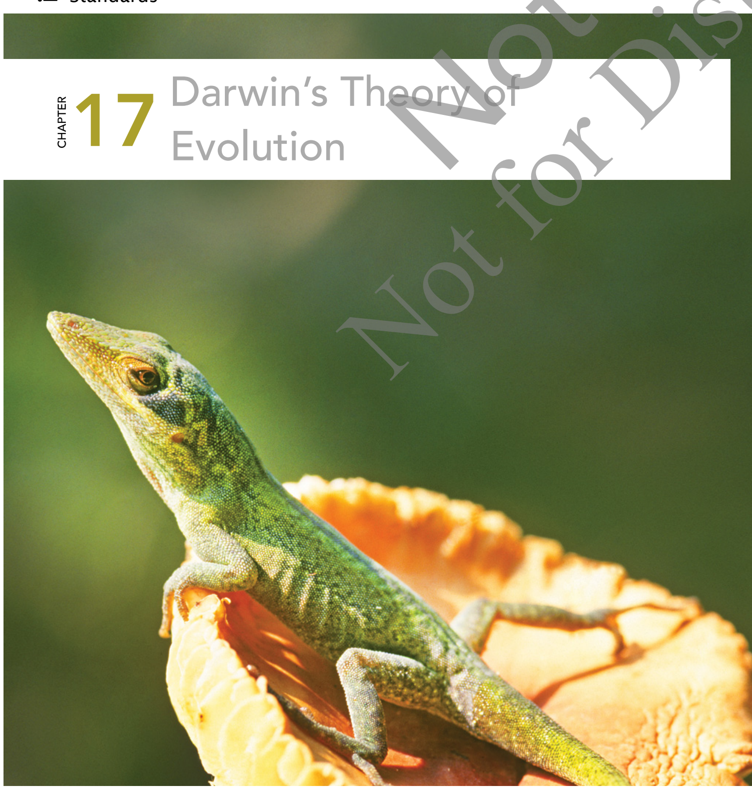
Chapter 17: Darwin's Theory of Evolution,Brian

PEARSON

Standards

CHAPTER 17 Darwin's Theory of Evolution



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- Lessons
- Case Study

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CHAPTER 17 Case Study

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Lizards, Legs, and the Diversity of Life

Biologists looking at the living world are amazed at the variety of different living things that share our planet. Recognizing and naming all those organisms is tough enough. Figuring out how biological diversity arose has challenged scientists since science began. Some clues to the puzzle can be found in ancient fossils, while others, depending on where you live, may be staring at you, camouflaged in a nearby tree.

Some biologists try to study life's "big picture" by examining patterns that encircle the globe and changes in those patterns that span millions of years. Others focus on smaller subjects and changes that occur in just a few years.

Professor Jonathan Losos of Harvard University focuses his research on anoles, a group of small lizards found across the southeastern United States, the Caribbean, Central America, and northern South America. There are almost 400 anole species, 150 of which live in Florida and the Caribbean. Why do these lizards come in such a bewildering variety? That's the question Losos and like-minded biologists hope to answer through observation and experimentation. Two patterns seen in anole species fascinate biologists.

First pattern: Anole species living on the same island differ in body shape, behavior, and choice of niche. Species that prefer tree trunks near the ground, for example, have long back legs that enable them to jump long distances and run quickly. Species that live high in trees have very short legs and stickier toe pads. These species hang on to small twigs and creep slowly to avoid being spotted by predators.

Second pattern: Anoles living in the same niches on different islands have the same characteristics. BUT … the low-living species on different islands are different species, even though their body shapes and behaviors are similar. What's more, they are usually not closely related to the low-living species on other islands.

How do these patterns emerge? As part of his efforts to explain those patterns, Losos conducted ingenious experiments on small islands along Florida's Intracoastal Waterway. First, he studied the height of perches chosen by resident anoles of a native species, *Anolis carolinensis*. He also measured their legs and toe pads. He then introduced a small population of another species, *A. sagrei*, which had recently crossed to southern Florida from Cuba. What would happen? Would competition cause evolutionary change to occur? If so, how long would that take?

In only a few years, Losos saw evolution taking place before his eyes! The native anoles were moving higher in the trees than they had been before. Their legs and toe pads were also steadily changing to the forms found in higher tree-dwelling species! How do these kinds of changes help to explain the diversity of life on Earth?

Throughout this chapter, look for connections to the CASE STUDY to help you answer these questions.

LESSON 17.1 A Voyage of Discovery

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▸ Key Questions

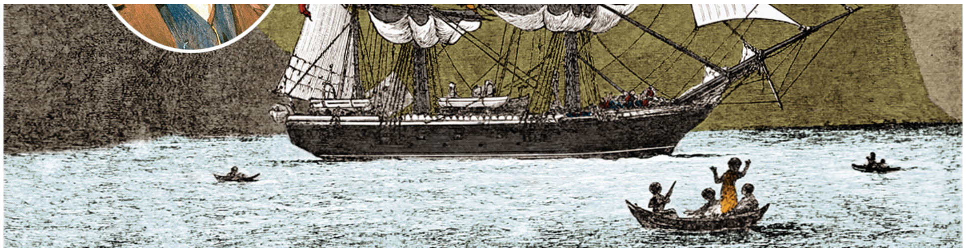
Vocabulary

evolution

fossil

READING TOOL

As you read the lesson, complete the main idea and details table in the **Foundations Reading and Study Guide Workbook** on your digital course.



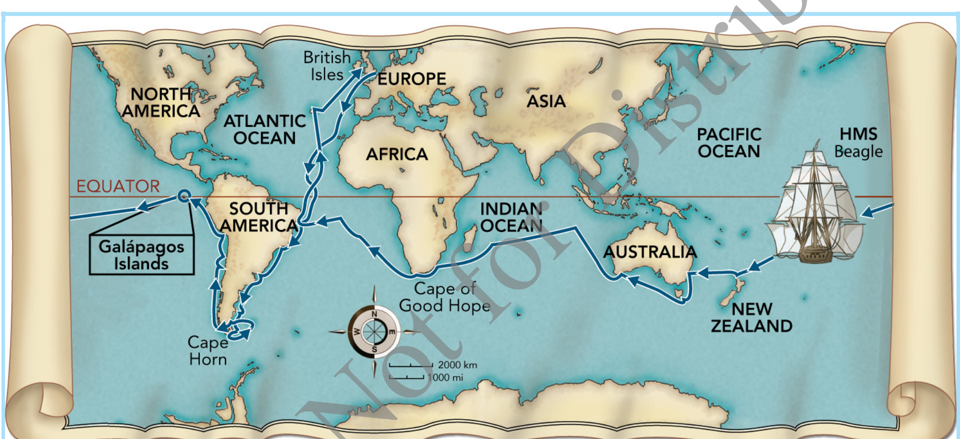
Charles Darwin sailed on the HMS *Beagle*.

If you'd met young Charles Darwin, you wouldn't have guessed that his ideas would shake the world. He wasn't a star student. He preferred nature watching and hunting over studying. His father complained, "You care for nothing but shooting, dogs, and rat-catching, and you will be a disgrace to yourself and all your family." Yet Darwin would come up with what has been called "the single best idea that anyone has ever had." That didn't happen because Darwin sailed to exotic places and saw strange things. Europeans had been exploring and cataloging exotic creatures for years. Darwin did something that scientific thinkers described as the true essence of discovery. He saw things that many before him had seen, and came up with entirely new ways of thinking about them. And he asked questions. That's what Darwin did.

Darwin's Epic Journey

Charles Darwin was born in England on February 12, 1809. Eager to see the world, he got his chance in 1831 when he was invited to join the HMS *Beagle* on the five-year voyage shown in **Figure 17-1**. The captain's job was to map coastlines and harbors. Darwin was added to keep the captain company during the long trip. No one knew it, but Darwin's presence on the *Beagle* would make this perhaps the single most important scientific voyage of all time.

Figure 17-1 Darwin's Journey
Darwin's life's work involved analyzing the many discoveries and observations he made on this journey. He was fortunate to visit a wide variety of habitats, especially the remote and isolated Galápagos Islands.



The *Beagle* set sail at a time when scientists in several fields were revolutionizing scientific understanding of the natural world. Geologists were suggesting that Earth was ancient and had changed over time. Biologists were suggesting that life had also changed, through a process they called evolution. But although those other scientists had argued long before Darwin's voyage that organisms *could* change over time, none of them had offered a scientific description of *how* that

Darwin's Epic Journey (cont.),Brian

LESSON

17.1 A Voyage of Discovery

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Darwin developed a theory of biological evolution that offered a scientific explanation for the unity and diversity of life, by proposing how modern organisms evolved through descent from common ancestors. Recall that a scientific theory is not a guess, a hunch, or a proposal. A scientific theory is a well-established, scientific explanation of events in the natural world. Scientific theories can be used to make predictions about events in the natural world that can be tested by experiments and observations. Darwin's work confirmed that the living world is constantly changing. Evolutionary theory helps us understand events such as the emergence and spread of drug-resistant bacteria and new strains of influenza. It helps us predict the dangers we will face if human actions drive too many species to extinction. For these reasons, all the biological and biomedical sciences are organized around the key ideas that Darwin developed more than 150 years ago.

READING CHECK **Summarize** How have scientists applied Darwin's theory of evolution?

NOTEBOOK

Analyzing Data: Darwin's Voyage,Brian

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LESSON 17.1 Analyzing Data

Standards

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Download the worksheet to complete the activity.

