SBI3U-C

Evolution

Introduction

The theory of evolution by natural selection is the most powerful tool we have for explaining the diversity of life on our planet. The theory is not merely of historical interest; we need to understand how evolution works in order to tackle current problems such as the appearance of drug-resistant bacteria and the need to protect the earth's shrinking biodiversity.

In Lesson 1, you will begin your study of evolution by researching the scientists whose theories contributed to the theory of evolution. In Lesson 2, you will investigate the evidence for the theory. Lesson 3 explores evolutionary mechanisms in detail. The unit ends with an examination of the factors that effect evolution in Lesson 4.

Overall Expectations

After completing this unit, you will be able to

- demonstrate an understanding of the theory of evolution, the evidence that supports it, and some of the mechanisms by which it occurs
- investigate evolutionary processes, and analyze scientific evidence that supports the theory of evolution
- analyze the economic and environmental advantages and disadvantages of an artificial selection technology, and evaluate the impact of environmental changes on natural selection and endangered species

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Origins of Evolutionary Theory

Introduction

This biology course starts with a unit on evolution. Why? Because everything else you learn about in biology is the result of it. Evolution is also a very important process in your own life, especially for your health, even though you may not realize it. For example, new strains of disease-causing bacteria are emerging; these bacteria have changed genetically because of the excessive amount of antibiotics they have been exposed to in their environment. Despite our best efforts, these bacteria—sometimes called "superbugs"—are evolving to get better at defeating the antibiotics we use to control them.

The process by which organisms evolve is called natural selection. The theory of evolution by natural selection caused a science revolution when it was proposed by Charles Darwin in his landmark book *On the Origin of Species* in to realize how living organisms evolve. You will also research the work of other key scientists who contributed to the development of Darwin's theory of evolution.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
The Importance of Evolution	¼
Development of Evolutionary Theory	1
Timeline: The Life and Work of Charles Darwin	1
Humans as Agents of Evolutionary Change	½
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- analyze, on the basis of research, and report on the contributions of various scientists to modern theories of evolution
- use appropriate terminology related to evolution
- evaluate the possible impact of an environmental change on natural selection and on the vulnerability of species (for example, how adaptation to environmental changes can affect the reproductive success of an organism)

The Importance of Evolution

Life possesses vast diversity, yet it is possible to identify characteristics that are common to all living things. This diversity is a product of the process of evolution, where all life shares a common ancestor.

Evolution is a gradual process by which something changes into a different and usually more complex or better form. The term most often refers to the process by which an organism becomes more adapted to its environment over time, driven by the mechanism of natural selection.

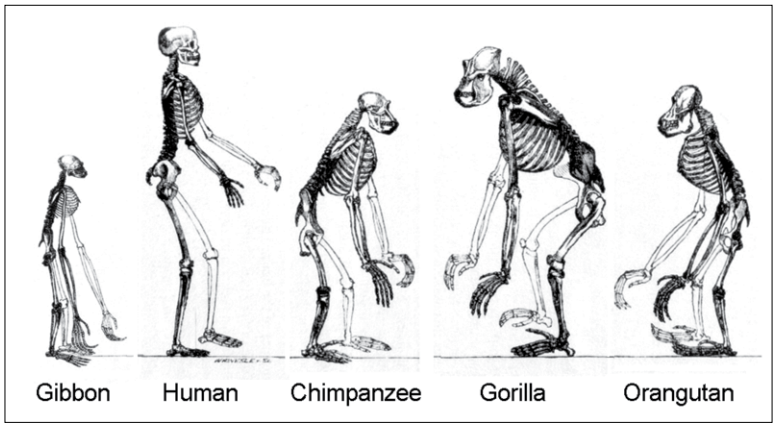

Figure 1.1: Image of five hominid skeletons. All hominids, including humans, come from a common ancestor.

The theory of evolution is the best scientific explanation we have to describe the origins of species. It has many practical applications in biology, from predicting the conservation status of a species to helping us fight new infections. You will learn more about these applications later in the lesson.

