16.1 Darwin’s Voyage of Discovery

THINK ABOUT IT If you’d met young Charles Darwin, you probably wouldn’t have guessed that his ideas would change the way we look at the world. As a boy, Darwin wasn’t a star student. He preferred bird-watching and reading for pleasure to studying. His father once complained, “You will be a disgrace to yourself and all your family.” Yet Charles would one day come up with one of the most important scientific theories of all time—becoming far from the disgrace his father feared he would be.

Darwin’s Epic Journey

What was Charles Darwin’s contribution to science?

Charles Darwin was born in England on February 12, 1809—the same day as Abraham Lincoln. He grew up at a time when the scientific view of the natural world was shifting dramatically. Geologists were suggesting that Earth was ancient and had changed over time. Biologists were suggesting that life on Earth had also changed. The process of change over time is called evolution. Darwin developed a scientific theory of biological evolution that explains how modern organisms evolved over long periods of time through descent from common ancestors.

Darwin’s journey began in 1831, when he was invited to sail on the HMS Beagle’s five-year voyage along the route shown in Figure 16–1. The captain and his crew would be mapping the coastline of South America. Darwin planned to collect specimens of plants and animals. No one knew it, but this would be one of the most important scientific voyages in history. Why? Because the Beagle trip led Darwin to develop what has been called the single best idea anyone has ever had.

If you think evolution is just about explaining life’s ancient history, you might wonder why it’s so important. But Darwin’s work offers vital insights into today’s world by showing how the living world is constantly changing. That perspective helps us understand modern phenomena like drug-resistant bacteria and newly emerging diseases like avian flu.

In Your Notebook Using what you know about ecology, explain how the ideas of a changing Earth and evolving life forms might be related.
Observations Aboard the Beagle

What three patterns of biodiversity did Darwin note?

As a collector of bugs and shells in his youth, Darwin had always been fascinated by biological diversity. On his voyage, the variety and number of different organisms he encountered dazzled him. In a single day’s trip into the Brazilian forest, he collected 68 species of beetles, and he wasn’t particularly looking for beetles!

Darwin filled his notebooks with observations about the characteristics and habitats of the different species he saw. But Darwin wasn’t content just to describe biological diversity. He wanted to explain it in a scientific way. He kept his eyes and mind open to larger patterns into which his observations might fit. As he traveled, Darwin noticed three distinctive patterns of biological diversity: (1) Species vary globally, (2) species vary locally, and (3) species vary over time.

Species Vary Globally Darwin visited a wide range of habitats on the continents of South America, Australia, and Africa and recorded his observations. For example, Darwin found flightless, ground-dwelling birds called rheas living in the grasslands of South America. Rheas look and act a lot like ostriches. Yet rheas live only in South America, and ostriches live only in Africa. When Darwin visited Australia’s grasslands, he found another large flightless bird, the emu.

Darwin noticed that different, yet ecologically similar, animal species inhabited separated, but ecologically similar, habitats around the globe.

Darwin also noticed that rabbits and other species living in European grasslands were missing from the grasslands of South America and Australia. What’s more, Australia’s grasslands were home to kangaroos and other animals that were found nowhere else. What did these patterns of geographic distribution mean? Why did different flightless birds live in similar grasslands across South America, Australia, and Africa, but not in the Northern Hemisphere? Why weren’t there rabbits in Australian habitats that seemed ideal for them? And why didn’t kangaroos live in England?

Darwin’s Voyage

1. Using a world map and Figure 16–1, count the number of lines of 10° latitude the Beagle crossed.

2. Using the biome map from Chapter 4 as a reference, identify three different biomes Darwin visited on his voyage.

Analyse and Conclude

1. Infer How did the geography of Darwin’s voyage give him far greater exposure to species variability than his fellow scientists back home had?

FIGURE 16–1 Darwin’s Voyage

On a five-year voyage aboard the Beagle, Charles Darwin visited several continents and many remote islands. Draw Conclusions Why is it significant that many of the stops the Beagle made were in tropical regions?
Isabela Island
Tortoise
Tortoises from Isabela Island have dome-shaped shells and short necks. Vegetation on this island is abundant and close to the ground.