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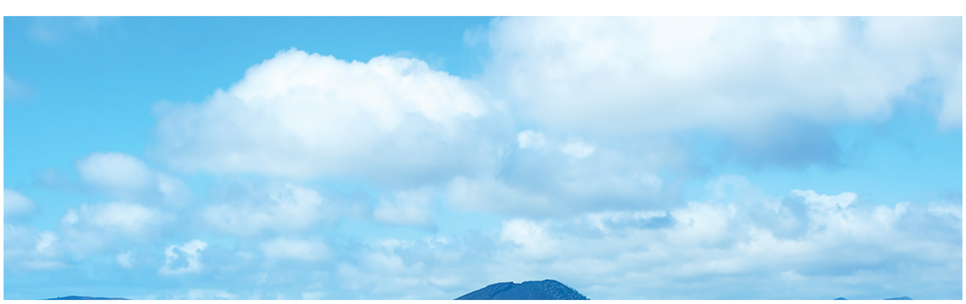
Darwin's Voyage

1. Using the biome map in Chapter 3 as a model, identify three different biomes that Darwin visited on his voyage.

2. Find an example of when Darwin visited the same biome on two different continents.



Analyze and Interpret Data

1. **Identify Patterns** Which biome did you identify as the same on two continents? Are similar types of animals found on both continents?
2. **Infer** How was a round-the-world voyage useful to Darwin for developing his theory of evolution?
3. **Evaluate Evidence** How does evidence from many places around the world, instead of only a single habitat or biome, help strengthen Darwin's theory of evolution?

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LESSON 17.1 A Voyage of Discovery

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READING TOOL

Make a table summarizing the observations made by Darwin during his travels. What types of variations did he notice globally, locally, and over time?

Observations from the Voyage

Darwin was fascinated by the diversity of life he saw during his trip. During a single day in a Brazilian forest he collected 68 species of beetles … and he wasn't even particularly looking for beetles! He was intrigued by how well suited to their local environments plants and animals seemed to be. He was impressed by the many ways that different organisms obtained food, protected themselves, and produced offspring. He was also puzzled by where different species lived—and did not live. He filled his notebooks with observations.

But Darwin wasn't content just to *describe* the diversity he saw. He wanted to *explain* it in a scientific way. He kept observing, asking questions, and formulating hypotheses. Those hypotheses guided him in making more observations to test those hypotheses. He kept looking for larger patterns into which his observations might fit. Over time, Darwin focused on three patterns of diversity: (1) species vary globally, (2) species vary locally, and (3) species vary over time.

Species Vary Globally Wherever Darwin went, he observed and asked questions. In the grasslands of South America, he found flightless, ground-dwelling birds called rheas, as shown in **Figure 17-2**. Rheas look and act a lot like ostriches. Yet rheas live only in South America, and ostriches live only in Africa. Why? Then, when Darwin visited Australia's grasslands, he found another large flightless bird, the emu. Darwin also noticed that rabbits and other species that lived in the grasslands of Europe did not live in the grasslands of South America and Australia. And when Darwin visited Australian not live in the grasslands of South America and Australia. And when Darwin visited Australian grasslands, he saw kangaroos and other animals that are found nowhere else.

To explore this topic further, launch this interactivity.

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Figure 17-2 Species Vary Globally
Ostriches and rheas live in similar habitats on separate continents. Darwin wondered why the two species were similar, yet not identical.

Darwin noticed that different, yet ecologically similar, species inhabited separated, but ecologically similar, habitats around the globe. What did these patterns of geographic distribution mean? Why did different flightless birds live in South America, Australia, and Africa, but not in the Northern Hemisphere? Why weren't there any rabbits in Australian habitats that seemed ideal for them? For that matter, why didn't kangaroos live in England?

Species Vary Locally,Brian

LESSON

17.1 A Voyage of Discovery

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Species Vary Locally There were other puzzles, too. ***Darwin noticed that different, yet related, species often occupied different habitats within a local area.*** For example, Darwin found *two* species of rheas in South America. One thrived in Argentina's grasslands, while a smaller species was adapted to the colder, harsher grass and scrubland to the south.

Darwin observed other examples of local variation in the Galápagos Islands, about 1000 kilometers off the Pacific coast of South America. These islands are relatively close to one another, but are ecologically different. Darwin was impressed and fascinated by the Galápagos, a region that he described as "a little world within itself" and "very remarkable" because it was home to a number of peculiar animals, including giant land tortoises such as those shown in **Figure 17-3**. At first, Darwin didn't think much about these beasts. In fact, like other travelers, Darwin ate several of them and tossed their remains overboard without studying them closely! Then the islands' vice-governor told Darwin that tortoises living on different islands were so different from one another that he could tell which island a tortoise came from just by looking at the shape of its shell. Darwin later admitted, "I did not for some time pay sufficient attention to this statement."

Figure 17-3 Galápagos Tortoises
These two tortoise species live on different Galápagos Islands. Like anole lizards, the tortoises have traits that vary. **Compare and Contrast** Describe differences and similarities between these two tortoises.

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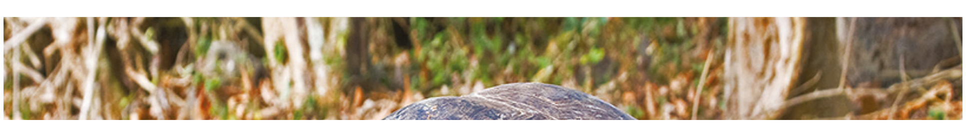

Darwin also observed that different islands had different varieties of mockingbirds, all of which resembled mockingbirds he had seen in South America. He also noticed several types of small brown birds with beaks of different shapes. He thought some of these birds were wrens, some were warblers, and some were blackbirds. He didn't consider them to be especially unusual or important—at first.

Species Vary Over Time In addition to collecting specimens of living species, Darwin also collected fossils, preserved remains or traces of ancient organisms. Scientists already knew that these remains formed a fossil record of organisms no longer living, although researchers in Darwin's day didn't yet know how to read and interpret that record.

Darwin noted that the fossil record included many extinct animals that were similar to, yet different from, living species. Among the most striking examples were fossils of extinct giant armored animals called glyptodonts. You can see in **Figure 17-4** that glyptodonts look like giant versions of modern armadillos, which live in the same area today. But why had glyptodonts disappeared? And why did modern armadillos resemble them? Could these animals have had a common ancestor? Darwin wrote: "This wonderful relationship in the same continent between the dead and the living, will, I do not doubt, hereafter throw more light on the appearance of organic beings on our Earth, and their disappearance from it, than any other class of facts."

Figure 17-4 Glyptodont vs. Armadillo

Fossils show that ancient organisms differed in important ways from those alive today, yet shared many similarities. **Ask Questions** What questions would you ask about the relationship between the ancient glyptodont and the modern armadillo?

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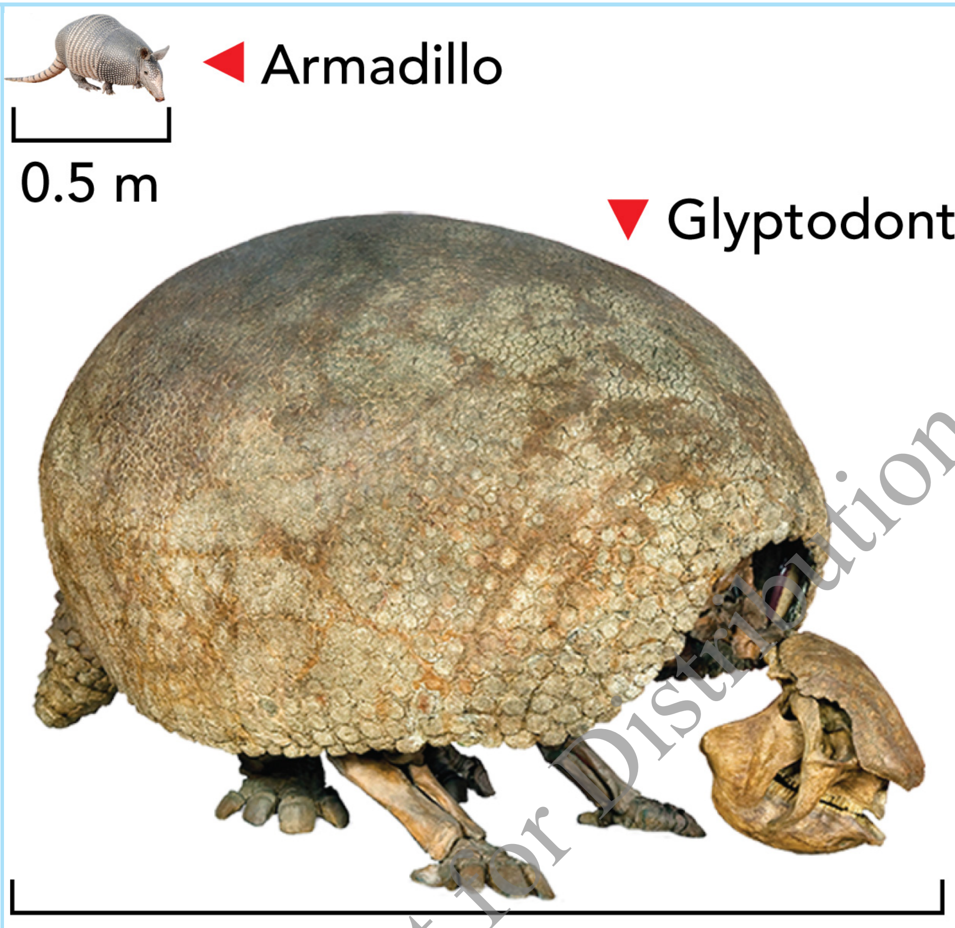

Putting the Puzzle Together,Brian

LESSON 17.1 A Voyage of Discovery

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Putting the Puzzle Together On the voyage home, Darwin thought about the patterns he had seen. When he returned to London, he visited experts to whom he he sent his specimens for identification. Those experts' evaluation of Darwin's specimens set the scientific community abuzz. It turned out that Galápagos mockingbirds belonged to three separate species found nowhere else on Earth! The little brown birds Darwin thought were wrens, warblers, and blackbirds were actually all species of finches! They, too, lived nowhere else, although they all resembled a single common finch species from South America. Yet in addition to being different from each other, those island species were different from that mainland species too. The same was true of Galápagos tortoises, marine iguanas, and many island plants.

