposed of as such.

Answers to Analysis

1. Students should describe their inferred arrangement of the pasta and explain how they used clues such as hearing sounds and feeling the weight of the rolling ball.
2. If others replicate the activity and come to the same or similar conclusions, the inference gains support. By forming testable hypotheses, further investigations could be run to determine if the inference is valid.

READING TOOLBOX

Using Words

Check that students have made their key-term folds correctly. It should include all of the terms on the Summary page of this chapter.

Using Language

1. Sample answers: theory of gravity, cell theory, "big bang" theory, atomic theory, theory of relativity
2. Sample concept map shown below.
3. Evolutionary theory describes the general trends and areas of investigation about how living things have come to change over time.

Taking Notes

1. Natural selection is the idea that the most well-adapted organisms survive and reproduce.
2. Macroevolution is the study of large scale observations representing events that have occurred over a very long time, such as the fossil record or homologous structures.
3. Microevolution is the study of small scale events that happen over a short period of time such as changes in allele frequencies through inheritance.

READING TOOLBOX

These reading tools can help you learn the material in this chapter. For more information on how to use these and other tools, see **Appendix: Reading and Study Skills.**

Using Words

Key-Term Fold A key-term fold is useful for studying definitions of key terms in a chapter. Each tab can contain a key term on one side and the term's definition on the other.

Your Turn Prepare a key-term fold for the key terms in this chapter. Fill it in as you read. Use it later to quiz yourself on the definitions.

1. Fold a sheet of lined notebook paper in half from left to right.
2. Using scissors, cut along every third line from the right edge of the paper to the center fold to make tabs.

Using Language

Hypothesis or Theory? In everyday language, there is little difference between a *hypothesis* and a *theory*. But in science, the meanings of these words are more distinct. A *hypothesis* is a specific, testable prediction for a limited set of conditions. A *theory* is a general explanation for a broad range of data. A theory can include hypotheses that have been tested and can also be used to generate new hypotheses. The strongest scientific theories explain the broadest range of data and incorporate many well-tested hypotheses.

Your Turn Use what you have learned about a hypothesis and a theory to answer the following questions.

1. List some scientific theories that you have heard of.
2. Make a simple concept map or Venn diagram to show the relationship between hypotheses and theories.
3. The word *theory* may also be used to describe general trends and areas of active investigation in a scientific field. In this context, what does the term *evolutionary theory* mean?

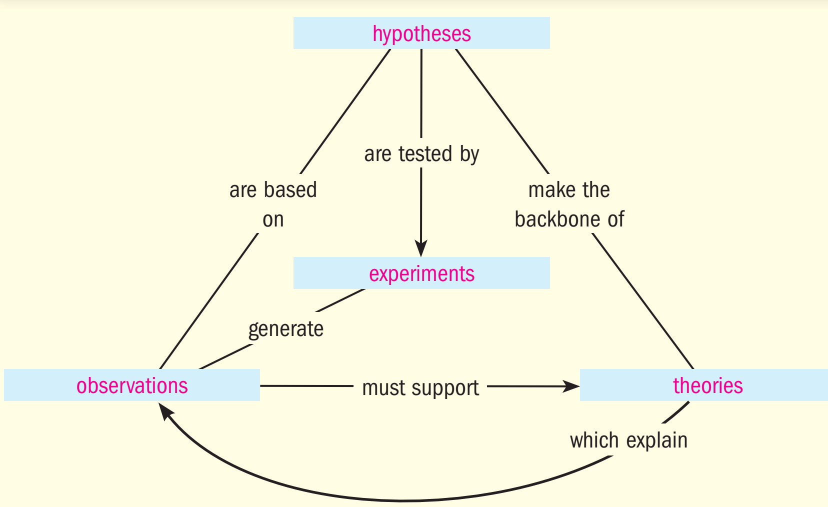
Taking Notes

Summarizing Ideas Summarizing ideas helps you condense important information. When you summarize, use your own words and keep your sentences short. Focus on key ideas.

Your Turn Prepare to take notes for this chapter. Use this table as an example. As you read, be sure to summarize the following concepts:

1. natural selection
2. macroevolution
3. microevolution

Notes about Evolution		
Natural selection	*Macroevolution*	*Microevolution*



Section 1

Developing a Theory

Key Ideas	Key Terms	Why It Matters
❯ Why is evolutionary theory associated with Charles Darwin? ❯ How was Darwin influenced by his personal experiences? ❯ How was Darwin influenced by the ideas of others?	evolution artificial selection	Many aspects of biology are best explained by evolutionary theory.

Recall that in biology, **evolution** is the process by which species change over time. The idea that life evolves is not new. Yet for centuries, scientists lacked clear evidence that evolution happens. They also lacked a strong theory to explain how evolution happens. In 1859, Charles Darwin pulled together these missing pieces. Darwin, shown in **Figure 1,** was an English naturalist who studied the diversity of life and proposed a broad explanation for it.

A Theory to Explain Change over Time

Recall that in science, a *theory* is a broad explanation that has been scientifically tested and supported. ❯ **Modern evolutionary theory began when Darwin presented evidence that evolution happens and offered an explanation of how evolution happens.** Like most scientific theories, evolutionary theory keeps developing and expanding. Many scientists since Darwin have tested and added to his ideas. Most of Darwin's ideas, including his main theory, remain scientifically supported.

❯ **Reading Check** *What does* **evolution** *mean in biology? (See the Appendix for answers to Reading Checks.)*

evolution the process of change by which new species develop from preexisting species over time

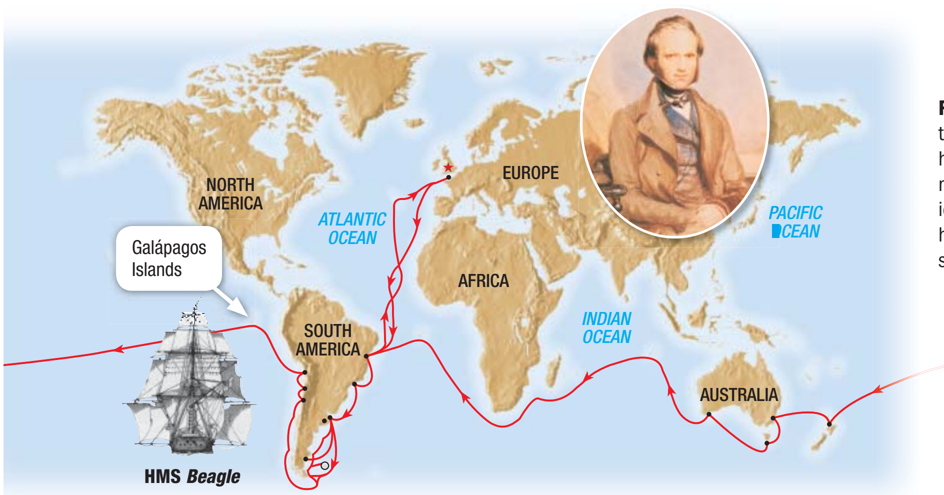


Figure 1 Charles Darwin took many years to publish his theory of evolution by natural selection. Many of his ideas were first inspired by his 1831 global voyage on a ship called the *Beagle.*

Section 1

❯ Focus

This section describes Darwin's experiences as a naturalist, how he concluded that evolution occurs, how he developed an explanation for the mechanism of evolution, and how his theory has been modified by other scientists with regard to formation of new species.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Demonstration

They're All Related! Bring to class as many of the following food crops as possible: cabbage, brussels sprouts, broccoli, cauliflower, kale, and kohlrabi. Try to get a wild mustard plant or a picture of one. Point out the parts of the plants that are eaten. Tell students that all of these different varieties have been bred from the same species, *Brassica oleracea.* Ask students how these varieties of the same species could look so different. (There is so much variation in the genes of this species.) Do you think it is possible for these varieties to become separate species? (Accept all reasonable responses.) **LS Visual**

Key Resources

Transparencies
D10 Darwin's Finches

Visual Concepts
Darwin's Theories
Lamarck's Theory of Evolution
Population

Teach, *continued*

Teaching Key Ideas

Finch Adaptation Have students examine **Figure 2** and describe the features of the finches' bills. Have students describe how each finch's bill is adapted to the bird's diet. (For example, the large ground finch's bill is thick and heavy, which enables these birds to crack open large seeds.) **LS Visual**

READING TOOLBOX

Key-Term Fold Check that students have the following terms, with similar definitions, in their key-term folds: **evolution** changes in species over time; **artificial selection** breeding organisms to produce offspring with specific traits **LS Visual**

Answers to Caption Questions

Figure 2: that all of the Galápagos finch species descended from a single South American finch population

READING TOOLBOX

Key-Term Fold On the back half of your key-term fold, under each flap, write your own definition for the key terms in this section.

artificial selection the human practice of breeding animals or plants that have certain desired traits

Darwin's Ideas from Experience

In Darwin's time, most people did not think that living things had changed over time. In fact, many doubted that Earth itself had ever changed. But Darwin saw evidence of gradual change. **Darwin's experiences provided him with evidence of evolution at work.**

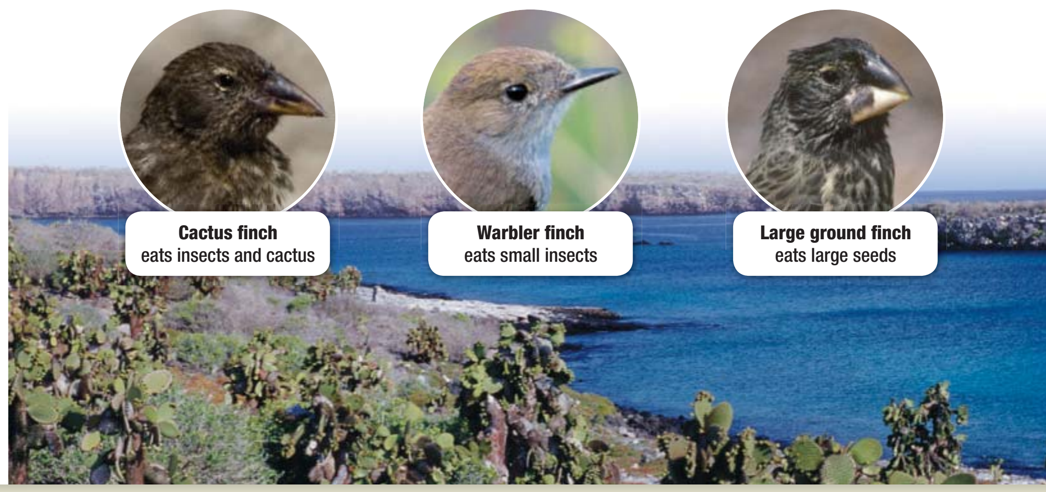
The Voyage of the *Beagle* Darwin's first evidence was gathered during a global voyage on a ship called the *Beagle*. As part of his work as a naturalist, Darwin collected natural objects from each place that he visited. For example, in South America, he collected fossils of giant, extinct armadillos. Darwin noticed that these fossils were similar, but not identical, to the living armadillos in the area.

Darwin also visited the Galápagos Islands in the Pacific Ocean. There, he collected several different species of birds called *finches*. Each of the finches are very similar, but differences can be seen in the size and shape of the bill (or beak), such as those shown in **Figure 2.** Each finch has a bill that seems suited to the finch's usual food.