Hood Island
Tortoise
The shells of Hood Island tortoises are curved and open around their long necks and legs. This enables them to reach the island’s sparse, high vegetation.

**FIGURE 16-2 Tortoise Diversity**
Among tortoises in the Galápagos Islands, shell shape corresponds to different habitats. Isabela Island has high peaks, is rainy, and has abundant vegetation. Hood Island, in contrast, is flat, dry, and has sparse vegetation.

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

Other examples of local variation came from the Galápagos Islands, about 1000 km off the Pacific coast of South America. These islands are close to one another, yet they have different ecological conditions. Several islands were home to distinct forms of giant land tortoises. Darwin saw differences among the tortoises but didn’t think much about them. In fact, like other travelers, Darwin ate several tortoises and tossed their remains overboard without studying them closely! Then Darwin learned from the islands’ governor that the tortoises’ shells varied in predictable ways from one island to another, as shown in Figure 16–2. Someone who knew the animals well could identify which island an individual tortoise came from, just by looking at its shell.

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

**Species Vary Over Time**
In addition to collecting specimens of living species, Darwin also collected fossils, which scientists already knew to be the preserved remains or traces of ancient organisms. Some fossils didn’t look anything like living organisms, but others did.
Darwin noticed that some fossils of extinct animals were similar to living species. One set of fossils unearthed by Darwin belonged to the long-extinct glyptodont, a giant armored animal. Currently living in the same area was a similar animal, the armadillo. You can see in Figure 16–3 that the armadillo appears to be a smaller version of the glyptodont. Darwin said of the organisms: “This wonderful relationship in the same continent between the dead and the living, will, I do not doubt, throw more light on the appearance of organic beings on our earth, and their disappearance from it, than any other class of facts.” So, why had glyptodonts disappeared? And why did they resemble armadillos?

Putting the Pieces of the Puzzle Together  On the voyage home, Darwin thought about the patterns he’d seen. The plant and animal specimens he sent to experts for identification set the scientific community buzzing. The Galápagos mockingbirds turned out to belong to three separate species found nowhere else! And the little brown birds that Darwin thought were wrens, warblers, and blackbirds were actually all species of finches! They, too, were found nowhere else, though they resembled a South American finch species. The same was true of Galápagos tortoises, marine iguanas, and many plants that Darwin collected on the islands.

Darwin was stunned by these discoveries. He began to wonder whether different Galápagos species might have evolved from South American ancestors. He spent years actively researching and filling notebooks with ideas about species and evolution. The evidence suggested that species are not fixed and that they could change by some natural process.

16.1 Assessment

Review Key Concepts

1. a. Review What is evolution?
   b. Apply Concepts What ideas were changing in the scientific community at the time of Darwin’s travels? How might those new ideas have influenced Darwin?

2. a. Review What three kinds of variations among organisms did Darwin observe during the voyage of the Beagle?
   b. Infer Darwin found fossils of many organisms that did not resemble any living species. How might this finding have affected his understanding of life’s diversity?

Apply the Big Idea Interdependence in Nature

3. You have learned that both biotic and abiotic factors affect ecosystems. Give some examples of each, and explain how biotic and abiotic factors could have affected the tortoises that Darwin observed on the Galápagos Islands.
16.2 Ideas That Shaped Darwin’s Thinking

SC.912.N.1.6 Describe how scientific inferences are drawn from scientific observations and provide examples from the Benchmark being studied.
Also covered: SC.912.N.1.1, SC.912.N.2.2, SC.912.L.15.1, SC.912.L.15.13,
LA.910.2.2.3

Key Questions
❖ What did Hutton and Lyell conclude about Earth’s history?
❖ How did Lamarck propose that species evolve?
❖ What was Malthus’s view of population growth?
❖ How is inherited variation used in artificial selection?

Vocabulary
artificial selection

Taking Notes
Outline Make an outline of this lesson using the green headings as main topics and the blue headings as subtopics. As you read, fill in details under each heading.