Darwin was stunned by these discoveries. The evidence caused him to wonder whether species were really fixed and unchanging, as people thought back then. Could organisms change over time, through some natural process? Could Galápagos species have evolved from common South American ancestors? Darwin spent years researching and filling notebooks with ideas about species and evolution.

LESSON 17.2 Ideas That Influenced Darwin

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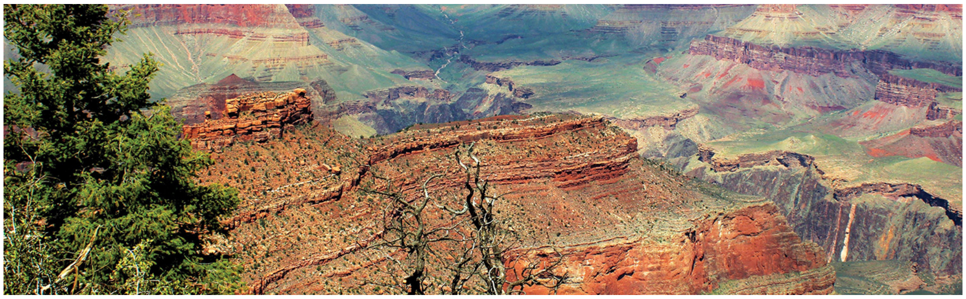
▸ Key Questions

Vocabulary
artificial selection

READING TOOL

As you read, identify the science concepts and ideas that influenced Darwin.

Complete the graphic organizer in the **Foundations Reading and Study Guide Workbook** on your digital course.



The Grand Canyon provides evidence of Earth's long history.

Like all great scientific thinkers, Darwin was profoundly influenced by the work of other scientists. The *Beagle's* voyage came during one of the most exciting periods in the history of science. Geologists studying Earth's structure and history were making new observations and inferences about forces that have shaped our planet. Naturalists were describing and analyzing connections between organisms and their environments. These and other new ways of thinking about the natural world helped shape and guide Darwin's thoughts as he proposed hypotheses and gathered data to test them.

An Ancient, Changing Earth

Many Europeans in Darwin's day thought that Earth was only a few thousand years old, and that it hadn't changed much during that time. By Darwin's time, however, a new generation of geologists were thinking in very different ways about Earth's history. Geologists James Hutton and Charles Lyell proposed important hypotheses based on the work of other researchers, and on data they uncovered themselves. ***Hutton and Lyell concluded that Earth is extremely old and that the processes that changed Earth in the past are the same processes that operate in the present.*** In 1785, Hutton presented his hypotheses about how geological processes have shaped Earth. Lyell, who built on the work of Hutton and others, published the first volume of his great work, *Principles of Geology*, in 1830.

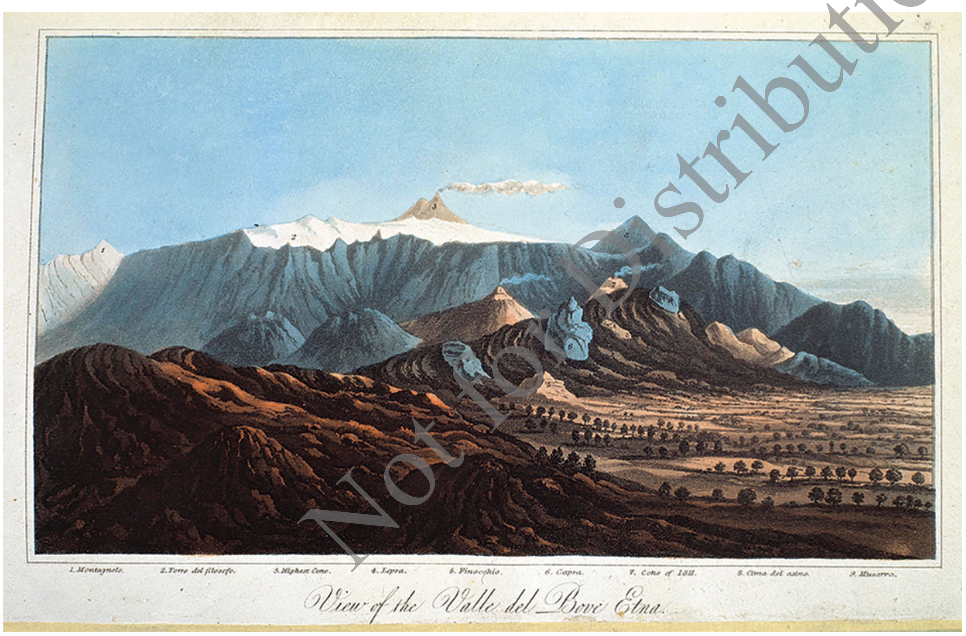


Illustration of Valle del Bove near Mt. Etna, *Principles of Geology*

Hutton and Geological Change,Brian

LESSON

17.2 Ideas That Influenced Darwin

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Hutton and Geological Change Hutton recognized the connections between geological processes and features, like mountains, valleys, and layers of rock that seemed to be bent or folded. Hutton realized, for example, that certain kinds of rocks are formed from molten lava. He also realized that some other kinds of rocks, like those shown in **Figure 17-5**, form very slowly, as sediments build up and are squeezed into layers.

To explore this topic further, launch this interactivity.

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Figure 17-5 Processes That Shape Earth
James Hutton described how geological processes could form and transform rocks, twist them, and lift them to the surface from deep within Earth. **Infer** How were geologic principles important to Darwin's work?

NOTEBOOK

Rocks in this formation were folded and twisted by intense pressure and movement along the San Andreas fault—a place where two continental plates are sliding past one another.

Water and wind wear down rock over time. The pieces that break away become sediment that is moved to a different area, also by water and wind.

Molten lava, emerging at the surface, creates new rocks and can build large land masses.

Hutton also proposed that forces beneath Earth's surface can push rock layers upward, tilting or twisting them in the process. Over long periods, those forces can build mountain ranges. Mountains, in turn, can be worn down by rain, wind, heat, and cold. Most of these processes, shown in **Figure 17-5**, operate very slowly. For these processes to have shaped Earth as we know it, Hutton concluded that our planet must be much older than a few thousand years. These data and inferences moved him to introduce a concept called *deep time*—the idea that our planet's history stretches back over a period of time so long that it is difficult for the human mind to imagine.

Lyell's *Principles of Geology* Lyell's great contribution was to argue that laws of nature are constant over time, so scientists must explain past events in terms of processes they can observe in the present. This way of thinking, called *uniformitarianism*, holds that the geological processes we see in action today are the same processes that shaped Earth millions of years ago. Ancient volcanoes released lava and gases, just as volcanoes do now. Ancient rivers slowly dug channels and carved canyons, just as they do today. Lyell's theories required enough time for these changes to occur. Like Hutton, Lyell argued that Earth is much older than a few thousand years. Otherwise, how would a river have enough time to carve out a valley?

Darwin read Lyell's books during his *Beagle* voyage. With Lyell's ideas fresh in his mind, Darwin had some spectacular good fortune. He saw a volcano erupt in Chile, and later learned that another volcano 480 miles away had blown its top the same night. Just over a month later, he experienced an earthquake that threw him to the ground and lifted a stretch of rocky shoreline more than 3 meters out of the sea with mussels and other sea animals clinging to it. Still later, when Darwin travelled inland, he observed beds of fossil marine animals in mountains thousands of feet above sea level.

Those experiences amazed Darwin and his companions. But only Darwin turned his observations into a brilliant scientific insight. Geological events like the earthquake he'd seen, repeated many times over many years, could push rocks upward a few feet at a time, forming mountains from rocks that had once been beneath the sea. He could see Lyell's principle of geological uniformitarianism in action, with his own eyes! Darwin asked himself, "If Earth can change over time, could life change too?"

READING CHECK **Infer** What evidence or logical reasoning suggested that Earth was much more than a few thousand years old?

NOTEBOOK

LESSON 17.2 Ideas That Influenced Darwin

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READING TOOL

Create a flowchart to show the sequence of events that would have had to occur for flamingos to gain longer legs, according to Lamarck's ideas.

Lamarck's Evolutionary Hypotheses

Darwin wasn't the first to suggest that species could evolve. The fossil record already provided strong evidence that life had changed over time. Ideas about how species could evolve, however, differed. French naturalist Jean-Baptiste Lamarck proposed two of the first hypotheses about how species could change over time. ***Lamarck suggested that individual organisms could change during their lifetimes by selectively using or not using various parts of their bodies. He also suggested that individuals could pass these acquired traits on to their offspring, enabling species to change over time.*** Lamarck published these hypotheses in 1809, the year Darwin was born.

Lamarck's Ideas Lamarck proposed that all organisms have an inborn urge to become more complex and perfect. As a result, organisms change and acquire features that help them live more successfully in their environments. He thought that organisms could change the size or shape of their organs by using their bodies in new ways. According to Lamarck, for example, water birds could have acquired long legs because they began to wade in deeper water looking for food. As a bird stretched its legs to stay above the water's surface, its legs would grow a little longer. Structures of individual organisms could also shrink if they were not used. If a bird stopped using its wings to fly, for example, its wings would become smaller. Lamarck called traits altered by an individual organism during its life *acquired characteristics*.

Lamarck also suggested that if a bird acquired a trait, like longer legs, during its lifetime, it could pass

Lamarck also suggested that if a bird acquired a trait, like longer legs, during its lifetime, it could pass that trait on to its offspring. This principle is called *inheritance of acquired characteristics*. Over a few generations, species like the flamingo shown in **Figure 17-6** would evolve longer legs than their ancestors.