Early scientists also established links between changes in species and their environment, but they did not know how the process worked. The answer came in 1859 when Charles Darwin published his famous book *On the Origin of Species*.

Before you learn more about the theory and how it came to be developed, it would be useful to see how people thought about the world before Darwin. This will help you understand why Darwin's theory was revolutionary, and why Darwin himself was at first reluctant to publish it.

Assumptions challenged by Darwin	Ideas proposed by Darwin
Earth is relatively young; its age is measured in thousands of years (6000 years)	Earth is relatively old; its age is measured in billions of years (4.6 billion)
The number and characteristics of species do not change over time	Organisms change, and several species may evolve from a single common ancestor
A creator (or god) determines the structure and function of all organisms	Adaptation to the environment explains the current structure and function of modern-day organisms
Observations and experiments do not determine theories	Observation and experimentation are used to test theories of evolution

Table 1.1: Common understandings before Darwin and after Darwin published his work called *On the Origin of Species*.

Development of Evolutionary Theory

In the early 1800s, there was a fascination with the collection and analysis of fossils. Extinct forms of animals and plants were being discovered all over the world. Some were very strange, like the giant dinosaurs. Even though these organisms had become extinct a long time ago, many were similar in structure to modern species. At the same time, naturalists were travelling the world creating a catalogue of all living things. They quickly noticed two things: first, that there was a huge diversity of species on earth; second, that species living far apart on the globe exhibited similar features. These observations led to obvious questions like: "How did all this variety come about?", "Why did species appear and disappear in the fossil record?" and "How were new species created?" Answering these questions would prove to be one of the greatest accomplishments in biology.

An Englishman, Charles Darwin (Figure 1.2), also thought about these questions, and in 1859 he gave us the answers.

Figure 1.2: Photograph of Charles Darwin taken in 1859, the year he published *On the Origin of Species*
Source: Wikipedia

Darwin knew about the research and ideas of the other scientists who were studying the earth's geology. But it was Darwin who assembled the evidence and developed an explanation of how new species arise. Darwin's discovery was the result of brilliant insight and years of hard work, but it could not have happened without the work of other scientists before him.

Contributions of Key Scientists Before Darwin

Science works by carefully building upon the work of others. Sir Isaac Newton, the famous mathematician and physicist, described the process this way: "If I have seen further than others, it is by standing upon the shoulders of giants."

Darwin's ideas about evolution didn't come out of thin air. He built upon the work of other scientists and naturalists before him.

Carl Linnaeus

A century before Darwin, the classification of organisms had been the main focus in biology. The science of classifying organisms is called taxonomy. The father of taxonomy was Carl Linnaeus (1707–1778), who is also famous for developing a system of naming organisms called binomial nomenclature. Linnaeus believed that species did not change. For most of his life, he did not consider the possibility of evolution. However, there is some evidence that Linnaeus performed some hybridization experiments that may have led him to consider that species change over time.

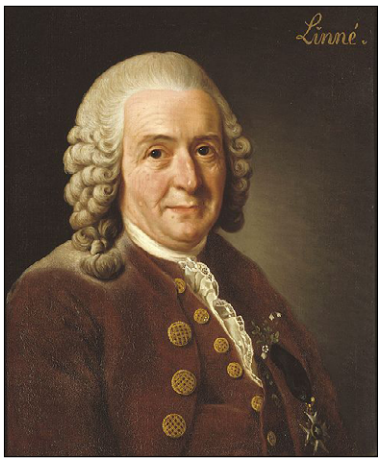

Figure 1.3: Portrait of Carl Linnaeus

Source: Wikipedia

Georges-Louis Leclerc

Georges-Louis Leclerc (1707–1788) was a French naturalist who devoted most of his life to writing a 44-volume book about plants and animals. In it, Leclerc mentions factors he thought could influence evolutionary change, such as the environment, migrating organisms, geographical isolation, overcrowding, and the struggle for existence. He did not present any evidence to support these ideas or explain how evolution might occur. Leclerc also publicly proclaimed his belief that species were created separately and did not change. These were the beliefs of the dominant religion at the time, and to go against them could have damaged his career and social standing.

