Darwin and the Theory of Evolution

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Chapter 1. Darwin and the Theory of Evolution

Lesson Objectives

• State Darwin’s theory of evolution by natural selection.
• Describe observations Darwin made on the voyage of the Beagle.
• Identify influences on Darwin’s development of evolutionary theory.
• Explain how a species can evolve through natural selection.

Vocabulary

• artificial selection
• fitness
• Galápagos Islands
• inheritance of acquired characteristics

Introduction

The Englishman Charles Darwin is one of the most famous scientists who ever lived. His place in the history of science is well deserved. Darwin’s theory of evolution represents a giant leap in human understanding. It explains and unifies all of biology.

An overview of evolution can be seen at http://www.youtube.com/watch?v=GcjgWov7mTM (17:39).

Darwin’s Theory at a Glance

Darwin’s theory of evolution actually contains two major ideas:

1. One idea is that evolution occurs. In other words, organisms change over time. Life on Earth has changed as descendants diverged from common ancestors in the past.
2. The other idea is that evolution occurs by natural selection. Natural selection is the process in which living things with beneficial traits produce more offspring than others do. This results in changes in the traits of living things over time.

In Darwin’s day, most people believed that all species were created at the same time and remained unchanged thereafter. They also believed that Earth was only 6,000 years old. Therefore, Darwin’s ideas revolutionized biology. How did Darwin come up with these important ideas? It all started when he went on a voyage.

**The Voyage of the HMS Beagle**

In 1831, when Darwin was just 22 years old, he set sail on a scientific expedition on a ship called the *HMS Beagle*. He was the naturalist on the voyage. As a naturalist, it was his job to observe and collect specimens of plants, animals, rocks, and fossils wherever the expedition went ashore. The route the ship took and the stops they made are shown in Figure 1.1. You can learn more about Darwin’s voyage at this link: [http://www.aboutdarwin.com/voyage/voyage03.html](http://www.aboutdarwin.com/voyage/voyage03.html).

![Figure 1.1](image)

**FIGURE 1.1**

Voyage of the Beagle. This map shows the route of Darwin's 5-year voyage on the HMS Beagle. Each stop along the way is labeled. Darwin and the others on board eventually circled the globe.

Darwin was fascinated by nature, so he loved his job on the *Beagle*. He spent more than 3 years of the 5-year trip exploring nature on distant continents and islands. While he was away, a former teacher published Darwin’s accounts of his observations. By the time Darwin finally returned to England, he had become famous as a naturalist.
Darwin’s Observations

During the long voyage, Darwin made many observations that helped him form his theory of evolution. For example:

- He visited tropical rainforests and other new habitats where he saw many plants and animals he had never seen before (see Figure 1.2). This impressed him with the great diversity of life.
- He experienced an earthquake that lifted the ocean floor 2.7 meters (9 feet) above sea level. He also found rocks containing fossil sea shells in mountains high above sea level. These observations suggested that continents and oceans had changed dramatically over time and continue to change in dramatic ways.
- He visited rock ledges that had clearly once been beaches that had gradually built up over time. This suggested that slow, steady processes also change Earth’s surface.
- He dug up fossils of gigantic extinct mammals, such as the ground sloth (see Figure 1.2). This was hard evidence that organisms looked very different in the past. It suggested that living things—like Earth’s surface—change over time.

![Figure 1.2](image)

On his voyage, Darwin saw giant marine iguanas and blue-footed boobies. He also dug up the fossil skeleton of a giant ground sloth like the one shown here. From left: Giant Marine Iguana, Blue-Footed Boobies, and Fossil Skeleton of a Giant Ground Sloth

The Galápagos Islands

Darwin’s most important observations were made on the Galápagos Islands (see map in Figure 1.3). This is a group of 16 small volcanic islands 966 kilometers (600 miles) off the west coast of South America.

Individual Galápagos islands differ from one another in important ways. Some are rocky and dry. Others have better soil and more rainfall. Darwin noticed that the plants and animals on the different islands also differed. For example, the giant tortoises on one island had saddle-shaped shells, while those on another island had dome-shaped shells (see Figure 1.4). People who lived on the islands could even tell the island a turtle came from by its shell. This started Darwin thinking about the origin of species. He wondered how each island came to have its own type of tortoise.

The Farallon Islands - “California’s Galapagos”

One of the most productive marine food webs on the planet is located on the Farallon Islands, just 28 miles off the San Francisco, California coast. These islands host the largest seabird breeding colony in the continental United States, with over 300,000 breeding seabirds. The Farallon Islands also have a rich diversity of marine life. They are
FIGURE 1.3
Galápagos Islands. This map shows the location of the Galápagos Islands that Darwin visited on his voyage.