Evaluating Lamarck's Hypotheses Today, we know that Lamarck's hypotheses are completely unsupported. Organisms do not have an inborn drive to become perfect. Evolution does not mean that a species becomes "better" over time. Also, evolution does not progress in a predetermined direction. We also know that traits acquired by individuals during their lifetime (such as loss of a limb), are not inherited by their offspring.

Still, Lamarck was one of the first naturalists to argue strongly that species are not fixed. He was among the first to propose a scientific description of natural processes he thought could enable species to change over time. Lamarck also recognized that organisms' adaptations are related to their environments and the way they "make a living." So, although Lamarck's hypotheses about evolutionary change were wrong, his ideas paved the way for later biologists, including Darwin.

Figure 17-6 Always Improving?
Lamarck thought that organisms such as these flamingos could improve their traits during their lifetimes, and then pass the improvements to their offspring.

READING CHECK **Draw Conclusions** What evidence refutes Lamarck's ideas about passing on acquired traits?

NOTEBOOK

Population Growth,Brian

LESSON

17.2 Ideas That Influenced Darwin

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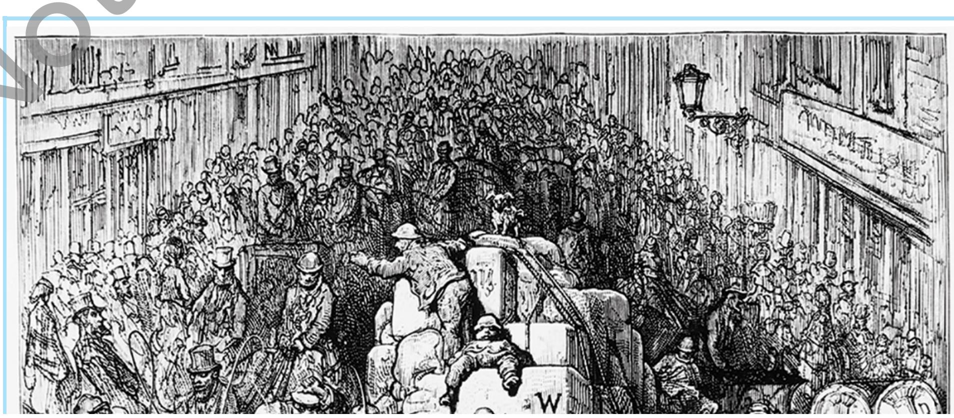
Population Growth

In 1798, English economist Thomas Malthus noted that people were being born faster than people were dying, causing overcrowding, as shown in **Figure 17-7**. ***Malthus reasoned that if the human population grew unchecked, there wouldn't be enough living space and food for everyone.*** The forces that work against population growth, Malthus suggested, include war, famine, and disease.

Figure 17-7 So Many People
This engraving shows the crowded conditions in London during Darwin's lifetime.
☑ Cause and Effect According to Malthus, what would happen if the population of London continued to grow?

NOTEBOOK



Darwin was thunderstruck when he read Malthus's work. He realized that if Malthus's reasoning applied to people, it applied even more to other organisms. Why? Because many organisms can produce lots more offspring than humans, and therefore have the potential to produce many more offspring than can survive. A maple tree produces thousands of seeds. An oyster can produce millions of eggs. Evaluating these facts, Darwin realized that if all descendants of even one pair of oysters survived, they would eventually overrun Earth. Obviously, this wasn't happening. In the struggle for existence, many die and only a few survive and reproduce. This is known in the language of evolutionary biology as differential reproductive success.

PEARSON

LESSON 17.3 Darwin's Theory: Natural Selection

Standards

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Key Questions

Vocabulary

adaptation
fitness
natural selection

READING TOOL

As you read, complete the natural selection concept map in the **Foundations Reading and Study Guide Workbook** on your digital course.

Variation within a population is necessary for natural selection to occur.

Darwin worked out the main elements of evolution by natural selection soon after reading Malthus and thinking about artificial selection. His scientific friends urged him to publish his brilliant arguments. Darwin did write up a complete draft of his ideas, but he put the work aside and didn't publish it for another 20 years. Why? Darwin knew that many scientists, including some of his own teachers, ridiculed Lamarck's ideas. Darwin's theory was even more radical, so he wanted to gather as much evidence as he could to support his ideas before he made them public.

Then, in 1858, Darwin reviewed an essay by Alfred Russel Wallace, a British naturalist working in Malaysia. Wallace's thoughts about evolution were almost identical to Darwin's! Not wanting to get "scooped," Darwin moved forward with his own work. Wallace's essay was presented together with some of Darwin's observations at a scientific meeting in 1858. The next year, Darwin published *On the Origin of Species*, which described his ideas in detail. Wallace had the right idea, but Darwin had data and observations to support his hypotheses.

Evolution by Natural Selection

Darwin's contribution was to describe a natural process, a scientific mechanism, that could operate like artificial selection. In *On the Origin of Species*, he supported his ideas with arguments from Malthus and Lamarck.

The Struggle for Existence Malthus's work had convinced Darwin that if all populations have the potential to produce more offspring than can survive, members of a population will compete for a finite supply of environmental resources. Darwin described this competition as *the struggle for existence*. But which individuals would succeed in surviving and reproducing?

Variation and Adaptation,Brian

LESSON 17.3 Darwin's Theory: Natural Selection

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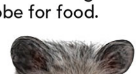
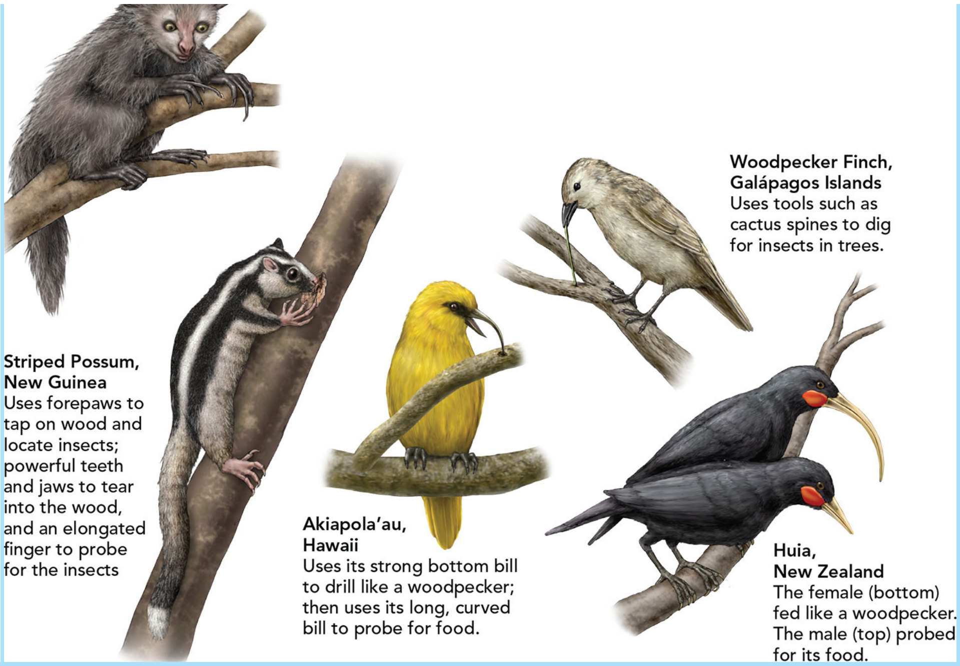
Variation and Adaptation Here's where natural inheritable variation took center stage. Darwin hypothesized that individuals with certain types of inherited variation are better suited, or adapted, to life in their environment than other individuals. Members of a predatory species that are faster or have longer claws or sharper teeth can catch more prey. And members of a prey species that are faster or better camouflaged can avoid being caught.

Any heritable characteristic that increases an organism's ability to survive and reproduce in its environment is called an adaptation. Adaptations can involve body parts or structures, like a tiger's claws. Adaptations can involve colors, like those that make camouflage possible. Some adaptations are physiological, like the way a plant carries out photosynthesis, or the way an animal hibernates to survive harsh winters. Many adaptations also involve behaviors, such as social behavior and avoidance of predators. All of the animals shown in **Figure 17-9** have adaptations that help them feed on insects that live in wood.

Figure 17-9 Many Adaptations
All of these animals are adapted to feed on insects that tunnel in trees. Long beaks and fingers can probe for food, as can thorns, when used as tools.

Aye-Aye, Madagascar
Uses its long middle finger to tap trees and listen for a hollow area that indicates an insect nest; then uses the long finger to probe for food.





Survival of the Fittest Darwin, like Lamarck, recognized that there must be a connection between the way an organism "makes a living" and the environment in which it lives. According to Darwin, differences in adaptations affect an individual's fitness. **Fitness** describes how well an organism can survive and reproduce in its environment.

Individuals with adaptations that are well suited to their environment can survive and reproduce and are said to have high fitness. Individuals with characteristics that are not well suited to their environment either die without reproducing or leave relatively few offspring and are said to have low fitness. This results in differential reproductive success, or, as some call it, *survival of the fittest*. Note that *survival* here means more than just staying alive. In evolutionary terms, *survival* means surviving, reproducing, and passing adaptations on to the next generation.

Natural Selection,Brian

LESSON

17.3 Darwin's Theory: Natural Selection

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READING TOOL

Before you read the section Natural Selection, look at **Figure 17-10**. Read the information in the figure, and then write three questions you have about it. As you read, answer the questions.

Natural Selection Darwin named his mechanism for evolution *natural selection*. Natural selection is the process by which organisms in nature with variations most suited to their local environment survive and leave more offspring. In both artificial and natural selection, only certain individuals produce offspring. But in natural selection, the environment—not a farmer or animal breeder—influences fitness.