Darwin noticed that many of the islands' plants and animals were similar, but not identical, to the plants and animals he saw in South America. Later, Darwin proposed that the Galápagos species had descended from species that came from South America. For example, he suggested that all of the finch species descended from one ancestral finch species that migrated from South America. Then, the descendant finches were modified over time as different groups survived by eating different types of food. Darwin called such change *descent with modification*. This idea was a key part of his theory.

Years of Reflection After returning from his voyage at the age of 27, Darwin spent years studying his data. He also continued studying many sciences. As he studied, his confidence grew stronger that evolution must happen. But Darwin did not report his ideas about evolution until much later. Instead, he took time to gather more data and to form a strong explanation for how evolution happens.

Figure 2 Darwin eventually learned that all Galápagos finch species were similar to each other and to one particular South American finch. **What explanation did Darwin propose for this similarity?**



Why It Matters

How the Tortoise Got Its Name Tell students that the Galápagos Islands were named for the large tortoises that inhabit this archipelago. When Spanish explorers arrived, they found so many giant tortoises they called the islands "Galápagos," Spanish for tortoises. Galápagos tortoises metabolize fat stored in their tissues and can survive without food or water for long periods of time. Because of this characteristic, the Spanish sailors collected and stored the tortoises for a convenient source of fresh meat. There were an estimated 250,000 tortoises. Approximately 15,000 remain today. **LS Interpersonal**

Differentiated Instruction

Basic Learners

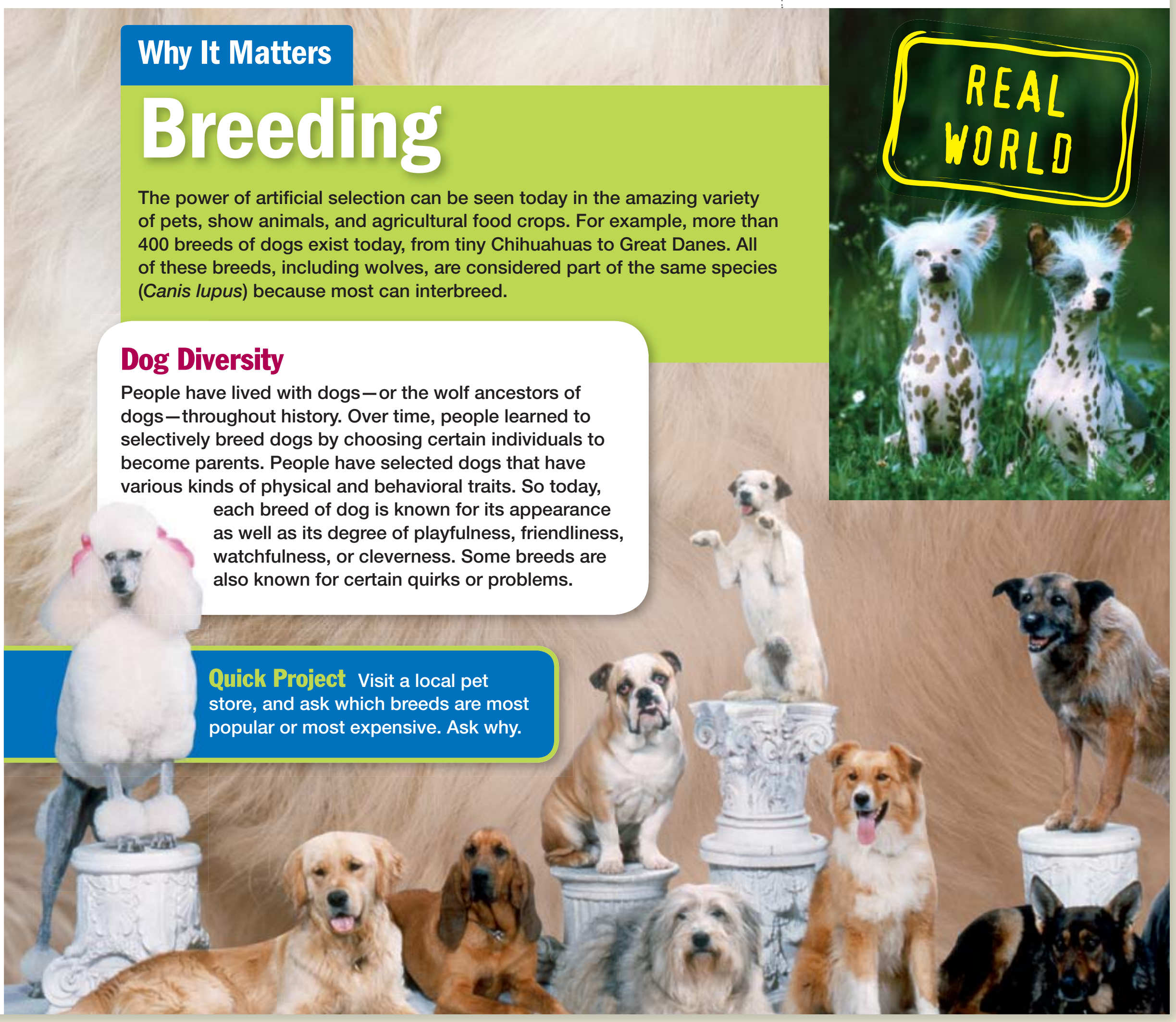
Evolution Examples Ask students what the word *evolution* means. (change over time) Ask students to brainstorm examples of groups of animals or plants that have changed over time. (They are likely to mention dinosaurs, birds, or mammals.) Direct them to think about plant evolution examples from agriculture. (trees, as opposed to mosses and ferns; modern hardy or pest-resistant varieties, and hybrid forms) **LS Verbal**

Breeding and Selection Darwin took interest in the practice of breeding, especially the breeding of exotic pigeons. He bred pigeons himself and studied the work of those who bred other kinds of animals and plants, such as dogs, orchids, and food crops. Eventually, Darwin gained a new insight: breeders take advantage of natural variation in traits within a species. If a trait can be inherited, breeders can produce more individuals that have the trait. Breeders simply select individuals that have desirable traits to be the parents of each new generation. Darwin called this process **artificial selection** because the selection is done by humans and not by natural causes.

Academic Vocabulary

insight a clear understanding of something

› **Reading Check** ***When did Darwin first see evidence of evolution?***



Why It Matters

Breeding

The power of artificial selection can be seen today in the amazing variety of pets, show animals, and agricultural food crops. For example, more than 400 breeds of dogs exist today, from tiny Chihuahuas to Great Danes. All of these breeds, including wolves, are considered part of the same species (*Canis lupus*) because most can interbreed.

Dog Diversity

People have lived with dogs—or the wolf ancestors of dogs—throughout history. Over time, people learned to selectively breed dogs by choosing certain individuals to become parents. People have selected dogs that have various kinds of physical and behavioral traits. So today, each breed of dog is known for its appearance as well as its degree of playfulness, friendliness, watchfulness, or cleverness. Some breeds are also known for certain quirks or problems.

Quick Project Visit a local pet store, and ask which breeds are most popular or most expensive. Ask why.

Teaching Key Ideas

Definition of Species Be sure students understand that the ability to mate with each other and produce future offspring is what defines a species (in sexually reproducing organisms). Ask why all dogs are the same species, but the finches on the previous page are different species. (Students may erroneously believe that a *breed* is synonymous with a *species*. Even though the finches look very similar, they are different species because they do not interbreed.) Now is a good time to reinforce the definition of population. **LS Visual**

Why It Matters

Teacher's Notes The domestic dog was once classified as *Canis familiaris*, while the grey wolf was classified as *Canis lupus*. In modern phylogeny, the domestic dog is considered a wolf subspecies, named *Canis lupus familiaris*. Another subspecies is the dingo, *Canis lupus dingo*. Species that are closely related to wolves and dogs include the coyote, *Canis latrans*, the red wolf, *Canis rufus*, and several species of jackals.

Answer to Quick Project

Typically, the most expensive breeds are the ones that are rare or have strict, documented pedigrees. Breeds that result from extreme inbreeding tend to have many recessive traits and require special care. Popular breeds are often the reliable, friendly pet or guard dogs, such as Labradors, but sometimes certain breeds become a fad. Many people prefer dogs that fit well into their lifestyle.

Teach, *continued*

QuickLab

Teacher's Notes Review the sample graphs, so students see how the shape of the line indicates linear or exponential growth.

Materials
- rice
- egg carton

Safety Caution Remind students not to taste food items and to wash their hands after this activity. Food items used should be treated as potentially pathogenic and should be disposed of as such.

Answers to Analysis

1. The graph from Step 2 should show linear growth; the graph from Step 4 should show exponential growth. Values should be as follows:
   Graph 1: 1, 2, 3, 4, 5, 6
   Graph 2: 1, 2, 4, 8, 16, 32
2. "Arithmetic" is related to the simple addition of an equal amount each time. "Geometric" is related to the multiplication of amounts each time. The second growth pattern is actually a series of powers of two (2^1, 2^2, 2^3, 2^4, etc.).

Answers to Caption Questions

Figure 3: Darwin's theory of evolution by natural selection assumed the existence of a mechanism for inheritance and variation in traits over time.

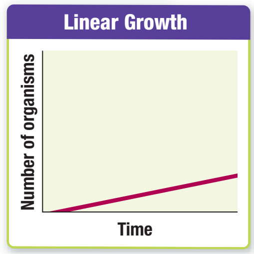
Hands-On QuickLab 15 min

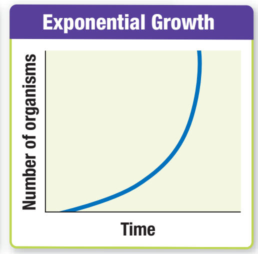
Two Kinds of Growth

Can you visualize the difference between linear growth and exponential growth?

Procedure

1. Place **grains of rice** in the cups of an **egg carton** in the following sequence: Place one grain in the first cup. Place two grains in the second cup. Place three grains in the third cup. In each of the remaining cups, place *one more* grain of rice than in the cup before.
2. Use a line graph to graph the results of step 1.
3. Repeat step 1, but use the following sequence: Place one grain in the first cup, two in the second cup, and four in the third cup. In each remaining cup, place twice as many grains as placed in the cup before.
4. Use a line graph to graph the results of step 3.





Analysis

1. **Match** your graphs to the graphs shown.
2. CRITICAL THINKING **Analyzing Terminology** Linear growth is also called *arithmetic growth,* and exponential growth is also called *geometric growth*. Propose an explanation for the use of these terms.

Figure 3 According to Lamarck's idea of inheritance, this baseball player's children would inherit strong arm muscles. **Why was this idea important to Darwin?**

Darwin's Ideas from Others

In Darwin's time, most people—including scientists—believed that each species was created once and stayed the same forever. But this view could not explain fossils of organisms that no longer exist, such as dinosaurs. Some scientists tried to explain such observations by saying that species could die out but never change. Others, including Darwin's own grandfather, proposed various mechanisms to explain how species may change over time. **Darwin was influenced by ideas from the fields of natural history, economics, and geology.** The ideas of Lamarck, Malthus, Cuvier, and Lyell were especially important.

Lamarckian Inheritance In 1809, the French scientist Jean Baptiste Lamarck proposed an explanation for how organisms may change over generations. Like Darwin and others, Lamarck noticed that each organism is usually well adapted to its environment. He proposed, as Darwin would later, that organisms change over time as they adapt to changing environments.

However, Lamarck had an incorrect idea about inheritance. He proposed that changes due to use or disuse of a characteristic would be passed on to offspring. For example, he knew that a person's muscles may decrease in size because of disuse or may increase in size because of use, as shown in **Figure 3.** He believed that offspring inherited these kinds of changes. This idea was eventually disproved, but not in Darwin's time. Darwin once accepted this idea because it proposed a role for inheritance in evolution.