FIGURE 1.4
Galápagos Tortoises. Galápagos tortoises have differently shaped shells depending on which island they inhabit. Tortoises with saddle-shaped shells can reach up to eat plant leaves above their head. Tortoises with dome-shaped shells cannot reach up in this way. These two types of tortoises live on islands with different environments and food sources. How might this explain the differences in their shells?

the spawning grounds for numerous fish and invertebrate species, and at least 36 species of marine mammals have been observed in surrounding waters. The islands are known as the Galapagos of California. Why?
Influences on Darwin

Science, like evolution, always builds on the past. Darwin didn’t develop his theory completely on his own. He was influenced by the ideas of earlier thinkers.

Earlier Thinkers Who Influenced Darwin

1. Jean Baptiste Lamarck (1744-1829) was an important French naturalist. He was one of the first scientists to propose that species change over time. However, Lamarck was wrong about how species change. His idea of the inheritance of acquired characteristics is incorrect. Traits an organism develops during its own lifetime cannot be passed on to offspring, as Lamarck believed.

2. Charles Lyell (1797-1875) was a well-known English geologist. Darwin took his book, Principles of Geology, with him on the Beagle. In the book, Lyell argued that gradual geological processes have gradually shaped Earth’s surface. From this, Lyell inferred that Earth must be far older than most people believed.

3. Thomas Malthus (1766-1834) was an English economist. He wrote an essay titled On Population. In the essay, Malthus argued that human populations grow faster than the resources they depend on. When populations become too large, famine and disease break out. In the end, this keeps populations in check by killing off the weakest members.

Artificial Selection

These weren’t the only influences on Darwin. He was also aware that humans could breed plants and animals to have useful traits. By selecting which animals were allowed to reproduce, they could change an organism’s traits. The pigeons in Figure 1.5 are good examples. Darwin called this type of change in organisms artificial selection. He used the word artificial to distinguish it from natural selection.

Wallace’s Theory

Did you ever hear the saying that “great minds think alike?” It certainly applies to Charles Darwin and another English naturalist named Alfred Russel Wallace. Wallace lived at about the same time as Darwin. He also traveled to distant places to study nature. Wallace wasn’t as famous as Darwin. However, he developed basically the same theory of evolution. While working in distant lands, Wallace sent Darwin a paper he had written. In the paper, Wallace explained his evolutionary theory. This served to confirm what Darwin already thought.
Darwin’s Theory of Evolution by Natural Selection

Darwin spent many years thinking about the work of Lamarck, Lyell, and Malthus, what he had seen on his voyage, and artificial selection. What did all this mean? How did it all fit together? It fits together in Darwin’s theory of evolution by natural selection. It’s easy to see how all of these influences helped shape Darwin’s ideas.


Evolution of Darwin’s Theory

It took Darwin years to form his theory of evolution by natural selection. His reasoning went like this:

1. Like Lamarck, Darwin assumed that species can change over time. The fossils he found helped convince him of that.
2. From Lyell, Darwin saw that Earth and its life were very old. Thus, there had been enough time for evolution to produce the great diversity of life Darwin had observed.

3. From Malthus, Darwin knew that populations could grow faster than their resources. This “overproduction of offspring” led to a “struggle for existence,” in Darwin’s words.

4. From artificial selection, Darwin knew that some offspring have chance variations that can be inherited. In nature, offspring with certain variations might be more likely to survive the “struggle for existence” and reproduce. If so, they would pass their favorable variations to their offspring.

5. Darwin coined the term **fitness** to refer to an organism’s relative ability to survive and produce fertile offspring. Nature selects the variations that are most useful. Therefore, he called this type of selection natural selection.

6. Darwin knew artificial selection could change domestic species over time. He inferred that natural selection could also change species over time. In fact, he thought that if a species changed enough, it might evolve into a new species.

Wallace’s paper not only confirmed Darwin’s ideas. They pushed him to finish his book, *On the Origin of Species*. Published in 1859, this book changed science forever. It clearly spelled out Darwin’s theory of evolution by natural selection and provided convincing arguments and evidence to support it.

**Applying Darwin’s Theory**

The following example applies Darwin’s theory. It explains how giraffes came to have such long necks (see Figure 1.6).

- In the past, giraffes had short necks. But there was chance variation in neck length. Some giraffes had necks a little longer than the average.
- Then, as now, giraffes fed on tree leaves. Perhaps the environment changed, and leaves became scarcer. There would be more giraffes than the trees could support. Thus, there would be a “struggle for existence.”
- Giraffes with longer necks had an advantage. They could reach leaves other giraffes could not. Therefore, the long-necked giraffes were more likely to survive and reproduce. They had greater fitness.
- These giraffes passed the long-neck trait to their offspring. Each generation, the population contained more long-necked giraffes. Eventually, all giraffes had long necks.