When does natural selection occur? ***Natural selection occurs in any situation in which more individuals are born than can survive (the struggle for existence), natural heritable variation affects the ability to survive and reproduce (variation and adaptation), and fitness varies among individuals (differential reproductive success).*** Well-adapted individuals survive and reproduce. From generation to generation, populations continue to change as they become better adapted, or as their environment changes. **Figure 17-10** shows a hypothetical example of natural selection. Note that natural selection acts only on inherited traits because those are the only characteristics that parents can pass on to their offspring.

To explore this topic further, launch this interactivity.

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Figure 17-10 Natural Selection

Forces in the environment, including those caused by humans, cause individuals with less favorable traits to pass on fewer or none of their genes. **Use Models** What selective forces are acting upon the grasshopper population shown here? What is the end result?

NOTEBOOK

This grasshopper population has green and yellow individuals.

Hungry birds can easily spot yellow grasshoppers. Green grasshoppers blend into their surroundings, so more of them survive and reproduce.

Over time, green grasshoppers become more common. Yellow grasshoppers, which are more likely to be eaten by birds, are less likely to pass their genes onto the next generation.

Natural selection does not make organisms "better." Adaptations don't have to be perfect—just good enough to enable an organism to pass its genes on to the next generation. Natural selection also doesn't move in a fixed direction. If local environmental conditions change, some traits that were once adaptive may no longer be useful, and different traits may become adaptive. This can lead to a great diversity of adaptations in species living in different environments. Importantly, if environmental conditions change faster than a species can adapt to those changes, the species may become extinct. Since Darwin's time, we have learned that natural selection is not the only mechanism that leads to evolutionary change. You will learn about other mechanisms in the next chapter.

READING CHECK **Compare** How is natural selection different from artificial selection?

NOTEBOOK

LESSON 17.3 Darwin's Theory: Natural Selection

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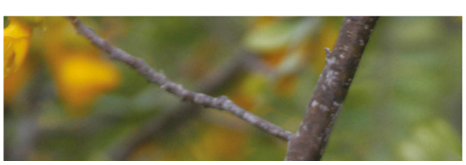
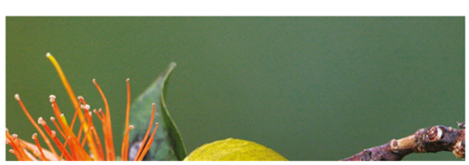
Common Ancestry

Natural selection depends on individuals' ability to reproduce and leave descendants. Every organism alive is descended from parents who survived and reproduced. Those parents descended from their parents, and so forth back through time. Just as well-adapted individuals in a species survive and reproduce, well-adapted species survive over time. Darwin proposed that living species are descended, with changes over time, from common ancestors—an idea called *descent with modification*. Over many generations, different sets of changing environmental conditions could lead to adaptations that could cause a single species to split into two or more new species, as with the honeycreepers in **Figure 17-11**. For evidence of descent with modification over long periods of time, Darwin pointed to the fossil record. Note that this process requires enough time for descent with modification to occur! This reminds us how Hutton and Lyell's work supported Darwin's theory: Deep time gave enough time for natural selection to act.

Figure 17-11 Hawaiian Honeycreepers
Similar to the Galápagos finches, the Hawaiian honeycreepers are a group of diverse birds that are descended from a common ancestor. Over time, different adaptations evolved for feeding and mating in their respective habitats. Compare How does common ancestry explain Losos's observations of anoles?

NOTEBOOK

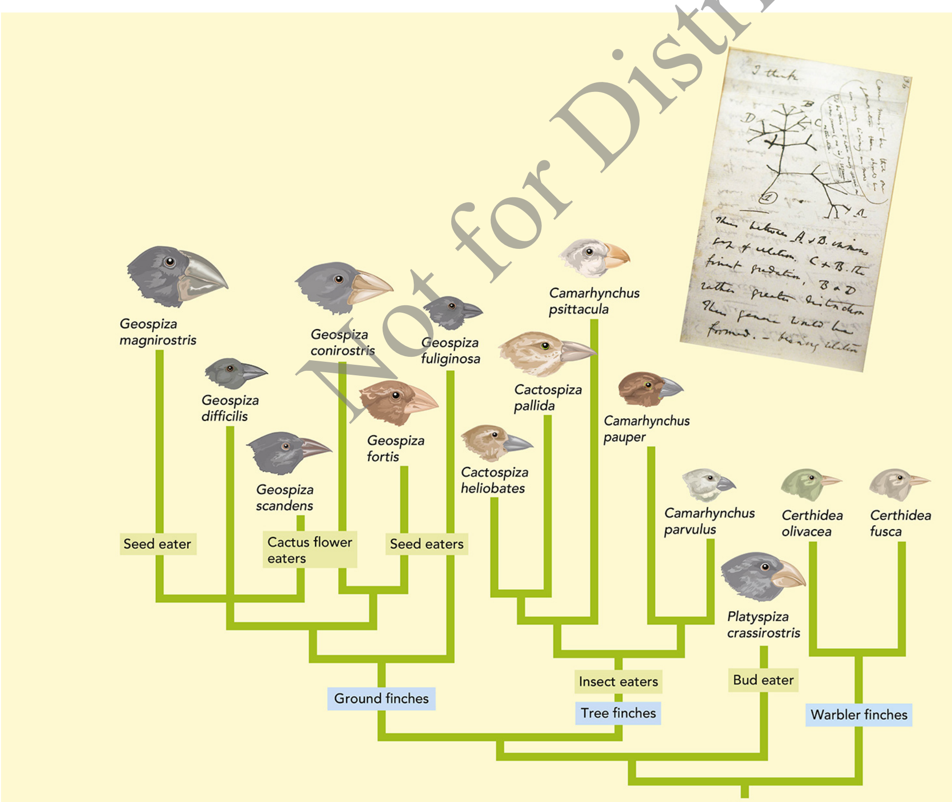




Darwin's idea that natural selection and adaptation can produce new species offered an explanation for both the unity and diversity of life. Darwin's sketched his thoughts about descent from common ancestors in the form of a branching tree. His evolutionary tree sketch is shown in **Figure 17-12**. This "tree-thinking" implies that all organisms are related. Look back in time, and you will find common ancestors shared by tigers, panthers, and cheetahs. Look farther back, and you will find ancestors that these felines share with dogs, then horses, and then bats. Farther back still is the common ancestor that all mammals share with birds, alligators, and fish. Far enough back are the common ancestors of all living things. ***According to the principle of common descent, all species—living and extinct—are united by descent from ancient common ancestors, and exhibit diversity due to natural selection and adaptation.*** A single "tree of life" links all living things.

Figure 17-12 The Tree Model

As shown by the illustration (below), all the finches of the Galápagos Islands descended from a common ancestor. Darwin was the first to use a tree-like model to represent common descent (right). The very first organisms form the base of the tree, and their descendants form the trunk and branches.



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Lesson Review

Standards

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KEY QUESTIONS

1. What three conditions are necessary for natural selection to occur?

NOTEBOOK

2. How does evolution explain both the unity and the diversity of all living things?

NOTEBOOK

CRITICAL THINKING

3. Construct an Explanation Why is high fitness a function of an organism's environment? Include animals from a specific environment, such as polar bears in the arctic tundra or frogs in the tropical rain forest, as evidence to support your explanation.

NOTEBOOK

4. CASE STUDY What adaptations might help different anole species survive in their environments?

NOTEBOOK

PEARSON

LESSON 17.4 Evidence of Evolution

Standards

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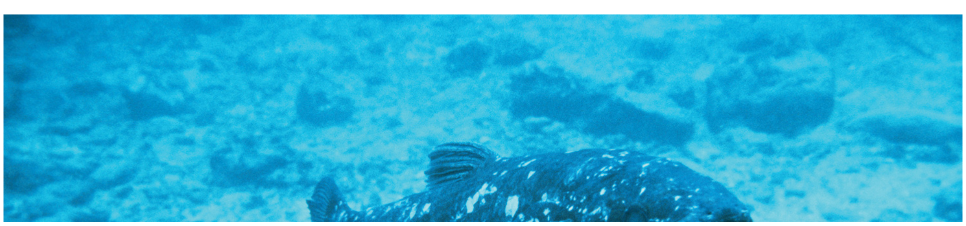
Key Questions

Vocabulary

biogeography
homologous structure
vestigial structure
analogous structure

READING TOOL

As you read, complete the chart in the **Foundations Reading and Study Guide Workbook** on your digital course to describe the evidence for evolution.



Coelacanth resembles fishes that lived millions of years ago.

Darwin's theory depended on assumptions involving many scientific fields. Scientists working in geology, physics, paleontology, chemistry, and embryology during Darwin's lifetime did not have the technology or understanding to test his assumptions. Other fields that are part of evolutionary theory today, such as genetics and molecular biology, didn't even exist yet! During the 160 years since Darwin published *On the Origin of Species*, research in all these fields has provided independent tests of hypotheses related to Darwinian theory. All of these tests could have either supported or refuted Darwin's work. Astonishingly, every scientific test has supported Darwin's basic ideas about evolution.

Biogeography

Darwin recognized the importance of patterns in the distribution of life—the subject of the field called biogeography. **Biogeography** is the study of where organisms live now and where they and their ancestors lived in the past. ***Patterns in the distribution of fossils and living species, combined with information from geology, tell us how modern organisms evolved from their ancestors.*** Recall that two observations involving biogeography were important to Darwin's thinking. First, closely related species can evolve diverse adaptations in different environments. Second, very distantly related species can evolve similar adaptations if they live in similar environments or face similar challenges in the struggle for existence.

Closely Related but Different To Darwin, the biogeography of Galápagos bird species suggested that populations of several island species had all evolved from a single mainland species. Over time, natural selection on different islands selected among individuals with different inherited variations. That caused populations on different islands to evolve into different, but closely related, species.