THINK ABOUT IT All scientists are influenced by the work of other scientists, and Darwin was no exception. The Beagle’s voyage came during one of the most exciting periods in the history of science. Geologists, studying the structure and history of Earth, were making new observations about the forces that shape our planet. Naturalists were investigating connections between organisms and their environments. These and other new ways of thinking about the natural world provided the foundation on which Darwin built his ideas.

An Ancient, Changing Earth
❖ What did Hutton and Lyell conclude about Earth’s history?
Many Europeans in Darwin’s day believed Earth was only a few thousand years old, and that it hadn’t changed much. By Darwin’s time, however, the relatively new science of geology was providing evidence to support different ideas about Earth’s history. Most famously, geologists James Hutton and Charles Lyell formed important hypotheses based on the work of other researchers and on evidence 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 the Earth. Lyell, who built on the work of Hutton and others, published the first volume of his great work, Principles of Geology, in 1830.

FIGURE 16–4 Ancient Rocks
These rock layers in the Grand Canyon were laid down over millions of years and were then slowly washed away by the river, forming a channel.
Hutton recognized the connections between a number of geological processes and geological features, like mountains, valleys, and layers of rock that seemed to be worn down 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 16–4, form very slowly, as sediments build up and are squeezed into layers.

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 operate very slowly. For these processes to have produced Earth as we know it, Hutton concluded that our planet must be much older than a few thousand years. He introduced 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—to explain his reasoning.

Lyell’s Principles of Geology

Lyell argued that laws of nature are constant over time and that 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 must be the same ones that shaped Earth millions of years ago. Ancient volcanoes released lava and gases, just as volcanoes do now. Ancient rivers slowly dug channels, like the one in Figure 16–5, and carved canyons in the past, just as they do today. Lyell’s theories, like those of Hutton before him, relied on there being enough time in Earth’s history for these changes to take place. Like Hutton, Lyell argued that Earth was much, much older than a few thousand years. Otherwise, how would a river have enough time to carve out a valley?

Darwin had begun to read Lyell’s books during the voyage of the Beagle, which was lucky. Lyell’s work helped Darwin appreciate the significance of an earthquake he witnessed in South America. The quake was so strong that it threw Darwin onto the ground. It also lifted a stretch of rocky shoreline more than 3 meters out of the sea—with mussels and other sea animals clinging to it. Sometime later, Darwin observed fossils of marine animals in mountains thousands of feet above sea level.

Those experiences amazed Darwin and his companions. But only Darwin turned them into a startling scientific insight. He realized that he had seen evidence that Lyell was correct! Geological events like the earthquake, repeated many times over many years, could build South America’s Andes Mountains—a few feet at a time. Rocks that had once been beneath the sea could be pushed up into mountains. Darwin asked himself, If Earth can change over time, could life change too?

**FIGURE 16–5** A woodcut from Lyell’s Principles of Geology shows geological features near Italy’s Mount Etna. Among them is a deep channel, labeled “B,” carved into a bed of lava. The channel, shown in the photo, was formed gradually by the movement of water in the Simeto River.
Lamarck's Evolutionary Hypotheses

How did Lamarck propose that species evolve?

Darwin wasn't the first scientist to suggest that characteristics of species could change over time. Throughout the eighteenth century, a growing fossil record supported the idea that life somehow evolved. Ideas differed, however, about just how life evolved. The French naturalist Jean Baptiste Lamarck proposed two of the first hypotheses. 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 published his ideas 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, a water bird could have acquired long legs because it began to wade in deeper water looking for food. As the bird tried to stay above the water's surface, its legs would grow a little longer. Structures of individual organisms could also change if they were not used. If a bird stopped using its wings to fly, for example, its wings would become smaller. Traits altered by an individual organism during its life are called acquired characteristics.

Lamarck also suggested that a bird that acquired a trait, like longer legs, during its lifetime could pass that trait on to its offspring, a principle referred to as inheritance of acquired characteristics. Thus, over a few generations, birds such as the one in Figure 16–6 could evolve longer and longer legs.