Differentiated Instruction

Advanced Learners/GATE

Lamarckian Inheritance Have students design a simple, hypothetical experiment to test Lamarck's theory of evolution and inheritance of acquired characteristics. They should ask questions, formulate a testable hypothesis, and suggest how they would conduct the experiment. LS **Logical**

Population Growth Another key influence on Darwin's thinking about evolution was an essay by Thomas Malthus. In 1798, this English economist observed that human populations were increasing faster than the food supply. Malthus pointed out that food supplies were increasing *linearly*. More food was being produced each year, but the amount by which the food increased was the same each year. In contrast, the number of people was increasing *exponentially*. More people were added each year than were added the year before. Malthus noted that the number of humans could not keep increasing in this way, because many people would probably die from disease, war, or famine.

Darwin simply applied Malthus's idea to all populations. Recall that a *population* is all of the individuals of the same species that live in a specific place. Darwin saw that all kinds of organisms tend to produce more offspring than can survive. So, all populations must be limited by their environments.

Figure 4 Layers of rock contain evidence of changes occurring over millions of years in organisms and environments on Earth. Darwin realized that such evidence supported his ideas about evolution.

Geology and an Ancient Earth In Darwin's time, scientists had become interested in the study of rocks and landforms, and thus began the science of *geology*. In particular, scientists such as Georges Cuvier, James Hutton, and Charles Lyell studied fossils and rock layers, such as those shown in **Figure 4.** Cuvier argued that fossils in rock layers showed differences in species over time and that many species from the past differed from those of the present. But Cuvier did not see species as changing gradually over time. He thought that changes in the past must have occurred suddenly.

Hutton and Lyell, on the other hand, thought that geologic processes—such as those that wear away mountains and form new rocks and fossils—work gradually and constantly. Lyell carefully and thoroughly presented his ideas in a book, which Darwin read. Lyell's ideas fit well with Darwin's observations and showed that Earth's history was long enough for species to have evolved gradually.

SCILINKS.
www.scilinks.org
Topic: Charles Darwin
Code: HX80262

Reading Check *What idea did Darwin and Lamarck once share?*

Section 1 Review

KEY IDEAS

1. **Describe** Darwin's relationship to modern evolutionary theory.
2. **Identify** personal experiences that contributed to Darwin's thinking about evolution.
3. **Identify** other scientists that influenced Darwin's thinking.

CRITICAL THINKING

4. **Applying Process Concepts** Darwin observed that artificial selection can produce specific traits. Suppose a farmer has a corn crop in which each ear of corn has some yellow kernels and some white kernels. Describe how the farmer could produce a variety of corn that has all white kernels.

METHODS OF SCIENCE

5. **Scientific Testing** According to Lamarck's idea of inheritance, an individual that developed an improved trait within its lifetime, especially through repeated use, could pass that trait on to its offspring. Propose a way to test the accuracy of this idea.

Teach, *continued*

Teaching Key Ideas

Lamarkian Inheritance Lamarck theorized that when an organism uses a part of its body, that part becomes more developed as a result of its use, as shown in **Figure 3.** He reasoned that the modification is then passed on to the organism's offspring. Tell students that if Lamarck were correct, the offspring of bodybuilders would be born with enormously developed muscles.

Close

Formative Assessment

What term best describes the deliberate breeding of drought-resistant crops by humans?

A. adaptation (Incorrect. Adaptation is a result of natural selection.)
B. artificial selection (Correct! Desirable traits are selected by humans for growing the next generation of plants.)
C. speciation (Incorrect. Speciation occurs when a new species evolves.)
D. mutation (Incorrect. A mutation is a change in alleles from one generation to the next.)

Answers to Section Review

1. Darwin presented evidence that evolution occurs, along with an explanation for how it occurs.
2. his travels, his years of study and reflection, and his experience and observation of artificial breeding
3. Darwin was influenced by ideas about inheritance from Lamarck, ideas about economics and population growth from Malthus, and ideas about geology from Cuvier, Hutton, and Lyell.
4. The farmer would look for ears of corn that had more white kernels than usual. The farmer would breed those plants and any corn plants from the next generation that had even more white kernels would be chosen for breeding. This process would continue until the farmer had plants that produced corn with all white kernels.
5. Test the idea by having individuals change a trait. Then, study the offspring to look for the appearance of the trait. For example, train a batch of mice to run fast and then see if all of their offspring run faster than untrained mice.

Section 2

Focus

This section provides examples of population changes that have resulted from natural selection. It also provides the evidence of evolution that scientists use to make inferences from fossil records, molecular similarities, anatomical similarities, and similarities between the developmental patterns of organisms.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Teaching Key Ideas

Looks Like a Leaf Have students study **Figure 5** showing *Phyllium pulchrifolium* (the name means "beautiful leaf"). Ask students to describe the advantage of looking like a leaf. (Leaf-dwelling insects that resemble leaves are hidden from both predators and prey.) Ask students to predict what would happen to this insect's chances of survival if it were growing in an environment that had plants only with red leaves. (It would not blend in as well, so it would be more likely to be captured by predators.) LS Visual

Answers to Caption Questions

Figure 5: Darwin's theory provided a mechanism (natural selection) by which organisms could become adapted to their environment over time.

Section 2

Applying Darwin's Ideas

Key Ideas	Key Terms	Why It Matters
What does Darwin's theory predict? Why are Darwin's ideas now widely accepted? What were the strengths and weaknesses of Darwin's ideas?	natural selection adaptation fossil homologous	The principles of evolution are used daily in medicine, biology, and other areas of modern life to understand, predict, and develop advancements in each area.

Darwin applied Malthus's idea to all species. Every living thing has the potential to produce many offspring, but not all of those offspring are likely to survive and reproduce.

Evolution by Natural Selection

Darwin formed a key idea: Individuals that have traits that better suit their environment are more likely to survive. For example, the insect in **Figure 5** is less likely to be seen (and eaten) than a brightly colored insect is. Furthermore, individuals that have certain traits tend to produce more offspring than others do. These differences are part of **natural selection.** Darwin proposed that natural selection is a cause of evolution. In this context, *evolution* is a change in the inherited characteristics of a population from one generation to the next.

Steps of Darwin's Theory Darwin's explanation is often called the *theory of evolution by natural selection.* **Darwin's theory predicts that over time, the number of individuals that carry advantageous traits will increase in a population.** As shown in **Figure 6,** this theory can be summarized in the following four logical steps:

Step 1 Overproduction Every population is capable of producing more offspring than can possibly survive.

Step 2 Variation Variation exists within every population. Much of this variation is in the form of inherited traits.

Step 3 Selection In a given environment, having a particular trait can make individuals more or less likely to survive and have successful offspring. So, some individuals leave more offspring than others do.

Step 4 Adaptation Over time, those traits that improve survival and reproduction will become more common.

Figure 5 This insect is well adapted to its environment. **How does Darwin's theory help explain this observation?**

Key Resources

Transparencies
- D13 Evidence of Whale Evolution
- D14 Forelimbs of Vertebrates
- D16 Hemoglobin Comparison

Visual Concepts
- Natural Selection
- Adaptation
- Biology
- Similarities in Macromolecules
- Homologous Features
- Similarities in Embryology

Differentiated Instruction

English Learners

Steps of Darwin's Theory Help students understand **Figure 6**, by asking the following. How is *overproduction* shown? (There are too many organisms in a small space.) How is *variation* shown? (The animals are of two different sizes and coat colors.) What has happened to show *selection*? (There's a change in the environment. Smaller animals with light-colored coats have died, changing the ratio of light and dark coats in the population.) How is adaptation shown? (The population now has a greater number of animals with dark-colored coats.)

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interact online
Keyword: HX8EVOF6

The Theory of Evolution by Natural Selection

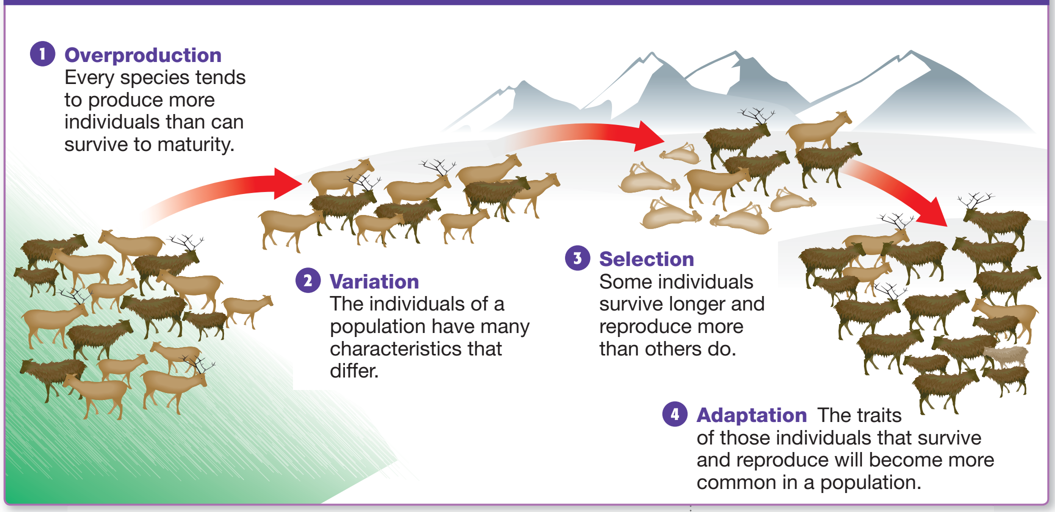


Figure 6 Darwin proposed a logical process by which evolution may occur.
› **Can this process act on individuals?**

Selection and Adaptation Darwin's theory explains why living things vary in form yet seem to fit their environment. Each habitat presents unique challenges and opportunities to survive and reproduce. So, each species evolves because of the "selection" of those individuals that survive the challenges or make best use of the opportunities. Put another way, each species becomes *adapted* to its environment as a result of living in it over time. An **adaptation** is an inherited trait that is present in a population because the trait helps individuals survive and reproduce in a given environment.

In sum, Darwin's theory explains evolution as a gradual process of adaptation. Note that Darwin's theory refers to *populations* and *species*—not *individuals*—as the units that evolve. Also, keep in mind that a species is a group of populations that can interbreed.

Publication of the Theory In 1844, Darwin finally wrote an outline of his ideas about evolution and natural selection. But he showed it only to a few scientists that he knew well. He was afraid that his ideas would be controversial. Then in 1858, he received a letter from another young English naturalist named Alfred Russel Wallace. Wallace asked for Darwin's opinion on a new theory—a theory much like Darwin's! Because of this similarity, Darwin and Wallace jointly presented their ideas to a group of scientists. Darwin was finally motivated to publish a full book of his ideas within the next year.

Darwin's book *On the Origin of Species by Means of Natural Selection* presented evidence that evolution happens and offered a logical explanation of how it happens. Biologists began to accept that evolution occurs and that natural selection helps explain it.

› **Reading Check** ***Is natural selection the same thing as evolution?***

READING TOOLBOX

Hypothesis or Theory? Why isn't Darwin's explanation simply called *the theory of evolution*? Why isn't it called a *hypothesis*?

natural selection the process by which individuals that are better adapted to their environment survive and reproduce more successfully than less well adapted individuals do

adaptation a trait that improves an organism's ability to survive and reproduce; the process of becoming adapted

go.hrw.com
interact online

Students can interact with "Evolution by Natural Selection" by going to go.hrw.com and typing in the code HX8EVOF6.

