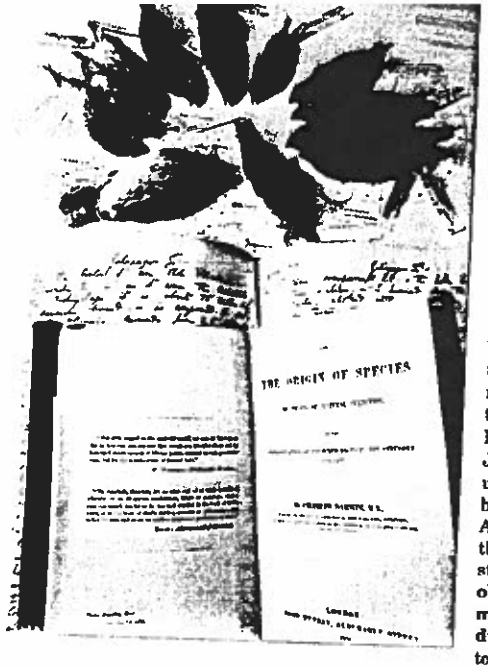


A Figure 15–4 Darwin's notebooks and some of the finch specimens he collected have been preserved for today's scientists to study. **Inferring** *What might modern scientists learn from examining evidence collected by earlier investigators?*

Darwin also saw several types of small, ordinary-looking brown birds hopping around, looking for seeds. As an eager naturalist, he collected many specimens, several of which are shown in **Figure 15–4**. However, he did not find them particularly unusual or important. As Darwin examined the birds, he noted that they had differently shaped beaks. He thought that some of the birds were wrens, some were warblers, and some were blackbirds. But he came to no other conclusions—at first.

The Journey Home

While heading home, Darwin spent a great deal of time thinking about his findings. Examining different mockingbirds from the Galápagos, Darwin noticed that individual birds collected from the island of Floreana looked different from those collected on James Island. They also looked different from individuals collected on other islands. Darwin also remembered that the tortoises differed from island to island. Although Darwin did not immediately understand the reason for these patterns of diversity, he had stumbled across an important finding. **Darwin observed that the characteristics of many animals and plants varied noticeably among the different islands of the Galápagos.** After returning to England, Darwin began to wonder if animals living on different islands had once been members of the same species. According to this hypothesis, these separate species would have evolved from an original South American ancestor species after becoming isolated from one another. Was this possible? If so, it would turn people's view of the natural world upside down.

15-1 Section Assessment

1. **Key Concept** What did Darwin's travels reveal to him about the number and variety of living species?
2. **Key Concept** How did tortoises and birds differ among the islands of the Galápagos?
3. What is evolution? Why is evolution referred to as a theory?
4. What is a fossil?
5. **Critical Thinking Inferring** Darwin found fossils of many organisms that were different from any living species. How would this finding have affected his understanding of life's diversity?

FOCUS ON BIG IDEAS

Interdependence in Nature In Chapter 5, you learned that both biotic and abiotic factors affect ecosystems. Distinguish between these two factors, give some examples of each, and explain how they might have affected the tortoises that Darwin observed on the Galápagos Islands.

15–2 Ideas That Shaped Darwin's Thinking

7.3.b. Students know the reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution. **BITE 1.a. Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent (e.g. the Piltdown Man fossil or unidentified flying objects) and that the theory is sometimes wrong (e.g. the Ptolemaic model of the movement of the Sun, Moon, and planets).**

If Darwin had lived a century earlier, he might have done little more than think about the questions raised during his travels. But Darwin's voyage came during one of the most exciting periods in the history of Western science. Explorers were traversing the globe, and great thinkers were beginning to challenge established views about the natural world. Darwin was powerfully influenced by the work of these scientists, especially those who were studying the history of Earth. In turn, he himself greatly changed the thinking of many scientists and non-scientists. Some people, however, found Darwin's ideas too shocking to accept. To understand how radical Darwin's thoughts appeared, you must understand a few things about the world in which he lived.

