Evolution Reading Packet
6.1 Evolution by Natural Selection

Learning Objectives

- Explain the process of evolution and the observations that lead to the development of this theory.

Introduction

This picture was taken in the Galápagos Islands, which is off the west coast of South America. The Galápagos Islands are home to many unique organisms, such as these tree-like cacti. Darwin's observations on these islands led to his development of the theory of evolution.

Guided Learning

Darwin's Theory of Evolution

Do you ever wonder why some birds are big like ostriches and some birds are small like robins? Or why a lion has a mane while a leopard has spots? In the 19th century, an English natural scientist named Charles Darwin (Figure below) was also fascinated by the diversity of life on Earth. He set out to answer the following questions:

- Why are organisms different?
- Why are organisms similar?
- Why are there so many different types of organisms?

To answer his questions, he developed what we now call "the theory of evolution by natural selection."

This theory is one of the most important theories in the field of life science. In everyday English,

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1 Photo by CK-12 / CC-BY-SA 3.0.
"evolution" simply means "change." In biology, **evolution** is the process that explains why species change over time. Darwin spent over 20 years traveling around the world and making observations before he fully developed his theory.

Charles Darwin was one of the most influential scientists who has ever lived. Darwin introduced the world to the theory of evolution by natural selection, which laid the foundation for how we understand the living world today.

**Voyage of the HMS Beagle**

In 1859, Charles Darwin published his book, *On the Origin of Species by Means of Natural Selection*. His book describes the observations and evidence that he collected over 20 years of research, beginning with a five-year voyage around the world on a British research ship, the *HMS Beagle*. During the voyage (**Figure** below), Darwin made observations about plants and animals around the world. He also collected specimens to study for when he returned to England.

Each time the *HMS Beagle* stopped at a port, Darwin went on land to explore and look at the local plants, animals, and fossils. One of the most important things Darwin did was keep a diary. He took detailed notes and made drawings.

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2 **Photo** by GEORGE RICHMOND / CK-12 / CC-BY-SA 3.0.
Charles Darwin’s famous five year voyage was aboard the HMS Beagle from 1831-1836.

The Galápagos Islands

While the crew of the HMS Beagle mapped the coastline of South America, they traveled to a group of islands called the Galápagos. The Galápagos are a group of 16 volcanic islands near the equator, about 600 miles from the west coast of South America. Darwin spent months on foot exploring the islands. The specimens he collected from the Galápagos and sent back to England greatly influenced his ideas of evolution (Figure below).

On the Galápagos, Darwin observed that the same kind of animal differed from one island to another. For example, the iguanas (large lizards) differed between islands (Figure below). The members of one
iguana species spent most of their time in the ocean, swimming and diving underwater for seaweed, while those of another iguana species lived on land and ate cactus. Darwin wondered why there were two species of iguanas on the same set of islands that were so different from one another. What do you think?

The Galápagos iguanas are among the signature animals of the Galápagos Islands. Here both a land iguana and a marine iguana are shown.

Giant Tortoises

Darwin also observed giant tortoises on the Galápagos (Figure below). These tortoises were so large that two people could ride on them. Darwin noticed that different tortoise species lived on islands with different environments. He realized that the tortoises had traits that allowed them to live in their particular environments. For example, tortoises that ate plants near the ground had rounded shells and shorter necks. Tortoises on islands with tall shrubs had longer necks and shells that bent upward, allowing them to stretch their necks (Figure below). Darwin began to hypothesize that organisms developed traits over time because of differences in their environments.

The name “Galápagos” means “giant tortoise.” When Darwin arrived on the Galápagos Islands, he was amazed by the size and variety of shapes of these animals. The giant tortoise (left) is a unique animal found only in the

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5 Iguanas by STEVE HERMANN / CK-12 / CC-BY-SA 3.0.
6 Tortoise by YOTCMRD / CK-12 / CC-BY-SA 3.0.
Galápagos Islands. There are only about 200 tortoises remaining on these islands. This Pinta Island tortoise (right) is able to reach leaves high in shrubs with its long neck and curved shell.

Darwin’s Finches

The most studied animals on the Galápagos are finches, a type of bird (Figure below). When Darwin first observed finches on the islands, he did not even realize they were all finches. But when he studied them further, he realized they were related to each other. Each island had its own distinct species of finch. The birds on different islands had many similarities, but their beaks differed in size and shape.

Four of Darwin’s finch species from the Galápagos Islands. The birds came from the same finch ancestor. They evolved as they adapted to different food resources on different islands. The first bird uses its large beak to crack open and eat large seeds. Bird #3 is able to pull small seeds out of small spaces.