Evaluating Lamarck's Hypotheses

Today, we know that Lamarck's hypotheses were incorrect in several ways. For one thing, organisms don't have an inborn drive to become more perfect. Evolution does not mean that over time a species becomes "better" somehow, and evolution does not progress in a predetermined direction. We now also know that traits acquired by individuals during their lifetime cannot be passed on to offspring. However, Lamarck was one of the first naturalists to suggest that species are not fixed. He was among the first to try to explain evolution scientifically using natural processes. He also recognized that there is a link between an organism's environment and its body structures. So, although Lamarck's explanation of evolutionary change was wrong, his work paved the way for later biologists, including Darwin.

In Your Notebook

Why are Lamarck's ideas called scientific hypotheses and not scientific theories?
Population Growth

What was Malthus's view of population growth?

In 1798, English economist Thomas Malthus noted that humans were being born faster than people were dying, causing overcrowding—just as shown in Figure 16-7. Malthus reasoned that if the human population grew unchecked, there wouldn't be enough living space and food for everyone. The forces that worked against population growth, Malthus suggested, include war, famine, and disease.

Darwin realized that Malthus's reasoning applied even more to other organisms than it did to humans. A maple tree can produce thousands of seeds each summer. One oyster can produce millions of eggs each year. If all the descendants of almost any species survived for several generations, they would overrun the world. Obviously, this doesn't happen. Most offspring die before reaching maturity, and only a few of those that survive manage to reproduce.

Why was this realization so important? Darwin had become convinced that species evolved. But he needed a mechanism—a scientific explanation based on a natural process—to explain how and why evolution occurred. When Darwin realized that most organisms don't survive and reproduce, he wondered which individuals survive ... and why.

Artificial Selection

How is inherited variation used in artificial selection?

To find an explanation for change in nature, Darwin studied change produced by plant and animal breeders. Those breeders knew that individual organisms vary—that some plants bear larger or smaller fruit than average for their species, that some cows give more or less milk than others in their herd. They told Darwin that some of this variation could be passed from parents to offspring and used to improve crops and livestock.

Quick Lab

Guided Inquiry

Variation in Peppers

1. Obtain a green, yellow, red, or purple bell pepper.
2. Slice open the pepper and count the number of seeds it contains.
3. Compare your data with the data of other students who have peppers of a different color.

Analyze and Conclude

1. Calculate Find the average (mean) number of seeds in your class's peppers. Then determine by how much the number of seeds in each pepper differs from the mean number. Math

2. Pose Questions Think of the kinds of variations among organisms that Darwin observed. If Darwin had seen your data, what questions might he have asked?
Farmers would select for breeding only trees that produced the largest fruit or cows that produced the most milk. Over time, this selective breeding would produce more trees with even bigger fruit and cows that gave even more milk. Darwin called this process artificial selection. In artificial selection, nature provides the variations, and humans select those they find useful. Darwin put artificial selection to the test by raising and breeding plants and fancy pigeon varieties, like those in Figure 16–8.

Darwin had no idea how heredity worked or what caused heritable variation. But he did know that variation occurs in wild species as well as in domesticated plants and animals. Before Darwin, scientists thought variations among individuals in nature were simply minor defects. Darwin's breakthrough was in recognizing that natural variation was very important because it provided the raw material for evolution. Darwin had all the information he needed. His scientific explanation for evolution was now formed—and when it was published, it would change the way people understood the living world.

**16.2 Assessment**

**Review Key Concepts**

1. **a. Review** What were Hutton's and Lyell's ideas about the age of Earth and the processes that shape the planet?
   **b. Apply Concepts** How would Hutton and Lyell explain the formation of the Grand Canyon?

2. **a. Review** What is an acquired characteristic? What role did Lamarck think acquired characteristics played in evolution?
   **b. Evaluate** What parts of Lamarck's hypotheses have been proved wrong? What did Lamarck get right?

   **b. Draw Conclusions** How did Malthus influence Darwin?

4. **a. Review** What is artificial selection?
   **b. Infer** Could artificial selection occur without inherited variation? Explain your answer.

**Creative Writing**

5. Imagine you are Thomas Malthus and the year is 1798. Write a newspaper article that explains your ideas about the impact of a growing population on society and the environment.