Most Europeans in Darwin's day believed that the Earth and all its forms of life had been created only a few thousand years ago. Since that original creation, they concluded, neither the planet nor its living species had changed. A robin, for example, has always looked and behaved as robins had in the past. Rocks and major geological features were thought to have been produced suddenly by catastrophic events that humans rarely, if ever, witnessed.

By the time Darwin set sail, numerous discoveries had turned up important pieces of evidence. A rich fossil record, including the example in **Figure 15–5**, was challenging that traditional view of life. In light of such evidence, some scientists even adjusted their beliefs to include not one but several periods of creation. Each of these periods, they contended, was preceded by a catastrophic event that killed off many forms of life. At first, Darwin may have accepted these beliefs. But he began to realize that much of what he had observed did not fit neatly into this view of unchanging life. Slowly, after studying many scientific theories of his time, Darwin began to change his thinking dramatically.

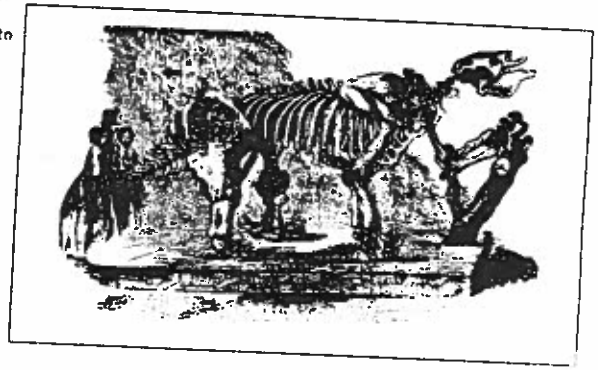
Guide for Reading

Key Concepts

- How did Hutton and Lyell describe geological change?
- According to Lamarck, how did species evolve?
- What was Malthus's theory of population growth?

Reading Strategy: Finding Main Ideas

As you read about the individuals who influenced Darwin's thinking, write a sentence briefly describing what Darwin learned from each one.



▶ **Figure 15–5** This engraving, made around 1850, shows the fossil remains of a giant sloth from South America. During the 1800s, explorers were finding the remains of numerous animal types that had no living representatives. **Inferring** *What did such fossil evidence indicate about life in the past?*

▲ **Figure 15–6** These huge rocks, which are composed of sandstone, show distinct layers that were laid down over millions of years.
⊂ **Hutton and Lyell cited geological features such as these rocks as evidence that Earth is many millions of years old.**

An Ancient, Changing Earth

During the eighteenth and nineteenth centuries, scientists examined Earth in great detail. They gathered information suggesting that Earth was very old and had changed slowly over time. Two scientists who formed important theories based on this evidence were James Hutton and Charles Lyell.

⊂ **Hutton and Lyell helped scientists recognize that Earth is many millions of years old, and the processes that changed Earth in the past are the same processes that operate in the present.**

Hutton and Geological Change In 1795, the geologist James Hutton published a detailed hypothesis about the geological forces that have shaped Earth. Hutton proposed that layers of rock, such as those shown in **Figure 15–6**, form very slowly. Also, some rocks are moved up by forces beneath Earth's surface. Others are buried, and still others are pushed up from the sea floor to form mountain ranges. The resulting rocks, mountains, and valleys are then shaped by a variety of natural forces—including rain, wind, heat, and cold temperatures. Most of these geological processes operate extremely slowly, often over millions of years. Hutton, therefore, proposed that Earth had to be much more than a few thousand years old.

Lyell's *Principles of Geology* Just before the *Beagle* set sail, Darwin had been given the first volume of geologist Charles Lyell's book *Principles of Geology*. Lyell stressed that scientists must explain past events in terms of processes that they can actually observe, since processes that shaped the Earth millions of years earlier continue in the present. Volcanoes release hot lava and gases now, just as they did on an ancient Earth. Erosion continues to carve out canyons, just as it did in the past.