LESSON

17.4 Evidence of Evolution

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Distantly Related but Similar In contrast, Darwin noted that ground-dwelling birds in ecologically similar grasslands in Europe, Australia, and Africa resembled one another, although they were not closely related. Differences in those birds' body structures provide evidence that they evolved from different ancestors. But natural selection in similar habitats led to similar adaptations, such as long legs and feet with toes adapted to running.

The Age of Earth and Fossils

Two potential difficulties for Darwin's theory involved the age of Earth and gaps in the fossil record. Data collected since Darwin's time addressed those difficulties and provided dramatic support for an evolutionary view of life.

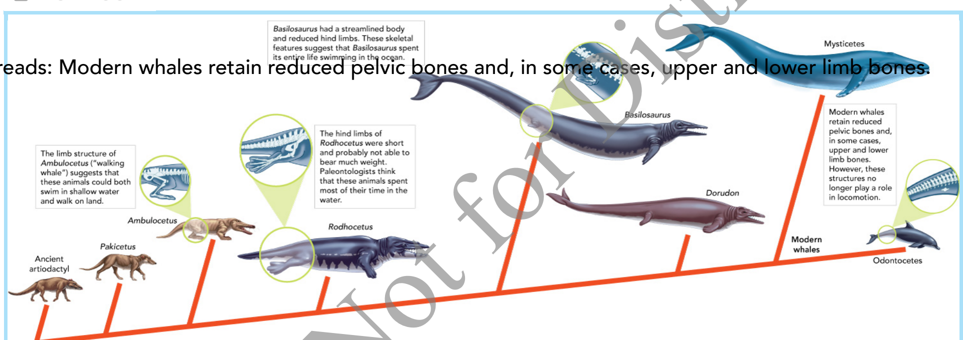
The Age of Earth Darwin knew that for life to have evolved the way he thought it had, Earth must be very old. Hutton and Lyell had argued that Earth was a lot older than people used to think, but couldn't determine just *how* old. The discovery of radioactivity and the technique of radioactive dating enabled geologists to establish the age of certain rocks and fossils starting in the early twentieth century. If this technique had shown that Earth was young, Darwin's ideas would have been refuted. Instead, radioactive dating indicates that Earth is about 4.5 billion years old—plenty of time for evolution by natural selection to take place.

Recent Fossil Finds Darwin also struggled with what he called the "imperfection of the geological record." Paleontologists in Darwin's time hadn't found enough fossils to document the evolution of modern species from their ancestors. But that's changed with the discovery of hundreds of fossils, like the ancient whale skeleton shown in **Figure 17-13**. ***Many recently discovered fossils now show clearly how modern species evolved from extinct ancestors.*** A fossil series shown on the next page in **Figure 17-14** documents the evolution of whales from ancient land mammals. Other recent fossil finds connect the dots between dinosaurs and birds, and between fishes and four-legged land animals. So many intermediate forms have been found that it is often hard to tell where one group begins and another ends. All historical records are incomplete, and the history of life is no exception. The evidence we do have, however, tells an unmistakable story of evolutionary change.

Figure 17-13 Fossil Discoveries
This fossil of *Basilosaurus*, discovered in Egypt, provides evidence of the evolution of whales from land mammals. It also provides evidence for how Earth has changed over time. This site was once an ancient sea.

Figure 17-14 Whale Evolution
Researchers have found more than 20 related fossils that document the evolution of whales from ancestors that walked on land. Several reconstructions, based on fossil evidence, are shown here.
☑ **Infer** Which of the animals shown was probably the most recent to live primarily on land?

NOTEBOOK



ion reads: Modern whales retain reduced pelvic bones and, in some cases, upper and lower limb bones.

☑ READING CHECK **Identify** What technology helped to support Hutton and Lyell's hypothesis that Earth is much older than many people thought?

NOTEBOOK

LESSON 17.4 Evidence of Evolution

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READING TOOL

As you read about homologous structures, look for examples in the illustrations shown in **Figure 17-14**.

Comparing Anatomy and Development

By Darwin's time, scientists had noted that the bones in all vertebrate limbs resembled each other to a surprising degree, as shown in **Figure 17-15**. That resemblance was clear, even though some of those limbs were used for crawling, some for climbing, some for running, and others for flying. Why do the same basic structures appear over and over again with such different purposes?

To explore this topic further, launch this interactivity.

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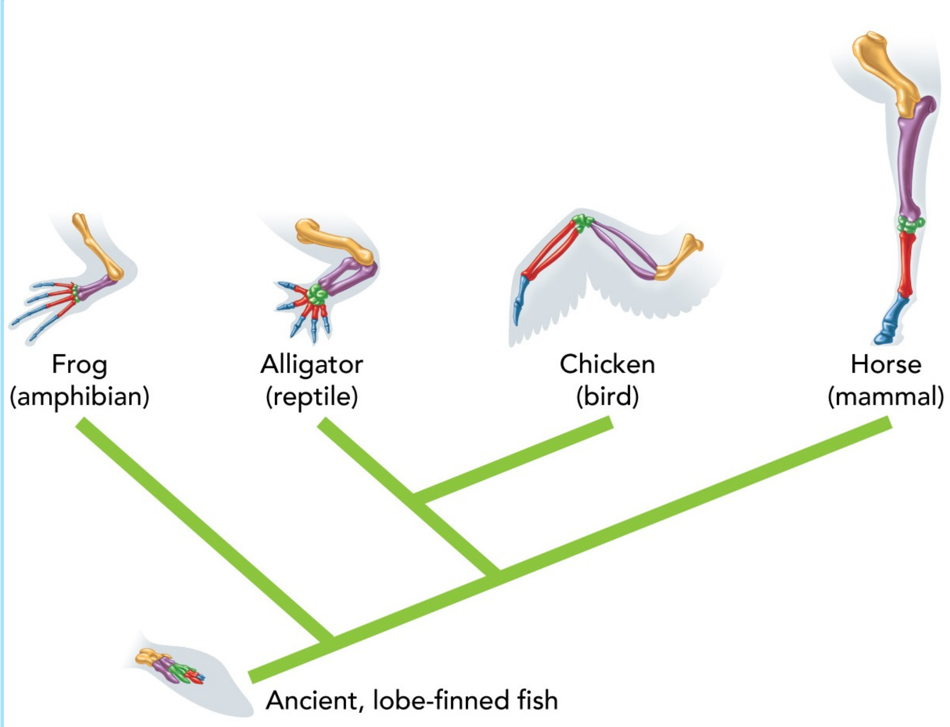
Figure 17-15 Homologous Structures
Color-coding is used to show the homologous bones in the forelimbs of select modern vertebrates. These limbs evolved from the front limbs of a common ancestor whose bones resembled those of an ancient fish. If these animals had no recent common ancestor, they would be unlikely to share so many common structures.



Homologous Structures Similar structures, like the bones of vertebrate limbs, that are shared by related species and have been inherited from a common ancestor are called homologous structures. ***Evolutionary theory explains the existence of homologous structures adapted to different purposes as the result of descent with modification from a common ancestor.*** Biologists test whether structures are homologous by studying anatomical details, the way structures develop in embryos, and the pattern in which they appeared over evolutionary history.

Similarities and differences among homologous structures help determine how recently species shared a common ancestor. For example, many bones of reptiles and birds are more similar to one another in structure and development than they are to homologous bones of mammals. This shows that the common ancestor of reptiles and birds lived more recently than the common ancestor of reptiles, birds, and mammals. So birds are much more closely related to crocodiles than they are to bats, even though both birds and bats have wings! Note that the key to identifying homology is common structure and origin during development, not common function. A bird's wing and a horse's front limb (which are homologous structures) have similar structures and development, but different functions. Homology occurs among plants, too. Certain groups of plants share homologous stems, roots, leaves, and flowers.

Analogous Structures,Brian

LESSON 17.4 Evidence of Evolution

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Some homologous structures don't serve important functions. Vestigial structures are inherited from ancestors, but have lost much of their original size and function. Recently, researchers in Australia studied a clade of skinks, a type of lizard. This group of skinks has elongated bodies like snakes. Many of them have remnants of limbs that they no longer use, as shown in **Figure 17-16**. Using molecular evidence, the researchers hypothesized relationships among species of this clade and developed a timeline for limb size reduction. Another example of a vestigial structure is the hipbones of dolphins. You can see a dolphin hipbone in **Figure 17-14**. Why do these vestigial structures persist? One possibility is that they don't affect an organism's fitness, so selection does not act to eliminate them.

Figure 17-16 Vestigial Structures
Lerista lineopunctulata, known as the dotted-line robust slider, belongs to a clade of skinks that are known for their limb reduction over the past several million years. Note the small remnant of a limb resting on the leaf.

Analogous Structures Body parts that serve similar functions, but do not share structure and development, are called analogous structures. The wing of a bee and the wing of a bird are examples of analogous structures. Both are used for flight, but they grow and develop from different embryonic tissues.

Development Researchers noticed long ago that early developmental stages of many vertebrates look similar. Recent observations make clear that the same groups of embryonic cells develop in the same order and in similar patterns to produce many homologous tissues and organs. For example, the very differently shaped limb bones in **Figure 17-15** all develop from the same clump of embryonic cells. Darwin recognized that evolutionary theory offers the most logical explanation for these similarities. ***Similar patterns of embryological development provide further evidence that organisms have descended from a common ancestor.***

Darwin could not have anticipated, however, the support for his theory that would come from evidence he couldn't see. An incredible amount of evidence regarding homology has been found from studies in genetics and molecular biology that investigate genes that control the development of both visible and microscopic homologous structures.

READING CHECK **Summarize** How do homologous structures provide evidence for evolutionary relationships?