Answers to Caption Questions

Figure 6: No; natural selection acts only to change the traits of populations or species over time.

Teaching Key Ideas

Process of Natural Selection Have students make a labeled diagram showing the process of natural selection using the species of their choice. The chosen species could even be one that the student makes up. In their diagrams, students should include the four important points about natural selection discussed in this section.
(Example: taller trees
Overproduction: too many trees of the same height competing for light
Variation: trees that are slightly taller have an advantage
Selection: taller trees survive longer and produce more seeds
Adaptation: taller trees become more common in the population) **LS Visual**

READING TOOLBOX

Hypothesis or Theory? Evolutionary theory today has grown beyond Darwin's original ideas and continues to be modified. Darwin's explanation for evolution is much more than a hypothesis; it explains a broad range of observations and forms the basis of multiple, testable hypotheses.

Differentiated Instruction

Advanced Learners/GATE

What Would You Say? Tell students that while Wallace was in Indonesia, he wrote a paper describing his idea about how evolution occurred and sent it to Darwin. Ask students to write a letter that Darwin could have written to Wallace in response. **LS Verbal**

Special Education Students

Darwin's Theory To help visually impaired students understand **Figure 6**, provide them with sets of plastic farm animals. Each set should feel slightly different from the others to represent variation in the population. Give each student 16 animals to represent the overproduction stage in the figure. Take students through the stages of the theory by telling them how the population would change at each successive step. **LS Kinesthetic**

Teach, *continued*

Teaching Key Ideas

Fossil Evidence Tell students that the first three animals in **Figure 7** are known only from their fossil remains. The fourth animal is a living species. It is rare to find a complete skeleton for any one fossil. As more fossils of a species are found, all of the skeleton bones may eventually be found. Paleontologists estimate what these bones probably looked like. Ask students how the backbones of the fossils in the figure correlate to the ratio of time the animal spent in water. (The backbones became larger.) What is the advantage of this change? (Whales use up-and-down motions of their bodies to swim. A larger backbone better supports the muscles.) **LS Visual**

Teaching Key Ideas

Intermediate Forms Another form of evidence linking whales to other mammals is molecular. Recent genetic phylogenetic analysis of many mammals suggests that whales are most closely related to hippos, meaning that these two orders share a common ancestor more recently than any other two mammal orders. Interestingly enough, manatees and dugongs, which are another branch of marine mammals, seem most closely related to elephants.

fossil the trace or remains of an organism that lived long ago, most commonly preserved in sedimentary rock

Academic Vocabulary

infer to derive by reasoning

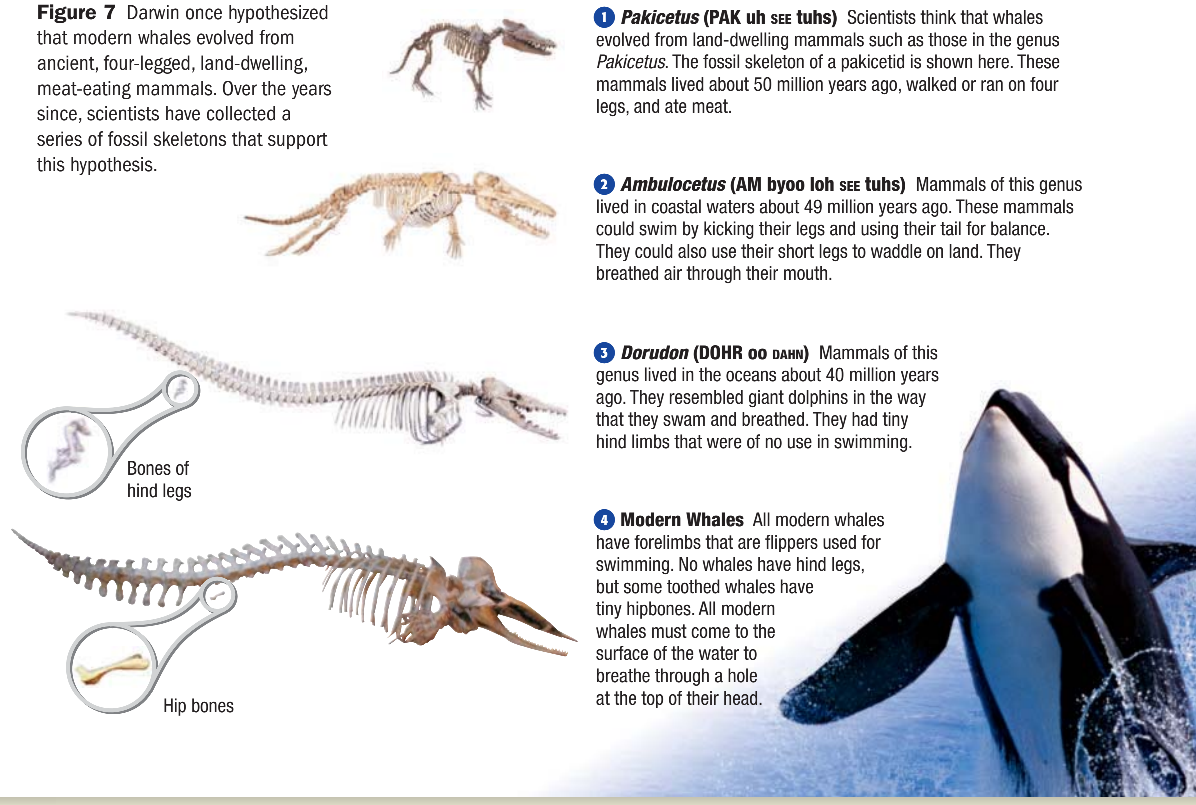
What Darwin Explained

Darwin's book was more than an explanation of his theory. It also included a thorough presentation of the evidence that living species evolved from organisms that lived in the past. Darwin had studied much of the data that was available in his time. **Darwin presented a unifying explanation for data from multiple fields of science.** Today, these sciences include geology, geography, ecology, developmental biology, anatomy, genetics, and biochemistry. Scientists continue to draw upon the power of Darwin's explanations.

The Fossil Record Have you ever looked at a series of historical maps of a city? You can infer that buildings and streets have been added, changed, or destroyed over time. Similarly, you can infer past events by looking at **fossils,** traces of organisms that lived in the past. All fossils known to science make up the *fossil record*.

Sometimes, comparing fossils and living beings reveals a pattern of gradual change from the past to the present. Darwin noticed these patterns, but he was aware of many gaps in the patterns. For example, Darwin suggested that whales might have evolved from a mammal that lived on land. But at the time, no known fossils were "in between" a land mammal and a whale.

Figure 7 Darwin once hypothesized that modern whales evolved from ancient, four-legged, land-dwelling, meat-eating mammals. Over the years since, scientists have collected a series of fossil skeletons that support this hypothesis.



1 ***Pakicetus*** **(PAK uh SEE tuhs)** Scientists think that whales evolved from land-dwelling mammals such as those in the genus *Pakicetus*. The fossil skeleton of a pakicetid is shown here. These mammals lived about 50 million years ago, walked or ran on four legs, and ate meat.

2 ***Ambulocetus*** **(AM byoo loh SEE tuhs)** Mammals of this genus lived in coastal waters about 49 million years ago. These mammals could swim by kicking their legs and using their tail for balance. They could also use their short legs to waddle on land. They breathed air through their mouth.

3 ***Dorudon*** **(DOHR oo DAHN)** Mammals of this genus lived in the oceans about 40 million years ago. They resembled giant dolphins in the way that they swam and breathed. They had tiny hind limbs that were of no use in swimming.

4 **Modern Whales** All modern whales have forelimbs that are flippers used for swimming. No whales have hind legs, but some toothed whales have tiny hipbones. All modern whales must come to the surface of the water to breathe through a hole at the top of their head.

Why It Matters

Extinct Organisms Tell students that scientists estimate that 99 percent of all animal and plant species that ever existed are now extinct. A large number of extinct species have been discovered by paleontologists. In one small area in Wyoming, early Eocene rocks have yielded fossils of more than 50 species of animals.

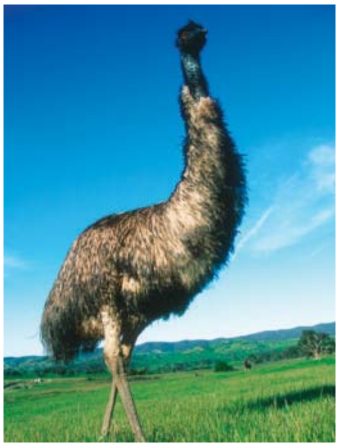
Differentiated Instruction

Basic Learners

Anatomical Comparisons Have students look online at museum sites to find photos or artistic skeletal reconstructions for the whale, hippo, manatee, and elephant. Students should compare images of the skulls and leg bones of these mammals. Have them create a poster of their findings. **LS Visual, Kinesthetic**


Rhea (South America)


Ostrich (Africa)


Emu (Australia)

Darwin predicted that *intermediate forms* between groups of species might be found. And indeed, many new fossils have been found, such as those shown in **Figure 7.** But the conditions that create fossils are rare, so we will never find fossils of every species that ever lived. The fossil record will grow but will never be complete.

Biogeography *Biogeography* is the study of the locations of organisms around the world. When traveling, Darwin and Wallace saw evolution at work when they compared organisms and environments. For example, Darwin saw the similarity of the three species of large birds in **Figure 8.** He found each bird in a similar grassland habitat but on a separate continent. This finding was evidence that similar environments shape the evolution of organisms in similar ways.

Sometimes, geography separates populations. For example, a group of organisms may become separated into two groups living on two different islands. Over time, the two groups may evolve in different patterns. Generally, geologists and biologists have found that the movement of landforms in Earth's past helps to explain patterns in the types and locations of both living and fossil organisms.

Developmental Biology The ancestry of organisms is also evident in the ways that multicellular organisms develop from embryos. The study of such development is called *embryology*. This study is interesting because embryos undergo many physical and genetic changes as they develop into mature forms.

Scientists may compare the embryonic development of species to look for similar patterns and structures. Such similarities most likely derive from an ancestor that the species have in common. For example, at some time during development, all vertebrate embryos have a tail. *Vertebrates* are animals that have backbones.

Reading Check *Why is the fossil record incomplete?*

Figure 8 Three unique bird species are shown here. Each of these is similar in size, shape, eating habits, and habitat. However, each species lives on a separate continent. **What does this pattern suggest about evolution?**

SCILINKS.
www.scilinks.org
Topic: Fossil Record
Code: HX80615

READING TOOLBOX

Visual Literacy Tell students that the three birds illustrated in **Figure 8** may have evolved from the same ancestral species. Early geologic history suggests that the Earth's continents separated, thus separating the original lineages into different groups.

Answers to Caption Questions

Figure 8: that environments influence the evolution of new organisms

Differentiated Instruction

Basic Learners

Organizing Concepts Have students study samples or pictures of different types of fossils. Students should note any similarities between the fossils and modern organisms. LS Visual

MISCONCEPTION ALERT

Selection, Not Induction Selection cannot induce changes. Some people think the environment can induce mutations in organisms, or that organisms can be "forced" to adapt. This is similar to Lamarck's mistaken idea. We now know that natural selection does not induce changes in genes. Rather, it selects from existing genes, indirectly, by selecting organisms with the most adaptive traits for a given time and place. Adaptation is the net average result of many individual instances of survival and reproduction (or death and extinction) over time.