In his diary, Darwin pointed out how each animal is well-suited for its particular environment. The shapes of the finch beaks on each island were well-matched with the seeds available on that island, but not the seeds on other islands. For example, a larger and stronger beak was needed to break open large seeds on one island, and a small beak was needed to eat the small seeds on a different island.

Review

- Charles Darwin developed what we now call “the theory of evolution by natural selection.”
- Darwin’s observations on the Galápagos Islands suggested that animals are well-suited for their specific environments.

Vocabulary

Evolution

The change in populations of organisms over time.

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7 [Darwin's Finches](#) by JOHN GOULD / CK-12 / CC-BY-SA 3.0.
6.2 Natural Selection

Learning Objectives

- Explain how natural selection works.

Introduction

How is this deer mouse well adapted for life in the forest?

Notice how its dark coloring would allow the deer mouse to easily hide from predators on the darkened forest floor. On the other hand, deer mice that live in the nearby Sand Hills are a lighter, sand-like color. What caused the deer mice to be so well adapted to their unique environments? Natural selection.

Guided Learning

Natural Selection

The theory of evolution by natural selection means that the inherited traits of a population change over time. Inherited traits are features that are passed from one generation to the next. For example, your eye color is an inherited trait. You inherited your eye color from your parents. Inherited traits are different from acquired traits, or traits that organisms develop over a lifetime, such as strong muscles from working out (Figure below).

8 Photo by CK-12 / CC-BY-SA 3.0.
Human earlobes may be attached or free. You inherited the particular shape of your earlobes from your parents. Inherited traits are influenced by genes, which are passed on to offspring and future generations. Things not influenced by genes are not passed on to your offspring. Natural selection only operates on traits like earlobe shape that have a genetic basis, not on traits that are acquired, like a summer tan.

**Natural selection** explains how organisms in a population develop traits that allow them to survive and reproduce. Natural selection means that traits that offer an advantage will most likely be passed on to offspring. Evolution occurs by natural selection. Take the giant tortoises on the Galápagos Islands as an example. If a short-necked tortoise lives on an island with fruit located at a high level, will the short-necked tortoise survive? No, it will not, because it will not be able to reach the food it needs to survive. If all of the short necked tortoises die, and the long-necked tortoises survive, then, over time, only the long-necked trait will be passed down to offspring. All of the tortoises with long-necks will be "naturally selected" to survive.

Every plant and animal depends on its traits to survive. Survival may include getting food, building homes, and attracting mates. Traits that allow a plant, animal, or other organism to survive and reproduce in its environment are called **adaptations**.

Natural selection occurs when:
1. There is some variation in the inherited traits of organisms within a species.
2. Some of these traits will give individuals an advantage over others in surviving and reproducing.
3. These individuals will be likely to have more offspring.

Imagine how in the Arctic, dark fur makes a rabbit easy for foxes to spot and catch in the snow. Therefore, white fur is a beneficial trait that improves the chance that a rabbit will survive, reproduce, and pass the trait of white fur on to its offspring (**Figure** below). Through this process of natural selection, dark fur rabbits will become uncommon over time. Rabbits will adapt to have white fur.

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9 **Earlobes** by CHARLES WHITEFIELD / CK-12 / CC-BY-SA 3.0.
The white fur of the Arctic hares may make it more difficult for fox and other predators to locate hares against the white snow.

Mutation

How do we get variation among a population for evolution to occur? The answer is mutation. Most of the time when we hear the word mutation we think of a person having a third eye, an extra arm, or maybe even a tail. However, mutations aren’t always harmful, sometimes they can be helpful, and sometimes we don’t even notice that they have happened. If a harmful mutation occurs than that organism will be less likely to survive and reproduce successfully, therefore the trait will not continue into subsequent generations. If the trait does not affect the organism, or if it even helps the organism to survive or increase its rate of reproduction then the trait will be passed on to the next generation and will become a variation within the population.

A mutation occurs when there is a change in the organism’s DNA sequence. Our DNA is what makes up our genes and determines our phenotype. If there is even a slight change to our DNA sequence it can create drastic changes to our genotype and phenotype.

Why So Many Species?

Scientists estimate that there are between 5 million and 30 million species on the planet. But why are there so many? As environments change over time, organisms must constantly adapt to those environments. Diversity of species increases the chance that at least some organisms adapt and survive.

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10 *Arctic Hares* by USFWS / CK-12 / CC-BY-SA 3.0.
any major changes in the environment. For example, if a natural disaster kills all of the large organisms on the planet, then the small organisms will continue to survive.