Erasmus Darwin

Erasmus Darwin (1731–1802) was Charles Darwin's grandfather. He was a physician and a naturalist who wrote many books about plants and animals as well as some rough notes about evolution. His observations about evolution were based on the changes undergone by animals during their development, artificial selection by humans, and the presence of vestigial organs (organs that were functional in an ancestor but no longer functional in present-day species). He never published any formal theory of evolution.

FIgure 1.4: Portrait of Erasmus Darwin

Source: Wikipedia

Georges Cuvier

Georges Cuvier (1769–1832) was a zoologist who used comparative anatomy to classify animals. He noticed that related animals presented slight modifications of their anatomy when compared to each other, suggesting they had a common ancestor. He proposed a series of catastrophes (natural disasters such as floods) that caused some organisms to become extinct, allowing the survivors to take their place. This explanation for the history of life came to be known as catastrophism.

Figure 1.5: Portrait of Georges Cuvier

Source: Wikipedia

Jean-Baptiste Lamarck

Jean-Baptiste Lamarck (1744–1829) also believed that plants and animals adapted to their environment. He proposed a theory based on the inheritance of acquired characteristics. His most famous example to support this theory was an explanation of how the modern-day giraffe obtained its incredibly long neck. He explained that this trait was acquired because generations of giraffes kept stretching their necks to obtain food from taller trees. Eventually this acquired trait (stretched neck) was passed on to successive generations. Modern genetics proves this theory false, as we know now that all of our traits are determined from the genes in the sex cells that combined to create us. Even though his theory turned out to be wrong, Lamarck was one of the first to propose a simple natural mechanism for how species could evolve.

Figure 1.6: Portrait of Jean-Baptiste Lamarck

Source: Wikipedia

Support Questions

Be sure to try the Support Questions on your own before looking at the suggested answers provided.

1. Match the following contributions to Darwin's theory of evolution with the correct scientist.

Scientist	Contribution
1. Carl Linnaeus	a. He wrote a book mentioning things that could influence evolutionary change.
2. Georges-Louis Leclerc	b. He thought a series of natural distasters caused organisms to become extinct.
3. Erasmus Darwin	c. He proposed a theory (which was false) that organisms can acquire new characteristics through behavior and then pass them on.
4. Georges Cuvier	d. He made rough notes about evolution and noted the presence of vestigial organs.
5. Jean-Baptiste Lamarck	e. He created a system of naming organisms called binomial nomenclature.

Suggested answer

2. Describe the challenges Darwin may have faced if Carl Linnaeus had not done his work and shared it. Include an explanation of Linnaeus's contributions.

Suggested answer

Darwin's Theory of Evolution

Darwin was a born naturalist, and his fascination with plants and animals had him attending biology lectures in his spare time. His good friend Reverend John Henslow taught Darwin about these subjects, and recommended that he apply for a position as a naturalist on the British exploration ship *H.M.S. Beagle*.

A Voyage That Would Change the World

Darwin was only 22 when he joined the voyage on the *Beagle* in 1831. The trip was to take five years and explore the southern hemisphere, which has enormous biodiversity. The stated intent of the voyage was to obtain evidence that would support the biblical theory of creation as well as charting poorly known parts of the South American coastline. Darwin's job was to observe, record, and collect specimens of rocks, minerals, plants, and animals. The *Beagle* voyage covered over 60 000 km in five years (Figure 1.7).