NOTEBOOK

Genetics and Molecular Biology

The most troublesome "missing information" for Darwin had to do with inheritance. Darwin had no idea how heredity worked, and he was deeply worried that this lack of knowledge might prove fatal to his theory. Today, genetics provides some of the strongest evidence supporting evolutionary theory. A long series of discoveries, from Mendel to Watson and Crick to genomics, help explain how evolution works. ***At the molecular level, overwhelming similarities in the genetic code of all organisms, along with homologous genes and molecules, provide evidence of common descent.*** Also, we now understand how mutation and gene shuffling during sexual reproduction produce the heritable variation on which natural selection operates.

LESSON

17.4 Evidence of Evolution

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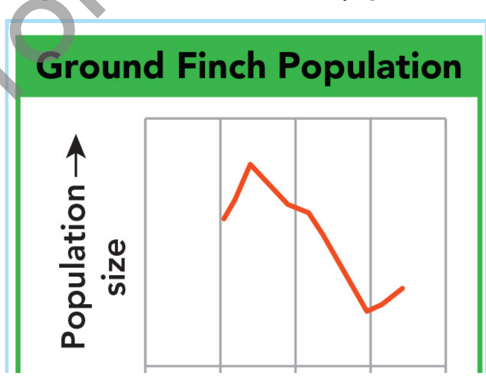
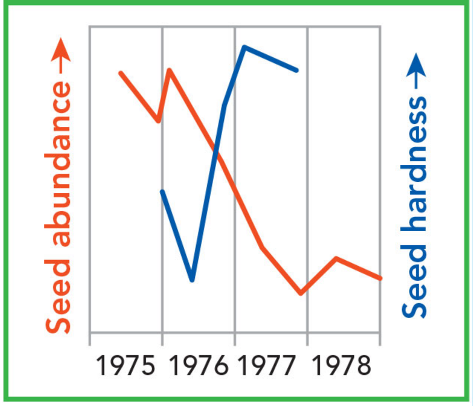
Natural Selection The Grants' data showed that there is lots of heritable variation in beak size and shape in finch populations. But is that variation related to differential survival and reproduction? Luck was on the Grants' side, because during their study, a severe drought hit the islands. Plants produced fewer seeds, so the number of seeds dropped steadily. Here's where things got interesting. As the drought continued, the birds ate the smaller and softer seeds first. So, over time, only the largest, hardest seeds remained. Many birds starved, and the total number of birds on the island fell. But the Grants' data showed that certain birds were more likely to survive than others. Individuals with the largest beaks had higher evolutionary fitness. Drought caused the average beak size in this finch population to change dramatically over just a few years. **Figure 17-18** shows the trends that the Grants observed during the drought.

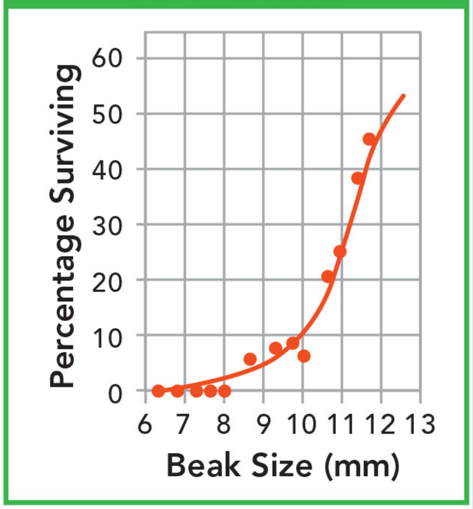
Figure 17-18 Data From the Galápagos



Seed Abundance and Hardness



Bird Survival Based on Beak Size



This amazing study supported two important hypotheses. ***The Grants documented that natural selection takes place in wild finch populations frequently, and sometimes rapidly.*** One of the Grants' colleagues calculated that it might take no more than 12 to 20 such droughts to change the birds' beak size enough to transform one species into another. Also, this work showed the importance of variation in providing raw material on which natural selection can operate. Variation within a species increases a population's ability to adapt to, and survive, environmental change. If the finch population hadn't had enough variation in beak size when the drought started, they would not have been able to adapt and change.

Evolutionary Theory Evolves Many scientific advances have confirmed and expanded Darwin's hypotheses. Today, evolutionary theory is vital to all biological and biomedical sciences, and is often

CHAPTER 17 Case Study Wrap-Up

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Careers on the Case

Work Toward a Solution

Taking outstanding animal images requires a wide knowledge of biology, especially behavior and ecology. Behavior is often best documented using photos and videos.

Wildlife Photographer

The best wildlife photographers do much more than just stalk their subjects. They need to know when and where to look for those magic moments of behavior, and how to capture the right images.

Watch this video to learn about other careers in biology.

hhmi | BioInteractive

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CHAPTER 17 Study Guide

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Lesson Review

17.2 Ideas That Influenced Darwin

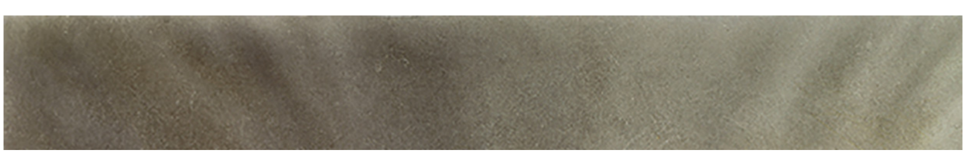
As Darwin worked out his theory of evolution, he was influenced by other scientists of his time. Hutton and Lyell concluded that Earth is extremely old and that the processes that changed Earth in the past are the same processes that operate in the present. Darwin wondered, if Earth's surface could change over time, could life also change over time?

Lamarck suggested that organisms could change during their lifetimes by selectively using or not using various parts of their bodies. He also suggested that individuals could pass these acquired traits on to their offspring, enabling species to change over time. Lamarck's hypotheses were not correct, but he did recognize that there is a connection between an organism's environment and body structures.

Malthus reasoned that if the human population grew unchecked, there wouldn't be enough living space and food for everyone. Darwin realized this was true for other organisms. If more offspring are born than can survive, what causes some to survive and others to die?

In artificial selection, nature provides the variations, and humans select those they find useful. Darwin realized that these natural variations also provide the raw material for evolution.

- artificial selection



Organize Information,Brian

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CHAPTER 17 Study Guide

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Organize Information

The factors that are required for natural selection to occur are listed in the table. In the right column, describe these factors and how they contribute to Darwin's theory of evolution by natural selection.

Organize Information,Brian

Factor	Contribution to Natural Selection
Struggle for existence	1.
Variation and adaptation	2.
Differential reproductive success	3.

PEARSON

Performance-Based Assessment

SCIENCE PROJECT

Standards

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Evolution in Action

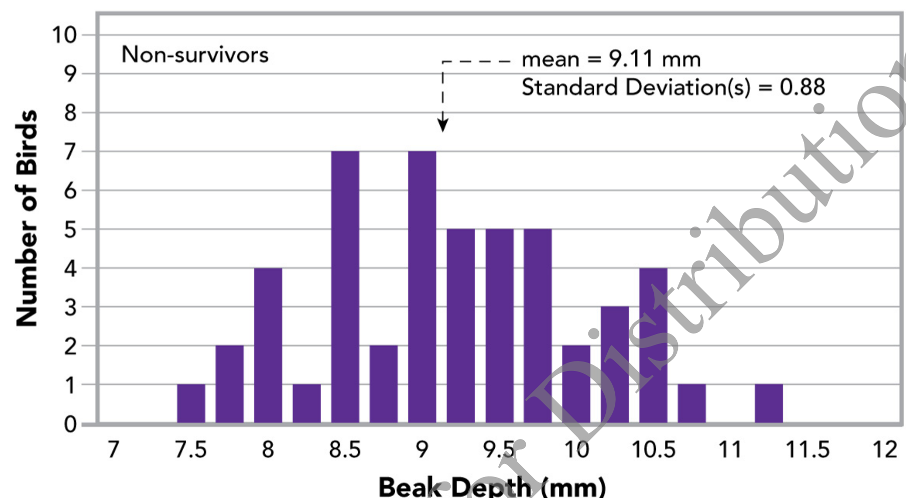
Beak Size Among Darwin's Finches

STEM **Analyze Data**

Darwin was just the first scientist to be puzzled and inspired by Galápagos finches. Peter and Rosemary Grant have been studying free-living birds there for decades. Their careful tagging and releasing of individual birds, combined with detailed measurements of beak size, have produced an amazing wealth of data. Those measurements have provided what researchers call "baseline data" on beak sizes. As you can see from the graphs shown here, beak size varies a lot. That's important, because beak size determines how efficiently birds can eat seeds of different sizes and levels of hardness.

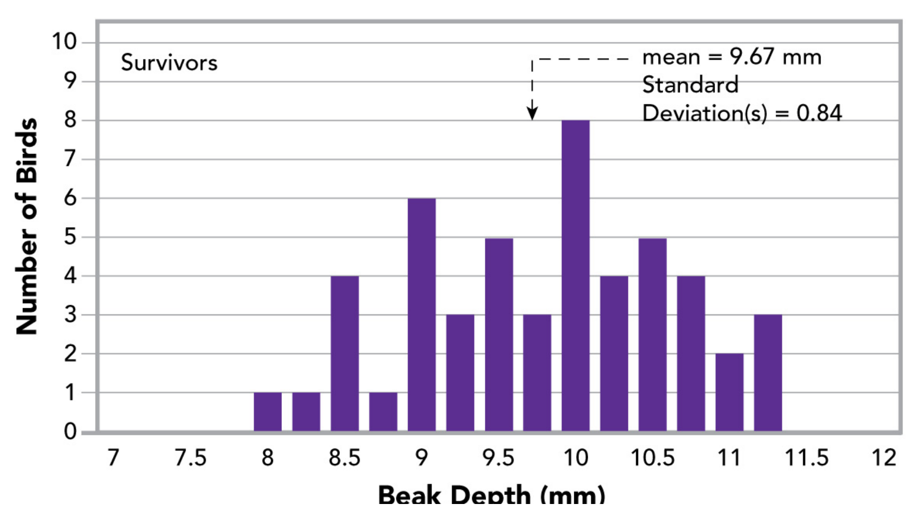
When a severe drought hit, plants on the island produced fewer seeds. Hungry birds soon devoured the smaller, softer seeds they prefer. What was left? Larger seeds that were harder to eat. What happened? Only half the tagged birds survived. But which half? Study the graphs. Then use the data and your knowledge of evolution to answer these questions.