Teach, *continued*

Teaching Key Ideas

Wing Structure Tell students that, although penguins are not able to fly, the movement of their wings under water resembles the motion of flying. Penguins have much heavier bones than birds that fly. Ask students what adaptive advantage this bone structure gives penguins. (The hefty bone structure of a penguin's wings is an advantage for moving through water, which is far denser than air. Also, heavier bones are not a disadvantage because of the buoyancy provided by water.)

READING TOOLBOX

Visual Literacy Direct students' attention to **Figure 9.** Have students identify the homologous parts of each animal (bones with matching colors). Another example of homologous structures is *vestigial* structures. For example, some bones in some animals are very small and have no apparent function. But similar bones in other, similar animals have a definite function. A hypothesis is that the animals with the "useless" bones evolved from animals with the functional bones. The hind limb bones of whales are vestigial structures.

Answers to Caption Questions

Figure 9: that all vertebrates share a common ancestor

Figure 10: Genes change (by mutation) over time; the genes of populations may diverge over time after once-related populations no longer interbreed.

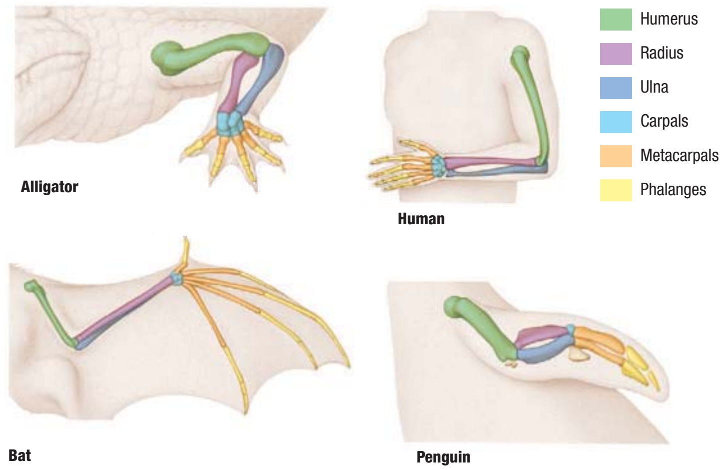


Figure 9 Although they look very different from one another on the outside, the forelimbs of most tetrapods (vertebrates that have four limbs) include a similar group of bones. **› What hypothesis does this observation support?**

Hemoglobin Comparison

Animal with hemoglobin	Amino acids that differ from human hemoglobin
Gorilla	1
Rhesus monkey	8
Mouse	27
Chicken	45
Frog	67
Lamprey	125

Figure 10 Scientists have compared the amino acids that make up hemoglobin proteins in several species. Organisms that have fewer differences are more likely to be closely related. **› How does this pattern relate to genetic change?**

Anatomy Another place to observe the results of evolution is inside the bodies of living things. The bodily structure, or *anatomy,* of different species can be compared. Many internal similarities are best explained by evolution and are evidence of how things are related.

For example, the hypothesis that all vertebrates descended from a common ancestor is widely accepted. Observations of the anatomy of both fossil and living vertebrates support this hypothesis. When modern vertebrates are compared, the difference in the size, number, and shape of their bones is clear. Yet the basic pattern of bones is similar. In particular, the forelimbs of many vertebrates are composed of the same basic groups of bones, as **Figure 9** shows. This pattern of bones is thought to have originated in a common ancestor. So, the bones are examples of **homologous** structures, characteristics that are similar in two or more species and that have been inherited from a common ancestor of those species.

Biochemistry To explain the patterns of change seen in anatomy, scientists make testable predictions. For example, if species have changed over time, the genes that determine their characteristics should also have changed. Recall that genes can change by mutation and that such change can make new varieties appear. Then, natural selection may "select against" some varieties and so "favor" others.

Scientists have observed that genetic changes occur over time in all natural populations. A comparison of DNA or amino-acid sequences shows that some species are more genetically similar than others. These comparisons, like those in anatomy, are evidence of hereditary relationships among the species. For example, comparing one kind of protein among several species reveals the pattern shown in **Figure 10.** The relative amount of difference is consistent with hypotheses based on fossils and anatomy.

› Reading Check *What explains similarities in bone structure?*

Differentiated Instruction

Advanced Learners/GATE

Cytochrome c Evidence Have students research studies of Cytochrome c as evidence for common ancestry among organisms. What is Cytochrome c? Have students find out how this substance has changed the way organisms are classified. Interested students could report their findings to the class. **LS Verbal, Logical**

Alternative Assessment

Evidence Brochure Have students create a brochure with the title "Why Are Darwin's Ideas Now Widely Accepted?" The brochure should include examples of the evidence used by the scientific community to support Darwin's ideas. Students should conclude the brochure with some of the unanswered evolution questions that are being explored by scientists. **LS Verbal**

Evaluating Darwin's Ideas

Why was Darwin such an important scientist? **Darwin's work had three major strengths: evidence of evolution, a mechanism for evolution, and the recognition that variation is important.** Today, Darwin is given credit for starting a revolution in biology.

Strengths Darwin was *not* the first to come up with the idea that evolution happens, but he was the first to gather so much evidence about it. He described his most famous book as "one long argument" that evolution is possible. Before publishing, Darwin collected and organized many notes, observations, and examples, such as the illustration shown in **Figure 11.** So, one strength of Darwin's work is that it is supported by, and helps explain, so much data.

Darwin also presented a logical and testable mechanism that could account for the process of evolution. His theory of natural selection was well thought out and convincing to scientists of his time as well as today. It has since become a foundation of biology.

Finally, Darwin changed the way scientists thought about the diversity of life. Before Darwin, most scientists saw species as stable, unchanging things. They classified species based on average appearances and ignored variation. But Darwin showed that variation was everywhere and could serve as the starting point for evolution.

Weaknesses Darwin's explanations were incomplete in one major way: He knew very little about genetics. **Inherited variation was crucial to Darwin's theory of natural selection, yet his theory lacked a clear mechanism for inheritance.** At different times, Darwin proposed or accepted several ideas for such a mechanism, but none of them were correct. He thought about this problem for much of his life.

Darwin never knew it, but Gregor Mendel had begun to solve this problem. However, Mendel's findings about heredity were not widely published until 1900. Those findings opened the door to a new age in the study of evolution. Today, an understanding of genetics is essential to understanding evolution.

Reading Check ***What did Darwin do before publishing his ideas?***

Figure 11 This drawing of a rhea was printed in one of Darwin's books. Darwin collected and organized a large amount of data to help explain his ideas. **How else did Darwin support his main theory?**

homologous (hoh MAHL uh guhs) describes a character that is shared by a group of species because it is inherited from a common ancestor

Section 2 Review

KEY IDEAS

1. **Outline** Darwin's theory of evolution by natural selection. Be sure to include four logical steps.
2. **List** the kinds of data that Darwin helped explain.
3. **Compare** the strengths and weaknesses of Darwin's ideas.

CRITICAL THINKING

4. **Applying Information** Use the theory of natural selection to explain how the average running speed of a population of zebras might increase over time.
5. **Elaborating on Explanations** Describe how a single pair of seed-eating bird species could have arrived on an island and evolved into an insect-eating species. (Hint: Consider the food available.)

USING SCIENCE GRAPHICS

6. **Process Cartoon** Create your own version of **Figure 6** in the form of a four-panel cartoon. Choose a unique type of organism to represent the population undergoing natural selection. Also, depict a unique set of traits and limiting conditions for the population.

Answers to Caption Questions

Figure 11: by collecting a vast amount of data and presenting his ideas clearly and logically

Close

Formative Assessment

Darwin's theory of evolution by natural selection explains changes in _____.

A. individuals (Incorrect. Individuals within a population do not evolve.)
B. genetic make up (Incorrect. The genetic make up of an individual refers to traits that are inherited; these can help in survival and reproduction, but are not explained by Darwin's theory.)
C. populations or species (Correct. Only populations or species are the units that can evolve due to natural selection.)
D. the environment (Incorrect. Darwin's theory explains changes in populations as a result of adapting to the environment.)

Answers to Section Review

1. Every population has overproduction and variation; only some individuals will be "selected" to survive; over time, the number of individuals that carry advantageous traits will increase in a population (adaptation).
2. data from geology, geography, ecology, developmental biology, anatomy, and biochemistry
3. strengths: his evidence of evolution, his mechanism for evolution, and his recognition that variation was important; weaknesses: lack of a clear mechanism for inheritance to explain inherited variations
4. Sample answer: Some zebras born into a population may be faster than others. These zebras could escape from predators better than slower zebras could. The faster zebras would be more likely to survive and reproduce. Over time, faster zebras would become more common in the population.
5. Sample answer: If the finches could eat and survive to reproduce several times, then finches with bills that were better for catching and eating insects would be more likely to survive and reproduce. Eventually, the insect-eating bill would be the most common trait in the population. Over time, the population would continue to change as it adapted to the island environment. If the population became so different from its ancestral population that it could no longer interbreed, then it would be considered a new species.
6. Students' cartoons will vary, but should describe and demonstrate visually the same four steps of natural selection shown in Figure 6.

Section 3

Focus

This section describes how discoveries in genetics and ongoing developments in other fields have been used to update Darwin's theory. Students then see how Darwin's updated theory is applied to explain evolution at different levels, or scales.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Why It Matters

Antibiotic-Resistant Bacteria

Antibiotic resistance has become a problem because of the widespread use of antibiotics to treat human diseases, prevent diseases, and to prevent disease in domestic animals used for food. In the presence of antibiotics, a bacterium's DNA with a mutation that allows it to survive in the antibiotic environment, will reproduce and pass on the mutation. Soon, bacteria with these mutations may constitute the majority of disease-causing bacteria.

Answers to Caption Questions

Figure 12: by looking at genetic changes in populations over time, or relating genes to changes in species

Section 3

Beyond Darwinian Theory

Key Ideas	Key Terms	Why It Matters
How has Darwin's theory been updated? At what scales can evolution be studied?	speciation	The study of evolution was new in Darwin's day, but it is essential to biology today.

Does modern evolutionary theory differ from Darwin's theory? Yes and no. Darwin observed and explained much about the large-scale patterns of biology, but some patterns have yet to be explained. He proposed a logical process (natural selection) for evolution, even though he could not explain evolution at the genetic level. Biology has made great progress since Darwin's time. Modern evolutionary theory relates patterns and processes at many levels.

Darwin's Theory Updated

Since Darwin's work was published, his theory has been thoroughly investigated. **Discoveries since Darwin's time, especially in genetics, have been added to his theory to explain the evolution of species.** Some parts of Darwin's theory have been modified, and new parts have been added. But mostly, Darwin's theory has been supported.

The first major advance beyond Darwin's ideas was the rediscovery, in 1900, of Mendel's *laws of heredity*. These ideas opened the door for a genetic explanation of evolution. By the 1940s, scientists began to weave Darwin's theory together with newer studies of fossils, anatomy, genetics, and more. This unification is called the *modern synthesis* of evolutionary theory.

In particular, biologists have learned that evolution can result from processes other than natural selection. For example, survival and reproduction can be limited by chance or by the way that genes work. In the modern view, any or all of these forces may combine with natural selection (as described by Darwin). This synthesis helps explain some of the patterns of evolution that were unexplained by natural selection alone.