Review

- Evolution occurs by natural selection, the process by which organisms with traits that better enable them to adapt to their environment will tend to survive and reproduce in greater numbers.
- Natural selection occurs when there is some variation in the inherited traits, some of these traits will give individuals an advantage over others, and the individuals with certain traits will be more likely to have more offspring.
- Variation in a population exists because of mutation. Mutation is the driving force behind evolution.

Vocabulary

**Acquired Trait**
Trait that organisms develops over a lifetime.

**Adaptation**
Trait that enhances an organism's ability to survive and reproduce in its environment.

**DNA (deoxyribonucleic acid)**
Hereditary material of a cell.

**Gene**
A portion of DNA that codes for a specific trait.

**Genotype**
The combination of alleles an individual has for a certain gene. The alleles are inherited from both parents and code for a phenotype.

**Inherited Trait**
Feature passed from parent to offspring.

**Mutation**
A change in an organism's DNA sequence. This change can be beneficial, harmful, or have no affect on the organism.

**Natural Selection**
Process by which organisms with traits that better enable them to adapt to their environment will tend to survive and reproduce in greater numbers, allowing these favorable traits to be passed on to the next generations.

**Phenotype**
An organism's appearance as coded for by the genotype.
6.3 Fossils

Learning Objectives

- Discuss the significance of the fossil record as evidence for evolution.

Introduction

What's on this rock?

This sedimentary rock contains a fossilized stalked crinoid. Scientists study fossils of plants, animals, and other organisms in order to better understand what life was like on Earth many years ago and how it has changed over time. Fossils are important evidence for the theory of evolution.

Guided Learning

The Fossil Record

Fossils are preserved remains of animals, plants, and other organisms from the distant past. Examples of fossils include bones, teeth, and impressions. By studying fossils, evidence for evolution is revealed. Paleontologists are scientists who study fossils to learn about life in the past. Paleontologists compare the features of species from different periods in history. With this information, they try to understand how species have evolved over millions of years (Figure below).

11 Photo by CK-12 / CC-BY-SA 3.0.
Evolution of the horse. Fossil evidence, depicted by the skeletal fragments, demonstrates evolutionary milestones in this process. Notice the 57 million year evolution of the horse leg bones and teeth. Especially obvious is the transformation of the leg bones from having four distinct digits to that of today's horse.

Until recently, fossils were the main source of evidence for evolution (Figure below). Through studying fossils, we now know that today's organisms look much different in many cases than those that were alive in the past. Scientists have also shown that organisms were spread out differently across the planet. Earthquakes, volcanoes, shifting seas, and other movements of the continents have all affected where organisms live and how they adapted to their changing environments.

About 40 to 60 million years ago these insects were trapped in a gooey substance, called resin, that comes from trees. The fossils in the movie Jurassic Park were trapped in resin.

Rock Layers and the Age of Fossils

There are many layers of rock in the Earth's surface. Newer layers form on top of the older layers.

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12 Modern Horse by CK-12 / CC-BY-SA 3.0.
13 Mosquito Fly Resin by FALK / CK-12 / CC-BY-SA 3.0.
Therefore, you can tell how old a fossil is by observing in which layer of rock it was found. The fossils and the order in which fossils appear is called the **fossil record**. The fossil record provides evidence for when organisms lived on Earth, how species evolved, and how some species have gone extinct. Geologists use a method called **radiometric dating** to determine the exact age of rocks and fossils in each layer of rock. This technique measures how much of the radioactive materials in each rock layer have broken down (Figure below).

![Spectrophotometer](https://example.com/spectrophotometer.jpg)

This device, called a spectrophotometer, can be used to measure the level of radioactive decay of certain elements in rocks and fossils to determine their age.

Radiometric dating has been used to determine that the oldest known rocks on Earth are between four and five billion years old. The oldest fossils are between three and four billion years old. Remember that during Darwin's time, people believed the Earth was just about 6,000 years old. The fossil record proves that Earth is much older than people once thought.

**Review**

- Fossils, or preserved parts of organisms from the distant past, have shown that species change over time.
- Radiometric dating can be used to determine the age of fossils by measuring the how much of the radioactive materials in each rock layer have broken down.

**Vocabulary**

**Fossil**

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14 Spectrophotometer by TIM VICKERS / CK-12 / CC-BY-SA 3.0.
Preserved part of animals, plants, and other organisms from the distant past.

**Fossil Record**
Complete set of fossils that has been discovered, and the order in which the fossils appear.

**Paleontologist**
Scientist who studies fossils to learn about life in the past.

**Radiometric Dating**
Procedure used to determine the age of rocks or fossils by measuring how much of the radioactive materials in each sample were broken down.