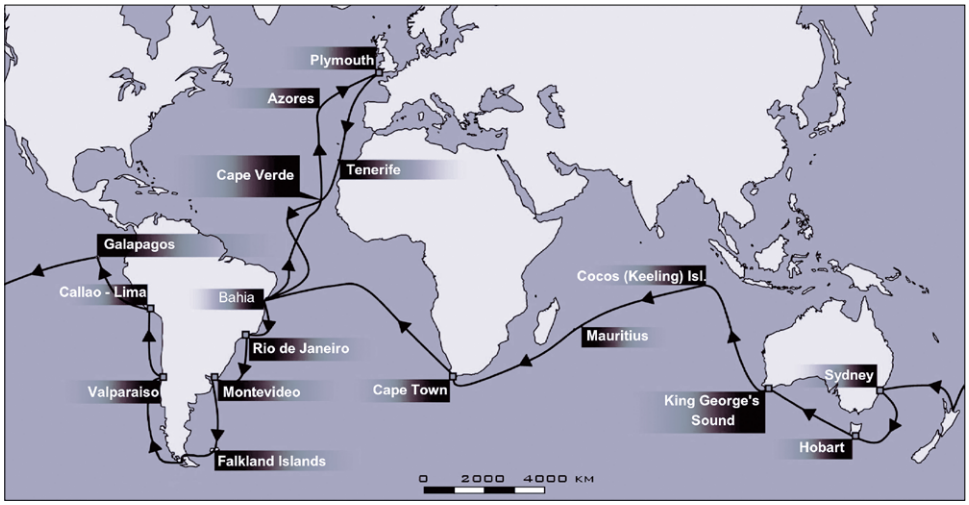

Figure 1.7: Map showing the voyage of the *H.M.S. Beagle*. It took Charles Darwin around the world to many exotic locations over five years, starting and ending in Plymouth, England

Source: Wikipedia

While on the voyage, Darwin began to obtain evidence that species do change over time and from place to place. Darwin began to consider that perhaps the earth was much older than the 6000 years it was believed to be at the time, and that small changes in species could also build up over time. More importantly, he began to wonder if environmental change could cause species to change.

On the voyage, Darwin collected thousands of specimens of the diverse plant and animal species found along the South American coastline. As the ship worked its way around the continent, Darwin was able to observe the various adaptations of plants and animals that inhabited many ecosystems such as the Brazilian jungles, the grasslands of Argentina, the lands of Tierra del Fuego and the Andes mountain range. He also collected many fossils. Two significant fossils he unearthed were those of a giant *Glyptodon* and *Megatherium*. Both of these species have been extinct for about 10 000 years, but were remarkably similar to the modern-day armadillo. Darwin also noticed signs of geological change, such as a section of shoreline suddenly lifted three metres after an earthquake.

Glyptodon – lived 2 500 000 to 10 000 years ago

Armadillo – lives presently in the Americas

Figure 1.8: Images of a *Glyptodon* and an armadillo showing their similarities

Source: Wikipedia

He also made key observations while visiting the Galapagos Islands, about 1000 km off the west coast of South America. Darwin noted, although the plants and animals closely resembled the species present in mainland South America, that the ones on the Galapagos Islands had unique traits. He also collected specimens of a common bird (a finch) there. He thought they were all forms of the same species. Later, these would be identified by the ornithologist John Gould as belonging to separate species. Gould identified at least 13 different species of finches from the specimens Darwin collected on the Galapagos Islands.

Figure 1.9: Map of the Galapagos Islands

Recommended Activity:

Do an Internet search using the terms "Galapagos Islands Darwin." Watch a video of these fascinating islands that played such an important part in the creation of Darwin's theory.

Although he did not realize it immediately, Darwin eventually concluded that each island had varieties of plants, birds and other animals that were unique species specifically adapted to their isolated environments. Yet all these species had close relatives living on the South American continent. Maybe they were all originally from South America and had evolved over a long period of time on the Galapagos Islands?

Darwin Develops His Theory

When Darwin returned to England in 1836, he learned that the finches he collected were in fact separate species. He now believed that species evolved from adaptations caused by a changing environment. He reasoned that individuals that were better able to adapt would survive and reproduce in greater numbers, and gradually evolve into a new species.

In 1844, Darwin wrote a long essay on the origin of species and natural selection. But he was reluctant to publish his theory, knowing that most people believed in biblical creation, which said that God had created species in their present form. Suggesting that the origin of species was really the result of evolution by natural selection could make him a social outcast; he also did not want to hurt his wife, who was deeply religious.