**FIGURE 1.6**

African Giraffes. Giraffes feed on leaves high in trees. Their long necks allow them to reach leaves that other ground animals cannot.
As this example shows, chance variations may help a species survive if the environment changes. Variation among species helps ensure that at least one will be able to survive environmental change.

A summary of Darwin’s ideas are presented in the Natural Selection and the Owl Butterfly video: http://www.youtube.com/watch?v=dR_BFmDMRaI (13:29).

KQED: Chasing Beetles, Finding Darwin

It’s been over 150 years since Charles Darwin published On the Origin of Species. Yet his ideas remain as central to scientific exploration as ever, and has been called the unifying concept of all biology. Is evolution continuing today? Of course it is.

QUEST follows researchers who are still unlocking the mysteries of evolution, including entomologist David Kavanaugh of the California Academy of Sciences, who predicted that a new beetle species would be found on the Trinity Alps of Northern California.

It's rare for a biologist to predict the discovery of a new species - even for someone like Kavanaugh, who has discovered many new species. For his prediction, Kavanaugh drew inspiration from Darwin’s own 1862 prediction. When Darwin observed an orchid from Madagascar with a foot-long nectare, he predicted that a pollinator would be found with a tongue long enough to reach the nectar inside the orchid’s very thin, elongated nectar "pouch," though he had never seen such a bird or insect. Darwin’s prediction was based on his finding that all species are related to each other and that some of them evolve together, developing similar adaptations. His prediction came true in 1903, when a moth was discovered in Madagascar with a long, thin proboscis, which it uncurls to reach the nectar in the orchid’s nectare. In the process of feeding from the orchid, the moth serves as its pollinator. The moth was given the scientific name Xanthopan morganii praedicta, in honor of Darwin’s prediction.

KQED: The California Academy of Sciences

Founded in 1853 as the first scientific institution in the western United States, the California Academy of Sciences’ mission is to explore, explain, and protect the natural world. The California Academy of Sciences has the largest collection of biological reference materials west of the Mississippi River. Dating back over 100 years, the collection provides a treasure trove of biological information for scientists and researchers studying the natural world http://www.calacademy.org/.
Norman Penny, collections manager of the entomology department of the California Academy of Sciences, gives QUEST viewers a peek at the California Academy of Sciences vast butterfly collection, and discusses the evolutionary importance of butterflies.

Lesson Summary

• Darwin’s theory of evolution by natural selection states that living things with beneficial traits produce more offspring than others do. This produces changes in the traits of living things over time.
• During his voyage on the Beagle, Darwin made many observations that helped him develop his theory of evolution. His most important observations were made on the Galápagos Islands.
• Darwin was influenced by other early thinkers, including Lamarck, Lyell, and Malthus. He was also influenced by his knowledge of artificial selection.
• Wallace’s paper on evolution confirmed Darwin’s ideas. It also pushed him to publish his book, On the Origin of Species. The book clearly spells out his theory. It also provides evidence and logic to support it.

Lesson Review Questions

Recall

2. Describe two observations Darwin made on his voyage on the Beagle that helped him develop his theory of evolution.
3. What is the inheritance of acquired characteristics? What scientist developed this mistaken idea?
4. What is artificial selection? How does it work?
5. How did Alfred Russel Wallace influence Darwin?

Apply Concepts

6. Apply Darwin’s theory of evolution by natural selection to a specific case. For example, explain how Galápagos tortoises could have evolved saddle-shaped shells.
Think Critically

7. Why did Darwin’s observations of Galápagos tortoises cause him to wonder how species originate?
8. Explain how the writings of Charles Lyell and Thomas Malthus helped Darwin develop his theory of evolution by natural selection.

Points to Consider

Darwin’s book *On the Origin of Species* is a major milestone in science. It introduced biology’s most important theory. It also provided an excellent example of how to think like a scientist. A scientist uses evidence and logic to understand the natural world. In this lesson, you read about some of the evidence Darwin used. This evidence included fossils and artificial selection.

- What other evidence might be used to show that evolution occurs? What about evidence based on molecules?
- Do you think it’s possible to see evolution occurring? How might that happen?

References

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2. From left to right: A. Davey; Nicolas de Camaret; Mariana Ruiz Villarreal. From left to right: http://www.flickr.com/photos/adavey/4114230491/; http://www.flickr.com/photos/ndecam/6214744005/; http://commons.wikimedia.org/wiki/File:Megatherium_americanum_complete.JPG . From left to right: CC BY 2.0; CC BY 2.0; Public Domain