Figure 12 Modern genetic science and Darwin's theory have been united. **How could this genetic scientist study evolution?**

Remaining Questions Some of the most important questions about evolution have been asked only recently. So, many questions are still being investigated, as shown in **Figure 12.** Modern biologists have tentative answers to the following questions:

- **Can an individual evolve?** Darwin correctly inferred that individuals do not evolve. They may respond to outside forces, but individuals do not pass on their responses as heritable traits. Rather, populations evolve when natural selection acts (indirectly) on genes.

Key Resources

Visual Concepts

Gradualism

Comparing Punctuated Equilibrium and Gradualism

Reproductive Isolation

Hands-On

QuickLab

Selection Model

15 min

In this lab, you will model the process of natural selection. Can you predict the outcome?

Procedure

1. Work with a partner. Spread out a **handful of small, colored candies** onto a **piece of cloth or paper that has a colorful design.** One person should act as "predator" of the candies while the other uses a **stopwatch** to monitor time and then records the results.
2. The "predator" should use **tweezers** to try to "capture" as many candies as possible within 10 s.
3. Record the results, and switch roles. Repeat 10 times.

Analysis

1. **Graph** the total number of each color of candy that was "captured." Use a bar graph.
2. CRITICAL THINKING **Evaluating Results** Explain why some colors were "captured" more often than others.
3. CRITICAL THINKING **Forming Hypotheses** Predict the outcome if the background is changed to solid red.

- **Is evolution the survival of the fittest?** Natural selection can act only on the heritable variation that exists in a population. Chance variations do not always provide the best adaptation for a given time and place. So, evolution does not always produce the "fittest" forms, just those that "fit" well enough to leave offspring.
- **Is evolution predictable?** Evolution sometimes results in larger or more-complex forms of life, but this result cannot be predicted. Many forms of life are simple yet successful. For example, bacteria have been abundant for billions of years. In contrast, some complex organisms, such as dinosaurs, have appeared, been successful for a time, and then almost completely disappeared. Mostly, scientists cannot predict the exact path that evolution will take.

> **speciation** (SPEE shee AY shuhn) the formation of new species as a result of evolution

Studying Evolution at All Scales

Because it affects every aspect of biology, scientists can study evolution at many scales. Generally, these scales range from microevolution to macroevolution, with speciation in between. Informally, *microevolution* refers to evolution as a change in the genes of populations, whereas *macroevolution* refers to the appearance of new species over time.

Speciation The link between microevolution and macroevolution is speciation. **Speciation,** the formation of new species, can be seen as a process of genetic change or as a pattern of change in the form of organisms. Recall that a *species* is a group of organisms that are closely related and that can mate to produce fertile offspring. So, speciation can begin with the separation of populations of the same species. For example, the two kinds of squirrels shown in **Figure 13** seem to be evolving from one species into two because of separation.

Figure 13 These squirrels are closely related but are almost different enough to be unique species. Their populations are separated by the Grand Canyon.

Reading Check *At what scales can evolution be studied?*

Differentiated Instruction

Basic Learners

What Can Evolve? Have students review the definition of evolution, and then write an explanation of why a single person or animal cannot evolve. (Evolution is a change in species over time; a single animal or person is just one member of a species; so, a change in one person or one animal does not equal a change in a species. Also, evolution involves generations over time, not just one lifetime.) LS Verbal

Struggling Readers

Everyday Words Have students read the first paragraph under "Studying Evolution at All Scales." Ask for a definition of *scales* in this context. (relative sizes) Ask for an explanation of how this definition applies to the topic. (Evolution happens on several levels or "sizes:" macro, large; micro, small.) LS Verbal

QuickLab

Teacher's Notes Help students see how the process model in this activity, if replicated over generations, results in changes to a population. Use candy with colors that match well with the colors of the background you select. Fabric and wrapping paper make good backgrounds.

Materials

- colored candies (10–15 pieces)
- multi-colored patterned background (cloth or paper)
- watch
- tweezers (plastic)

Safety Cautions Remind students not to taste food items and to wash their hands after the activity. Food items used should be treated as potentially pathogenic and disposed of as such.

Answers to Analysis

1. Check graphs for titles and labels on axes. Graphs should show that certain colors were captured more often than others.
2. The color(s) captured least often will be those that match or visually blend into the background; those that are captured most will be those that stand out visually.
3. Sample hypothesis: red and colors similar to red would be captured less often than green, blue, or yellow. (The actual outcome depends on the background used.)

Teach, *continued*

Teaching Key Ideas

Visual Literacy Tell students that the moth and orchid in **Figure 14** are examples of coevolution. When Darwin studied this orchid (*Angraecum sesquipedale*), he predicted that there must be a moth with a tongue long enough to reach into the 11-inch nectar tube. When the Madagascan sphinx moth was discovered 40 years later, it was named *Xanthopan morganii praedicta,* to honor Darwin's prediction. Ask students what it means to say that these species have coevolved to the point of being codependent. (Each species relies and benefits from the presence of the other. If either species were eliminated, the other would be less able to reproduce and survive.) **LS Visual**

SCILINKS. www.scilinks.org Topic: Evolution Code: HX80546

ACADEMIC VOCABULARY

random without aim or plan; purposeless

Processes of Microevolution To study microevolution, we look at the processes by which inherited traits change over time in a population. Five major processes can affect the kinds of genes that will exist in a population from generation to generation. These processes are summarized below. Notice that natural selection is only one of the five. You will learn more about these processes soon.

- **Natural Selection** As you have learned, natural selection can cause an increase or decrease in certain alleles in a population.
- **Migration** *Migration* is the movement of individuals into, out of, or between populations. Migration can change the numbers and types of alleles in a population.
- **Mate Choice** If parents are paired up randomly in a population, a random assortment of traits will be passed on to the next generation. However, if parents are limited or selective in their choice of mates, a limited set of traits will be passed on.
- **Mutation** Mutation can change the numbers and types of alleles from one generation to the next. However, such changes are rare.
- **Genetic Drift** The random effects of everyday life can cause differences in the survival and reproduction of individuals. Because of these differences, some alleles may become more or less common in a population, especially in a small population.

Patterns of Macroevolution To study macroevolution, we look at the patterns in which new species evolve. We may study the direction, diversity, or speed of change. Patterns of change are seen when relationships between living and fossil species are modeled.

- **Convergent Evolution** If evolution is strongly directed by the environment, then species living in similar environments should evolve similar adaptations. Many examples of this pattern were observed by Darwin and can be seen today.
- **Coevolution** Organisms are part of one other's environment, so they can affect one another's evolution. Species that live in close contact often have clear adaptations to one another's existence, as shown in **Figure 14.**

Figure 14 This moth species and this orchid species have coevolved in a close relationship. The moth feeds exclusively on the orchid, and the orchid's pollen is spread by the moth.

Differentiated Instruction

Struggling Readers

Key-Term Fold Have students create a Key-Term Fold with all of the bulleted paragraph titles on these two pages. Students should then provide an example or explanation of how each term relates to the topic of evolution. Terms to include are: *natural selection, migration, mate choice, mutation, genetic drift, convergent evolution, coevolution, adaptive radiation, extinction, gradualism,* and *punctuated equilibrium.* **LS Verbal, Kinesthetic**

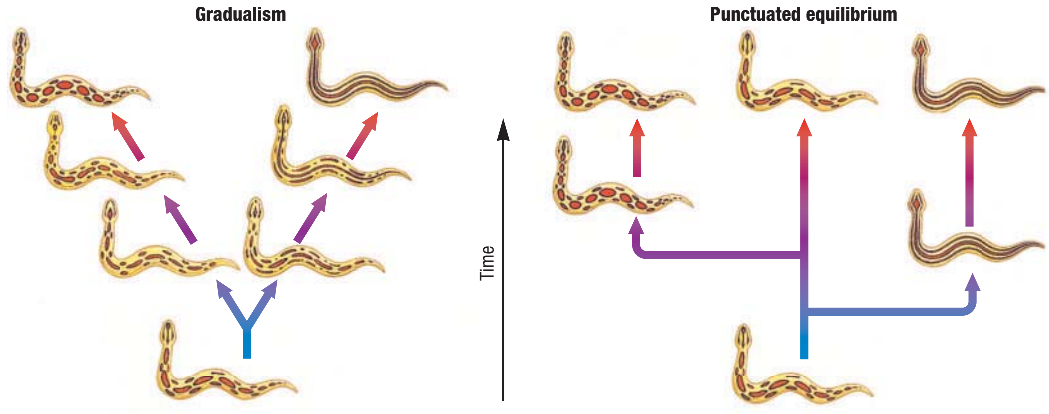


Figure 15 Two differing models of the pace of evolution have been proposed. **› Do these models show microevolution or macroevolution?**

- **Adaptive Radiation** Over time, species may split into two or more lines of descendants, or *lineages*. As this splitting repeats, one species can give rise to many new species. The process tends to speed up when a new species enters an environment that contains few other species. In this case, the pattern is called *adaptive radiation*.
- **Extinction** If all members of a lineage die off or simply fail to reproduce, the lineage is said to be *extinct*. The fossil record shows that many lineages have arisen and radiated, but only a few of their descendants survived and evolved into the species present today.
- **Gradualism** In Darwin's day, the idea of slow, gradual change was new to geology as well as biology. Darwin had argued that large-scale changes, such as the formation of new species, must require many small changes to build up gradually over a long period of time. This model is called *gradualism* and is shown in **Figure 15.**
- **Punctuated Equilibrium** Some biologists argue that species do not always evolve gradually. Species may remain stable for long periods until environmental changes create new pressures. Then, many new species may "suddenly" appear. This model is called *punctuated equilibrium* and is shown in **Figure 15.**

READING TOOLBOX

Taking Notes Complete your notes summarizing the major concepts from this chapter. Be sure to include microevolution and macroevolution.

Section 3 Review

› KEY IDEAS

1. **Describe** how Darwin's ideas have been updated. Be sure to mention the role of natural selection in modern evolutionary theory.
2. **List** the scales at which evolution can be studied, and list the patterns and processes studied.

CRITICAL THINKING

3. **Arguing Logically** A classmate states that because land animals evolved from fishes and then flying things evolved from walking things, we can predict that future life will evolve to travel in outer space. Write a logical argument against this statement. Be sure to support your argument with examples.

ALTERNATIVE ASSESSMENT

4. **Who's Who** Make a brochure or poster entitled "Who's Who of Evolutionary Theory." Use reference sources to find basic facts about major evolutionary scientists that lived during or after Darwin's lifetime.

Answers to Caption Questions

Figure 15: macroevolution

READING TOOLBOX

Taking Notes Notes should resemble the example shown on the Reading Toolbox page at the beginning of this chapter.

› Close

Formative Assessment

What term describes patterns in the overall direction, diversity or rate of change of species?

A. speciation (Incorrect. Speciation is the formation of new species.)
B. gradualism (Incorrect. Gradualism is one specific model of the pace of evolution.)
C. microevolution (Incorrect.)
D. macroevolution (Correct.)

Answers to Section Review

1. Discoveries since Darwin's time, especially in genetics, have been added to his theory to explain the evolution of species.
2. microevolution, speciation, and macroevolution; natural selection, migration, mate choice, mutation, genetic drift; convergent evolution, coevolution, adaptive radiation, extinction, gradualism, punctuated equilibrium.
3. The argument assumes that evolution has a direction or destination. However, there are many examples of lineages that evolve "back" to a prior type of adaptation, such as mammals that became adapted to ocean life (whales), or reptiles that evolved to lack limbs (snakes). Evolution is not exactly predictable.
4. possible scientists include: Ronald A. Fisher, J.B.S. Haldane, Sewall Wright, Theodosius Dobzhansky, Ernst Mayr, George Gaylord Simpson, Julian Huxley, Steven J. Gould, and Douglas J. Futuyma

Lab

Time Required

Two 45-minute class periods

Ratings

EASY → HARD

Teacher Prep

Student Setup

Concept Level

Cleanup

Safety Caution

Remind students to be careful with scissors and always cut in a direction away from the face and body.