Darwin was driven to publish his essay because of a letter he received in 1858. The letter came from a young English naturalist, Alfred Wallace, working in Indonesia. In it, Wallace stated his idea of evolution by natural selection, which was nearly identical to Darwin's. A frantic Darwin showed the letter to his friend Charles Lyell who urged Darwin to publish his own work as soon as possible, before Wallace did. Lyell brought Darwin's 1844 essay and Wallace's theory to the Linnaean Society on July 1st, 1858 where they were both presented. Darwin published his famous book *On the Origin of Species* shortly thereafter.

Although Wallace's idea was nearly identical to Darwin's, Darwin is credited as the "father of evolution" since he had developed the idea earlier, and had accumulated more extensive and detailed observations to support his theory. You will learn more about the theory of evolution by natural selection and the evidence in support of it in Lesson 2.

For more information about the formation of Charles Darwin's theory, read the following timeline of his life and work. You will not be tested on this information, but it will give you more insight on how the theory was developed.

Humans as Agents of Evolutionary Change

Evolution by natural selection is all around us. One dramatic example may pose a threat to public health.

When antibiotics were discovered, they were called "magic bullets" and "wonder drugs" because they were so effective at killing bacteria. People believed they were a miracle cure for any illness they might have. Soon, these powerful medicines were being overused, either to treat conditions for which other options are available, or prescribed incorrectly for illness not caused by bacteria. In addition, unused antibiotics are often disposed of improperly, ending up in water systems or soil. The situation is further complicated by the agriculture industry, which relies on the use of antibiotics to keep bacterial diseases out of crowded livestock barns.

The problem with the widespread use of antibiotics is that it has allowed the fittest, or strongest, bacteria to survive and multiply in this new environment. The weak bacteria are killed by the antibiotics while the stronger bacteria survive and produce more bacteria. These bacteria are strong enough to survive the antibiotic drug, so new, stronger antibiotics are then needed to kill them. This has left scientists racing to create new antibiotics to keep ahead of the evolving bacteria. But progress has been slow, and now some antibiotic-resistant bacteria are themselves becoming widespread. One of these is called methicillin-resistant staphylococcus aureus (MRSA), a type of bacteria that causes blood infections and pneumonia. The elderly and people with weakened immune systems have a higher risk of being infected with MRSA, which is difficult to treat and can be fatal.

Most staphylococcus (or "staph") bacteria respond to simple antibiotics, but the overuse of antibiotics has made them increasingly harder to kill. In some hospitals (particularly intensive care units) and nursing homes, where antibiotic use is often high, there is a higher incidence of MRSA. This does not mean those particular staph are any more likely to cause infection; it simply means that if they do cause infection, they will be much harder to kill.

It is important to avoid overusing antibiotics, and for patients to take their entire prescription of antibiotics when it is warranted. Any unused medication should be taken to the pharmacy for proper disposal, not flushed down the toilet where it could contaminate the environment. In general, the environment in which bacteria live is one that humans should strive to change as little as possible.

Support Questions

3. What are the main problems associated with the overuse of antibiotics? Suggested answer

Key Questions

Now work on your Key Questions in the online submission tool. You may continue to work at this task over several sessions, but be sure to save your work each time. When you have answered all the unit's Key Questions, submit your work to the ILC.

(13 marks)

1. What was the original purpose of Darwin's voyage on the *H.M.S. Beagle*, and what was the ultimate significance of the voyage? **(2 marks)**
2. Why does the antibiotic resistance problem present an example of evolution? **(3 marks)**
3. Using the material covered in this lesson, and your own research, describe how the work of Charles Lyell impacted the development of Charles Darwin's theory of evolution. Include the major work done by Lyell and what it led Darwin to consider. **(8 marks)**

Now go on to Lesson 2. Send your answers to the Key Questions to the ILC when you have completed Unit 1 (Lessons 1 to 4).