Lyell's work explained how awesome geological features could be built up or torn down over long periods of time. Lyell helped Darwin appreciate the significance of geological phenomena that he had observed. Darwin had witnessed a spectacular volcanic eruption. Darwin wrote about an earthquake that had lifted a stretch of rocky shoreline—with mussels and other animals attached to it—more than 3 meters above its previous position. He noted that fossils of marine animals were displaced many feet above sea level. Darwin then understood how geological processes could have raised these rocks from the sea floor to a mountaintop.

This understanding of geology influenced Darwin in two ways. First, Darwin asked himself: If the Earth could change over time, might life change as well? Second, he realized that it would have taken many, many years for life to change in the way he suggested. This would have been possible only if the Earth were extremely old.

CHECKPOINT *What are some ways the Earth has changed over time?*

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BIE 1.b

Biology and History

Origins of Evolutionary Thought

The groundwork for the modern theory of evolution was laid during the 1700s and 1800s. Charles Darwin developed the central idea of evolution by natural selection, but others before and during his time also built essential parts of the theory.

1785
James Hutton
Hutton proposes that Earth is shaped by geological forces that took place over extremely long periods of time. He estimates Earth to be millions—not thousands—of years old.

1798
Thomas Malthus
In his *Essay on the Principle of Population*, Malthus predicts that the human population will grow faster than the space and food supplies needed to sustain it.

1809
Jean-Baptiste Lamarck
Lamarck publishes his hypotheses of the inheritance of acquired traits. The ideas are flawed, but he is one of the first to propose a mechanism explaining how organisms change over time.

1831
Charles Darwin
Darwin sets sail on the H.M.S. *Beagle*, a voyage that will provide him with vast amounts of evidence leading to his theory of evolution.

1833
Charles Lyell
In the second and final volume of *Principles of Geology*, Lyell explains that processes occurring now have shaped Earth's geological features over long periods of time.

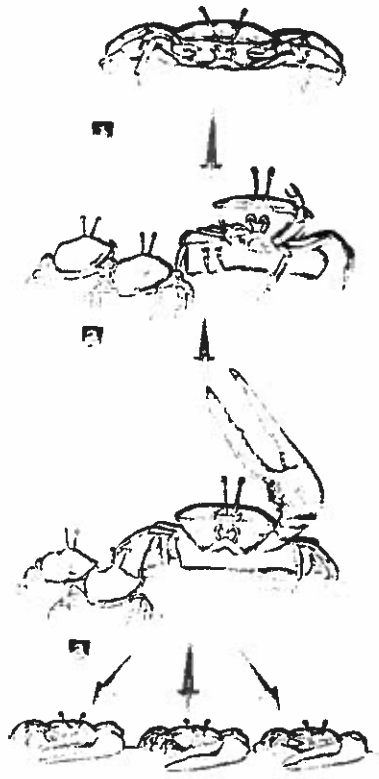
1858
Alfred Wallace
Wallace writes to Darwin, speculating on evolution by natural selection, based on his studies of the distribution of plants and animals.

1859
Darwin publishes *On the Origin of Species*.

1750 1800 1850 1900

Writing in Science

Use the library or the Internet to find out more about Darwin and Wallace. Write a dialogue between these two men, where the conversation shows the similarities in their careers and theories.



A Figure 15–7 **Lamarck proposed that the selective use or disuse of an organ led to a change in that organ that was then passed on to offspring.** This proposed mechanism is shown here applied to fiddler crabs. (1) The male crab uses its small front claw to attract mates and ward off predators. (2) Because the front claw has been used repeatedly, it becomes larger. (3) The acquired characteristic, a larger claw, is then passed on to the crab's offspring. Lamarck's explanation, proposed in 1809, was found to be incorrect.