Tips and Tricks

You may wish to review and clarify the principles of selection. Students will simulate the breeding of several generations of birds and observe the effect of changes in phenotype on the evolutionary success of these animals. The random nature of mutations is demonstrated by randomly changing the anterior and posterior wing position and wing circumference of the birds. To save time, have students create their data tables before beginning the lab.

Skills Practice

Chapter 16 Lab

Objectives

- Model natural selection.
- Relate favorable mutations to selection and evolution.

Materials

- construction paper
- meterstick or tape measure
- scissors
- cellophane tape
- soda straws
- marker, felt-tip
- penny or other coin
- die, six-sided

Safety

Natural Selection Simulation

In this lab, you will use a paper model of a bird to model the selection of favorable traits in a new generation. This imaginary bird, the Egyptian origami bird (*Avis papyrus*), lives in dry regions of North Africa. Imagine that the birds must fly long distances between water sources in order to live and reproduce successfully.

Procedure

Model Parental Generation

1. Cut a sheet of paper into two strips that are 2 cm × 20 cm each. Make a loop with one strip of paper. Let the paper overlap by 1 cm, and tape the loop closed. Repeat for the other strip.
2. Tape one loop 3 cm from one end of the straw and one loop 3 cm from the other end, as pictured. Use a felt-tip marker to mark the front end of the "bird." This bird represents the parental generation.
3. Test how far your parent bird can fly by releasing it with a gentle overhand pitch. Test the bird twice. Record the bird's average flight distance in a data table like the one shown.

Model First (F_1) Generation

4. Each origami bird lays a clutch of three eggs. Assume that one of the chicks is identical to the parent. Use the parent data to fill in your data table for the first new chick (Chick 1).
5. Make two more chicks (Chick 2 and Chick 3). Assume that these chicks have mutations. Follow Steps A through C for each chick to determine the effects of each mutation.

Data for All Generations

Bird	Coin flip (H or T)	Die throw (1–6)	Anterior wing (cm) Width	Anterior wing (cm) Circum.	Anterior wing (cm) Distance from front	Posterior wing (cm) Width	Posterior wing (cm) Circum.	Posterior wing (cm) Distance from back	Average distance flown (m)
Parent	NA	NA	2	19	3	2	19	3	
Generation 1									
Chick 1									
Chick 2									
Chick 3									
Generation 2									
Chick 1									

90 min

Step A Flip a coin to find out which end is affected by the mutation.

Heads = Front wing is affected.

Tails = Back wing is affected.

Step B Throw a die to find out how the mutation affects the wing.

⚀ = Wing position moves 1 cm toward the end of the straw.

⚁ = Wing position moves 1 cm toward the middle.

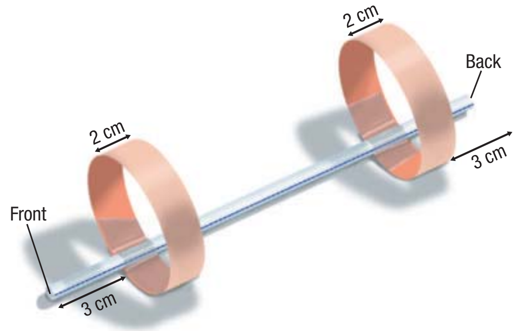
⚂ = Wing circumference increases by 2 cm.

⚃ = Wing circumference decreases by 2 cm.

⚄ = Wing width increases by 1 cm.

⚅ = Wing width decreases by 1 cm.

Step C If a mutation causes a wing to fall off the straw or makes a wing's circumference smaller than the circumference of the straw, the chick cannot "survive." If such a mutation occurs, record it as "lethal," and then produce another chick.



6. For each new chick, record the mutation and the new dimensions of each wing.
7. Test each bird twice by releasing it with a gentle overhand pitch. Release the bird as uniformly as possible. Record the distance that each bird flies. The most successful bird is the one that flies the farthest.

Model Subsequent Generations

8. Assume that the most successful bird in the previous generation is the sole parent of the next generation. Using this bird, repeat steps 4–7.
9. Continue to produce chicks and to test and record data for eight more generations.

Clean Up and Dispose

10. Clean up your work area and all lab equipment. Return lab equipment to its proper place. Dispose of paper scraps in the designated waste container. Wash your hands thoroughly before you leave the lab and after you finish all work.

Analyze and Conclude

1. **Summarizing Results** Describe any patterns in the evolution of the birds in your model.
2. **Evaluating Models** How well does this lab model natural biological processes? What are the limitations of this model?
3. **Analyzing Data** Compare your data with your classmates' data. Identify any similarities and differences. Try to explain any trends that you notice in terms of the theory of natural selection.

Extensions

4. **Design an Experiment** Propose a new hypothesis about natural selection that you could test by observing real organisms. Write a brief proposal describing an experiment that could test this hypothesis. Be sure to give your prediction, explain your methods, identify variables, and plan for control groups.

Answers to Analyze and Conclude

1. Most students should find a pattern of improving flight distance after a few generations.
2. This lab models a simple organism with only a few possible traits to affect success, so the selection and adaptation are quick and obvious, which is much simpler than real life. The process would be much slower and less obvious with real populations. The obvious and rapid results of the model present an advantage over doing an experiment with living populations.
3. Some students may have higher rates of chick mortality and lower rates of adaptation. Some students may reach a maximum flight distance after some generations, corresponding to the best possible combination of traits (within the bird's physical limits) for flight distance. The patterns of variation and gradual adaptation are consistent with the theory of natural selection.
4. Check that students include a prediction, explain methods, identify variables, and plan for control groups.

Key Resources

- Holt Lab Generator
- Lab Datasheet (Levels A, B, C)
- Holt Science Biology Video Labs
- Virtual Investigations

Chapter 16

SUPER SUMMARY

Have students connect the major concepts of this chapter through an interactive Super Summary. Visit **go.hrw.com** and type in keyword **HX8EVOS** to access the Super Summary for this chapter.

Reteaching Key Ideas

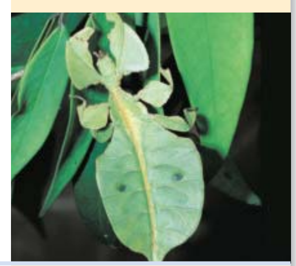
Models Explain that models are abstractions that describe and help us understand the mechanics of evolutionary change. Emphasize that a good scientist tries to make a model fit his or her research results, not the other way around. **LS Visual**

Crossword Study Tool Have students use the information in their Key-Term Folds to construct crossword puzzles using the definitions as the clues. Students should trade puzzles and complete them to test their understanding of the definitions. **LS Verbal**

Chapter 16 Summary

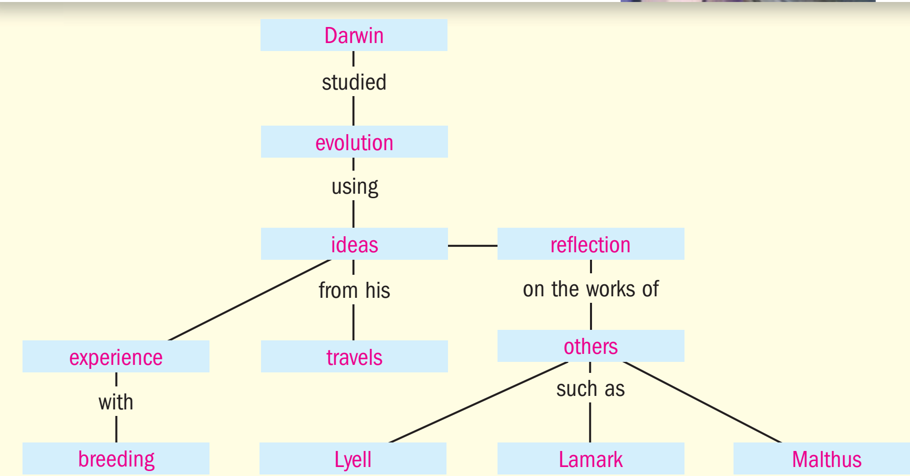
go.hrw.com
SUPER SUMMARY
Keyword: HX8EVOS

Key Ideas	Key Terms
1 Developing a Theory › Modern evolutionary theory began when Darwin presented evidence that evolution happens and offered an explanation of how evolution happens. › Darwin's experiences provided him with evidence of evolution at work. › Darwin was influenced by ideas from the fields of natural history, economics, and geology.	**evolution** (375) **artificial selection** (377)
2 Applying Darwin's Ideas › Darwin's theory of evolution by natural selection predicts that over time, the number of individuals that carry advantageous traits will increase in a population. › Darwin presented a unifying explanation for data from multiple fields of science. › The strengths of Darwin's work—evidence of evolution, a mechanism for evolution, and the recognition that variation is important—placed Darwin's ideas among the most important of our time. However, Darwin lacked a mechanism for inheritance.	**natural selection** (380) **adaptation** (381) **fossil** (382) **homologous** (384)
3 Beyond Darwinian Theory › Discoveries since Darwin's time, especially in genetics, have been added to his theory to explain the evolution of species. › Because it affects every aspect of biology, scientists can study evolution at many scales. Generally, these scales range from microevolution to macroevolution, with speciation in between.	**speciation** (387)



Answer to Concept Map

The following is one possible answer to Chapter Review question 2.



Chapter 16 Review

READING TOOLBOX

1. **Hypothesis or Theory?** Explain why Darwin's theory is not *the* theory of evolution.
2. **Concept Map** Make a concept map that describes the origins of Darwin's theory. Try to include the following words: *Darwin, ideas, evolution, experience, others, travels, reflection, breeding, Lamarck, Malthus,* and *Lyell.*

Using Key Terms

3. Explain the difference between the terms *natural selection* and *artificial selection*.
4. Use the following terms in the same sentence: *macroevolution, microevolution,* and *speciation.*

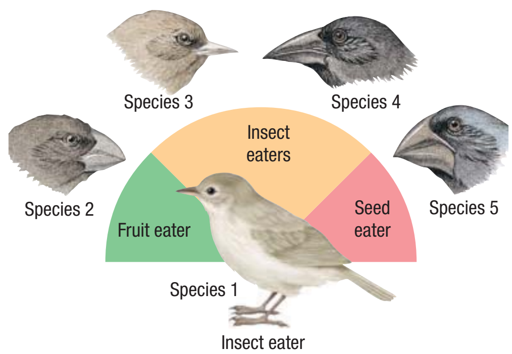
For each of the following terms, write a definition in your own words.

5. *evolution*
6. *homologous structures*

Understanding Key Ideas

7. After studying plant and animal life in South America and the Galápagos Islands, Darwin proposed that
   - **a.** Galápagos species had descended from South American species.
   - **b.** South American species had descended from Galápagos species.
   - **c.** Galápagos species and South American species were unrelated.
   - **d.** Galápagos species and South American species had descended from European species.
8. Darwin was influenced by Malthus's ideas about
   - **a.** inheritance.
   - **b.** populations.
   - **c.** the fossil record.
   - **d.** natural history.
9. Which of the following is a form of biochemical evidence that can be used to study evolution?
   - **a.** speciation.
   - **b.** intermediate forms.
   - **c.** homologous structures.
   - **d.** amino-acid similarities.
10. Which of the following was a weakness in Darwin's ideas about evolution?
    - **a.** lack of evidence for evolution
    - **b.** lack of a mechanism for evolution
    - **c.** lack of a mechanism for inheritance of traits
    - **d.** lack of recognition of the importance of variation
11. Modern evolutionary theory has incorporated most of Darwin's ideas except
    - **a.** Darwin's laws of heredity.
    - **b.** Darwin's theory of natural selection.
    - **c.** Darwin's idea that species evolve gradually.
    - **d.** Darwin's predictions of intermediate forms.