Beak Depths of 50 Medium Ground Finches that Did Not Survive the Drought



Source: Howard Hughes Medical Institute

Beak Depths of 50 Medium Ground Finches that Survived the Drought



CHAPTER 17 Assessment

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KEY QUESTIONS AND TERMS

17.2 Ideas That Influenced Darwin

8. According to Malthus, what would occur if the human population grew unchecked?

A. evolution of a new species
B. extinction of humans
C. disease, war, or famine
D. development of new traits in humans

NOTEBOOK

9. Which of the following would an animal breeder use to increase the number of cows that give the most milk?

A. overproduction
B. genetic isolation
C. acquired characteristics
D. artificial selection

NOTEBOOK

10. Describe an example of selective breeding.

NOTEBOOK

PEARSON

CHAPTER 17 Assessment

Standards

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KEY QUESTIONS AND TERMS

17.3 Darwin's Theory: Natural Selection

Akiapola'au, Hawaii

13. The akiapola'au uses its long top bill to probe for insects in trees. This beak is an example of

A. an adaptation.
B. fitness.
C. an acquired characteristic.
D. a variation.

NOTEBOOK

14. During the process of natural selection, what determines which organisms survive and reproduce?

A. number of adaptations
B. variety of adaptations
C. evolutionary fitness
D. population size

NOTEBOOK

15. How does natural variation affect evolution?

NOTEBOOK

16. According to the principle of common descent, what explains the diversity among organisms today?

NOTEBOOK

17. Do all adaptations involve body structures? Give an example to support your answer.

NOTEBOOK

Critical Thinking,Brian

CHAPTER 17 Assessment

Standards

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CRITICAL THINKING

24. Integrate Information Many scientists of Darwin's time were experts at identifying plant and animal species. How did Darwin's work differ from the work of these other experts?

NOTEBOOK

25. Infer In all animals with backbones, oxygen is carried in blood by a molecule called hemoglobin. What could this physiological similarity indicate about the evolutionary history of vertebrates - (animals with backbones)?

NOTEBOOK

26. Construct an Explanation How does Darwin's theory of evolution help to explain the spread of drug-resistant bacteria?

NOTEBOOK

Use the illustration of mice shown below to answer questions 27 to 29.

27. Interpret Visuals Which of the mice might be better adapted to their environment? Explain your answer.

NOTEBOOK

28. Construct an Explanation What event might change the relative fitness of the different mice? Explain how the change in fitness could occur.

NOTEBOOK

29. Synthesize Information Consider possible changes that could affect the mice. How is the variation among the mice useful to the mouse population?

NOTEBOOK

30. Evaluate Models According to Lamarck's ideas, an animal's actions could affect inheritance. An example is a wading bird that stretches its legs, who then passes the trait of longer legs on to its offspring. Cite evidence to evaluate this model of inheritance.

NOTEBOOK

31. Develop Models Darwin used the concept of artificial selection to model animal breeding, in which humans selected the traits that animals pass to offspring. How did Darwin develop this model to explain evolution in natural systems?

NOTEBOOK

32. Use Scientific Reasoning A scientist discovers a new species of vertebrate, or animal with a backbone, in a desert ecosystem. According to Darwin and to modern ideas about evolution, what kinds of traits can the species be expected to display? Include traits at the molecular level.

NOTEBOOK

Crosscutting Concepts,Brian

CHAPTER 17 Assessment

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CROSSCUTTING CONCEPTS

33. Patterns Describe one of the patterns among species that Darwin identified. How did this pattern help him develop his ideas about evolution?

NOTEBOOK

34. Cause and Effect According to Darwin's ideas, what is the cause of a change in the adaptations of a species over time? Describe a specific example.

NOTEBOOK

PEARSON

CHAPTER 17 Assessment

Standards

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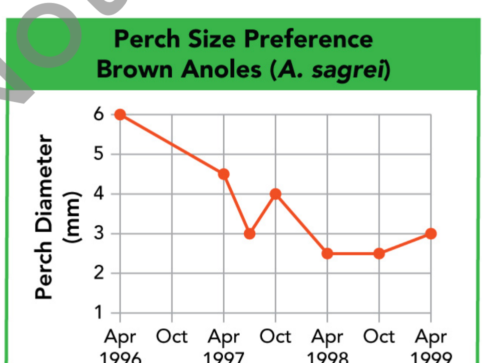
MATH CONNECTIONS

Analyze and Interpret Data

Use the following paragraph and the line graph to answer questions 35 to 37.

In the 1990s, scientists were studying a colony of brown anoles (*Anolis sagrei*) on a Caribbean island. These brown anoles live in trees and perch on branches. In 1996, a large, predatory lizard species arrived on the island, and they began hunting the brown anoles. The graph shows the change in the average diameter of the tree branches where the scientists found brown anoles.



Source: Thomas W. Schoener, David A. Spiller, and

Jonathan Losos. Predation on a common Anolis lizard: can the food-web effects of a devastating predator be reversed? 2002. *Ecological Monographs*. 73(3): 383–407.

35. Interpret Graphs How did the average branch diameter of the brown anoles' perches change during the time of this study?

NOTEBOOK

36. Construct an Explanation How might the introduction of the predatory lizard species have caused the change in perch diameter shown in the graph?

NOTEBOOK

37. Predict As a result of the introduction of the new predator, what other changes may occur to the brown anole population over time? Use the concepts of fitness, adaptation, and natural selection to justify your prediction.

NOTEBOOK

Use the following paragraph and the chart to answer questions 38 and 39.

Cytochrome c is a small protein that takes part in cellular respiration. The table compares the cytochrome c of various organisms to that of chimpanzees.

Math Connections,Brian

Organism	Number of Amino Acids That Are Different From Chimpanzee Cytochrome c
Dog	10
Moth	24
Penguin	11
Yeast	38

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38. Interpret Data How can you interpret the data in the chart to draw a conclusion about the evolutionary relationships among the species?

Language Arts Connection,Brian

CHAPTER 17 Assessment

Standards

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LANGUAGE ARTS CONNECTION

Write About Science

40. Write Informative Texts Write a paragraph to explain how studies in genetics and molecular biology provide evidence for the theory of evolution. Include specific examples in your explanation.

NOTEBOOK

41. Write Explanatory Texts Summarize the conditions under which natural selection occurs. Then, describe three lines of evidence that support the theory of evolution by natural selection.

NOTEBOOK

Read About Science

42. Determine Conclusions What conclusion did Darwin reach about the patterns he observed among Earth's living things?

NOTEBOOK

End-of-Course Test Practice

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1. A pond has several varieties of a species of frog that all eat the same kind of bug. Most of the frogs are fast-growing varieties that need to eat more bugs each day than the slow-growing variety. A drought drastically reduces the number of bugs, and the population of the fast-growing frogs declines drastically while the population of slow-growing frogs declines only slightly, so that most of the frogs in the pond are now the slow-growing variety. This is an example of which of the following?

   A. mutation
   B. natural selection
   C. biogeography
   D. artificial selection
   E. acquired characteristics

NOTEBOOK

2. Thomas Malthus argued that if the human population grew unchecked, then supplies of food and other resources would be exhausted. Which of these ideas about evolution did Darwin adapt from Malthus's work?

   A. An organism passes many of its traits to its offspring.
   B. All organisms fill a niche, or a role in their environment.
   C. Variations within a species are necessary for evolutionary change.
   D. Organisms are able to produce many more offspring than will survive.
   E. The environment selects the traits that an organism passes to offspring.

NOTEBOOK

3. Two species of fish are introduced to the same lake. Over time, only one species survives. According to Darwin's theory of evolution, what should characterize the surviving species?

A. greater genetic variation
B. more abundant food supply
C. a better ability to survive and reproduce in the lake
D. a better ability to withstand seasonal changes in the lake
E. common ancestors with other fish in the lake

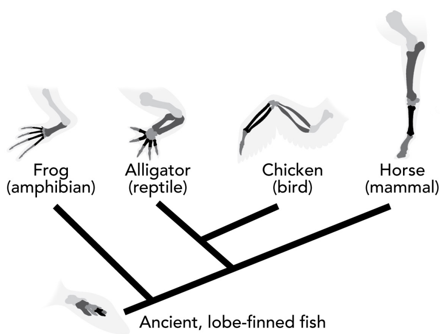
NOTEBOOK

4. Darwin's theory of evolution offers a scientific explanation for which of the following?

A. how genetic information is inherited
B. changes in species over time
C. human effects on biodiversity
D. the age of Earth
E. the origin of life

NOTEBOOK

5. Bernice is preparing a report on evidence for the common ancestry of species. She includes the figure of forelimbs shown.



The forelimbs are an example of which of the following?

A. analogous structures
B. vestigial structures
C. homologous structures
D. convergent structures
E. mutated structures

NOTEBOOK

If You Have Trouble With...

Chapter 17 End-of-Course Test Practice,Brian

Question	1	2	3	4	5
See Lesson	17.3	17.2	17.1	17.4	17.4
Performance Expectation	HS-LS4-2	HS-LS4-2	HS-LS4-4	HS-LS4-3	HS-LS4-1