Lamarck's Evolution Hypotheses

The French naturalist Jean-Baptiste Lamarck was among the first scientists to recognize that living things have changed over time—and that all species were descended from other species. He also realized that organisms were somehow adapted to their environments. In 1809, the year that Darwin was born, Lamarck published his hypotheses.

Lamarck proposed that by selective use or disuse of organs, organisms acquired or lost certain traits during their lifetime. These traits could then be passed on to their offspring. Over time, this process led to change in a species.

Tendency Toward Perfection Lamarck proposed that all organisms have an innate tendency toward complexity and perfection. As a result, they are continually changing and acquiring features that help them live more successfully in their environments. In Lamarck's view, for instance, the ancestors of birds acquired an urge to fly. Over many generations, birds kept trying to fly, and their wings increased in size and became more suited to flying.

Use and Disuse Because of this tendency toward perfection, Lamarck proposed that organisms could alter the size or shape of particular organs by using their bodies in new ways. For example, by trying to use their front limbs for flying, birds could eventually transform those limbs into wings. Conversely, if a winged animal did not use its wings—an example of disuse—the wings would decrease in size over generations and finally disappear.

Inheritance of Acquired Traits Like many biologists of his time, Lamarck thought that acquired characteristics could be inherited. For example, if during its lifetime an animal somehow altered a body structure, leading to longer legs or fluffier feathers, it would pass that change on to its offspring. By this reasoning, if you spent much of your life lifting weights to build muscles, your children would inherit big muscles, too.

Evaluating Lamarck's Hypotheses

Lamarck's hypotheses of evolution, illustrated in **Figure 15–7**, are incorrect in several ways. Lamarck, like Darwin, did not know how traits are inherited. He did not know that an organism's behavior has no effect on its heritable characteristics. However, Lamarck was one of the first to develop a scientific hypothesis of evolution and to realize that organisms are adapted to their environments. He paved the way for the work of later biologists.

Population Growth

Another important influence on Darwin came from the English economist Thomas Malthus. In 1798, Malthus published a book in which he noted that babies were being born faster than people were dying. **Malthus reasoned that if the human population continued to grow unchecked, sooner or later there would be insufficient living space and food for everyone.** The only forces he observed that worked against this growth were war, famine, and disease. Conditions in certain parts of nineteenth-century England, illustrated in **Figure 15–8**, reinforced Malthus's somewhat pessimistic view of the human condition.

When Darwin read Malthus's work, he realized that this reasoning applied even more strongly to plants and animals than it did to humans. Why? Because humans produce far fewer offspring than most other species do. A mature maple tree can produce thousands of seeds in a single summer, and one oyster can produce millions of eggs each year. If all the offspring of almost any species survived for several generations, they would overrun the world.

Obviously, this has not happened, because continents are not covered with maple trees, and oceans are not filled with oysters. The overwhelming majority of a species' offspring die. Further, only a few of those offspring that survive succeed in reproducing. What causes the death of so many individuals? What factor or factors determine which ones survive and reproduce, and which do not? Answers to these questions became central to Darwin's explanation of evolutionary change.

▶ Figure 15–8 **Malthus reasoned that if the human population continued to grow unchecked, sooner or later there would be insufficient food and living space for everyone.** He supported his theory with the evidence he observed in the streets of London.

15–2 Section Assessment

1. **Key Concept** What two ideas from geology were important to Darwin's thinking?
2. **Key Concept** According to Lamarck, how did organisms acquire traits?
3. **Key Concept** According to Malthus, what factors limited population growth?
4. How did Lyell's *Principles of Geology* influence Darwin?
5. **Critical Thinking Evaluating** Imagine that you are Thomas Malthus. Write an article describing your ideas. Explain the impact of a growing population on society and the environment.

Focus on Big Ideas

Science as a Way of Knowing Describe the idea and observations proposed by Lamarck regarding his theory of evolution. Include in your description what Lamarck observed and the conclusions he made based on his observations. In addition, include the scientific evidence that eventually proved Lamarck's theory incorrect.