This image shows several species of finches that are related by evolution. Species 1 is from South America. Species 2–5 live in the Galápagos Islands. Use the image to answer the following question.



12. The ancestor of all Galápagos finches was probably
    - **a.** a fruit eater.
    - **b.** a seed eater.
    - **c.** a fish eater.
    - **d.** an insect eater.

Explaining Key Ideas

13. **Describe** the relationship between Darwin's ideas and modern evolutionary theory.
14. **List** the four steps of evolution by natural selection.
15. **Explain** how biogeography provides evidence for the influence of environment on evolution.
16. **Identify** two mechanisms other than natural selection that can affect the relative ratios of traits in populations of organisms.

Assignment Guide

SECTION	ITEMS
1	2, 3, 5, 7, 8, 12, 13, 17, 18, 19, 20, 24, 25, 26, 27, 28
2	1, 3, 6, 9, 10, 14, 15
3	4, 11, 16, 21, 22, 23

Review

Reading Toolbox

1. Evolutionary theory today has grown beyond Darwin's original ideas and continues to be modified as new observations, hypotheses, ideas, and processes are discovered, proposed, investigated, and modeled.
2. See previous page for answer to concept map.

Using Key Terms

3. *Natural selection* is done by nature. *Artificial selection* is done by people for a purpose.
4. Evolution can be studied at the small scale of *microevolution* or at the large scale of *macroevolution*, while *speciation* is in between these two scales.
5. *Evolution* is the process of change in traits over time that can lead to changes in species over time.
6. *Homologous structures* are body parts in different species that have the same origin in an evolutionary ancestor.

Understanding Key Ideas

7. a **8.** b **9.** d **10.** c
11. a **12.** d

Explaining Key Ideas

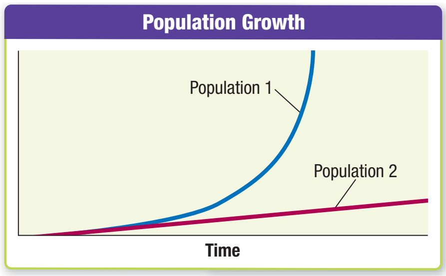
13. Darwin presented evidence and an explanation for how evolution happens through natural selection. Modern evolutionary theory includes other processes in addition to natural selection. Evidence to support the modern theory comes from a deeper understanding of genetics, fossils, and anatomy. Some of this evidence was completely unknown to Darwin.
14. overproduction, variation, selection, adaptation
15. Species with similar characteristics can be found in similar environments throughout the world. This observation supports the idea that environment shapes evolution.
16. Aside from natural selection, trait ratios in a population can be affected by migration, patterns in mate choice, mutations, and the long-term isolation of a population.

Interpreting Graphics

17. c **18.** b
19. d

Using Science Graphics

This graph shows the population growth of two different populations over the same period of time. Use the graph to answer the following question(s).



17. From the graph, it is evident that Population 1 underwent
- **a.** no growth.
- **b.** linear growth.
- **c.** exponential growth.
- **d.** equilibrium growth.

18. From the graph, it is evident that Population 2 underwent
- **a.** no growth.
- **b.** linear growth.
- **c.** exponential growth.
- **d.** equilibrium growth.

19. Darwin recognized that all natural populations
- **a.** never increase in the pattern of Population 2.
- **b.** always increase in the pattern of Population 1.
- **c.** are limited to increase in the pattern of Population 2.
- **d.** have the potential to increase in the pattern of Population 1.

Critical Thinking

20. Criticizing an Argument According to Lamarck's ideas about inheritance, people who developed large muscles would pass on those large muscles directly to their offspring. Use another example to show that this conclusion cannot be correct.

21. Explaining Processes Propose a series of steps by which a pair of insect-eating birds could arrive on an island and then evolve into several species, each specializing on a different kind of food.

22. Analyzing Language Explain why the phrase "survival of the fittest" is misleading.

23. Explaining Relationships Why might there be more variation in a population in which individuals mate with random partners each mating season than in a population in which pairs of individuals mate for life?

Why It Matters

24. Applying Concepts Describe how relationships between humans and wolves in ancient history may have led to modern domestic dogs.

25. Quick Project Conduct a survey among any dog owners you know. Ask what breed of dog they have, if the breed is known. Also ask what traits, if any, influenced their selection of this breed.

Alternative Assessment

26. Lyrics Create a song, rap, or poem that explains the difference between everyday uses of the word *theory* and the scientific meaning of the word.

Writing for Science

27. Letter to Scientific Peers Pretend that you are Charles Darwin. Write a letter to one of the people who influenced your ideas about evolution (Lamarck, Malthus, Cuvier, or Lyell). Explain to that person how his ideas helped you understand how organisms evolve.

Math Skills

28. Compound Interest An example of exponential growth is a bank account that earns interest. Often, interest is added once per year, and the new total earns more interest the next year. Thus, the interest is *compounded* each year. The equation for this kind of interest is:

$$P = C(1 + r)^t$$

where P is the future value, C is the initial deposit, r is the interest rate (expressed as a decimal), and t is the number of years invested. Suppose you open an account with an initial deposit of \$100.00 and a simple annual interest of 10% (or 0.10). This account would have \$110.00 after one year and \$121.00 after 2 years. Calculate the account balance over 10 years, and then draw a graph of this growth.

Critical Thinking

20. According to this idea, someone who broke an arm could pass on the broken-arm trait to offspring.

21. Multiple species could evolve through adaptive radiation from the original pair. The descendants could naturally adapt to prefer different kinds of food available. If each feeding group stopped breeding with the others, then speciation would occur forming separate populations.

22. Chance variation might not always select for the best adaptation. Natural selection produces a form that is fit enough to survive and reproduce but not necessarily the fittest possible.

23. More combinations of alleles are possible in a random-paired population, which would result in more natural variation.

Why It Matters

24. Early humans may have chosen wolves that were friendly and/or protective. They would have also chosen wolves that could help them to hunt. Wolves, chosen for these traits, would have mated and passed these traits on to their offspring. As humans continued to choose the best hunters or friendliest and most protective wolves from successive generations, a kind of artificial selection would occur to form a separate population.

25. Check that students have gathered and organized the data on dog breeds from their survey of dog owners.

Alternative Assessment

26. Lyrics should emphasize that a scientific theory is an explanation for a broad range of observations and ideas and is scientifically supported. In everyday language, a theory may simply be a guess or hunch about certain circumstances and may not be expected to have scientific support.

Writing Skills

27. Letters should be written as if from Darwin to a fellow scientist, and should include examples of how the ideas of the recipient were used by Darwin in forming his own ideas about evolution.

Math Skills

28. Answer: The balance at the end of each year is as follows:

Year 1	\$110.00
Year 2	\$121.00
Year 3	\$133.10
Year 4	\$146.41
Year 5	\$161.05
Year 6	\$177.16
Year 7	\$194.87
Year 8	\$214.36
Year 9	\$235.79
Year 10	\$259.37

Students should create a line graph showing exponential growth.

Chapter 16

Standardized Test Prep

TEST TIP Watch out for words that qualify or put conditions on an answer option, such as "only," "always," "some," or "most." These qualifiers are important clues to choosing the correct answer.

Science Concepts

1. Which of the following is the best definition of a scientific theory?
- **A** a group of ideas about a scientific concept
- **B** an explanation that is accepted by most people
- **C** an explanation that has been scientifically tested and supported
- **D** a specific question that can be tested using the scientific method

2. In forming his theory of evolution, Darwin most lacked an adequate understanding of
- **F** geology.
- **G** heredity.
- **H** anatomy.
- **J** geography.

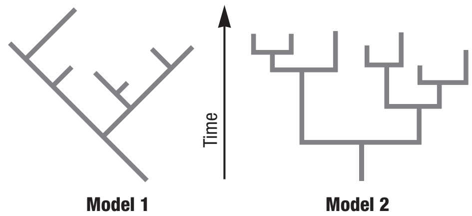
3. An inherited trait that helps an individual survive and reproduce in a particular environment is
- **A** an adaptation.
- **B** a survival trait.
- **C** a genetic trait.
- **D** natural variation.

4. A human arm and a bat wing are each made up of a similar number and arrangement of bones. This similarity is evidence that humans and bats
- **F** evolved at the same time.
- **G** have the same parents.
- **H** have an ancestor in common.
- **J** once shared the same habitat.

5. Which of the following is a true statement about evolution?
- **A** Individuals cannot evolve, but populations can evolve.
- **B** Natural selection is the only mechanism for evolution.
- **C** Evolution always results in more complex forms of life.
- **D** Organisms always evolve to have the best adaptations for their environment.

Using Science Graphics

This diagram shows two contrasting models of the pace of evolution. Use the diagram to answer the following question(s).



6. Model 1 is usually referred to as the model of
- **F** selection.
- **G** gradualism.
- **H** adaptive radiation.
- **J** punctuated equilibrium.

7. Model 2 is usually referred to as the model of
- **A** selection.
- **B** selectionism.
- **C** artificial selection.
- **D** punctuated equilibrium.

8. In Model 1, each point where one line splits into two lines represents
- **F** selection.
- **G** speciation.
- **H** adaptation.
- **J** punctuation.

This table shows the differences between the human hemoglobin protein and that of some animals. Use the table to answer the following question(s).

Animal with hemoglobin	Amino acids that differ from human hemoglobin
Mouse	27
Chicken	45
Frog	67
Lamprey	125

9. These data support the hypothesis that among the animals listed, the animal that is most closely related to humans by ancestry is the
- **A** mouse.
- **B** chicken.
- **C** frog.
- **D** lamprey.

Answers

1. C **2.** G **3.** A
4. H **5.** A **6.** G
7. D **8.** G **9.** A

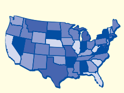
TEST DOCTOR

Question 3 Students need to understand the meanings of the choices. An adaptation is an inherited trait present in a population, so choice **A** is correct. Choice **B** is incorrect, because no definition has been given for a survival trait. Choice **C** is incorrect, because all traits are genetic, but not all traits help individuals survive and reproduce. Choice **D** is incorrect because natural variation refers to different traits that occur within a species.

Question 4 Choices **F** and **J** are incorrect, because there is nothing in the number or arrangement of bones that suggests a time period or habitat. Choice **G** is incorrect because similar numbers and arrangements of bones aren't enough data to establish parentage. Choice **H** is correct, because the number and arrangement of bones suggests a historical ancestral relationship.

Question 8 Students need to understand the definitions of the choices. Choice **F** is incorrect, because selection is a process of survival. Choice **H** is incorrect, because adaptation is an inherited trait. Choice **G** is correct, because speciation can begin when one population becomes geographically separated and a new species evolves. Choice **J** is incorrect, because punctuation refers to the rate of appearance of new species.

State Resources



For specific resources for your state, visit go.hrw.com and type in the keyword **HSHSTR**.

Test Practice with Guided Reading Development