**Sedimentary Rock**
Types of rock that are formed by the deposition of material at the Earth's surface and within bodies of water.
6.4 Structure Evidence for Evolution

Learning Objectives
- Discuss how vestigial structures and embryology support evolution theory.

Introduction

Why do you have a tailbone?
If you look closely at a skeleton, you might notice a triangular bone at the end of the spinal column. This is your tailbone. Why would you have a tailbone when you don't have a tail? You have a tailbone because your ancient ancestors did have a tail. These sorts of "leftover" structures support the theory of evolution.

Guided Learning

Structural Evidence
Even though two different species may not look similar, they may have similar internal structures that suggest they have a common ancestor. That means both evolved from the same ancestor organism a long time ago. Common ancestry can also be determined by looking at the structure of the organism as it evolves.
first develops.

**Vestigial Structures**

Some of the most interesting kinds of evidence for evolution are body parts that have lost their use through evolution (**Figure** below). For example, most birds need their wings to fly. But the wings of an ostrich have lost their original use. Structures that have lost their use through evolution are called **vestigial structures**. They provide evidence for evolution because they suggest that an organism changed from using the structure to not using the structure, or using it for a different purpose. Penguins also do not use their wings to fly in the air. However, they do use them to move in the water. The theory of evolution suggests that penguins evolved to use their wings for a different purpose. A whale’s pelvic bones, which were once attached to legs, are also vestigial structures. Whales are descended from land-dwelling ancestors that had legs.

![Mole rat](Mole Rats live underground where they do not need eyes to find their way around. This mole’s eyes are covered by skin. Body parts that do not serve their original function are vestigial structures.)

**Homologous Structures**

Another convincing piece of evidence for evolution is **homologous structures**. Homologous structures are structures that evolved from some structure in an ancestral organism. Through evolution an original structure of an organism has changed and been adapted for different purposes in several different related species. For example (**figure** below) you can find the ulna, radius, carpals, and phalangeal bones in primates, canines, felines, birds, and whales. This suggests that all of these species once shared a common ancestor that also had the same bones within the organism.

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16 **Mole Rat** by ONYSHCHENKO / CK-12 / CC-BY-SA 3.0.
Similar Embryos

Some of the oldest evidence of evolution comes from **embryology**, the study of how organisms develop. An embryo is an animal or plant in its earliest stages of development. This means looking at a plant or animal before it’s born or hatched. Centuries ago, people recognized that the embryos of many different species have similar appearances. The embryos of some species are even difficult to tell apart. Many of these animals do not differ much in appearance until they develop further.

Some unexpected traits can appear in animal embryos. For example, human embryos have gill slits just like fish! In fish they develop into gills, but in humans they disappear before birth. The presence of the gill slits suggests that a long time ago humans and fish shared a common ancestor.

The similarities between embryos suggests that these animals are related and have common ancestors. For example, humans did not evolve from chimpanzees. But the similarities between the embryos of both species suggest that we have an ancestor in common with chimpanzees. As our common ancestor evolved, humans and chimpanzees went down different evolutionary paths and developed different traits.

**Review**

- Vestigial structures, or structures that have lost their use through evolution, are important evidence of evolution.
- Studying the embryos of organisms also provides evidence that two very different animals could

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17 "Homology vertebrates" by Волков Владислав Петрович - CC0
http://commons.wikimedia.org/wiki/File:Homology_vertebrates.svg#mediaviewer/File:Homology_vertebrates.svg
have descended from a common ancestor.

**Vocabulary**

**Common Ancestor**
Organism from which two or more different organisms evolved a long time ago.

**Embryology**
Study of how organisms develop from a fertilized egg.

**Homologous Structure**
Body parts that are similar in origin and structure.

**Vestigial Structure**
Structure that has lost its use through evolution.
6.5 Origin of Species

Learning Objectives

- Describe three ways in which a new species can develop.

Introduction

Where did this diversity of life come from?

If you have ever been to the beach, then you realize there is not just one species of marine life. The wide variety of shells that wash up on the beach indicate that there are many forms of life in the ocean. This wide diversity of life requires that many new species have appeared over time. But how does a new species come into being?

Guided Learning

The Origin of Species

The creation of a new species is called speciation. Most new species develop naturally. But humans have also artificially created new breeds and species for thousands of years.

New species develop naturally through the process of natural selection. Due to natural selection, organisms with traits that better enable them to adapt to their environment will tend to survive and reproduce in greater numbers. Natural selection causes beneficial heritable traits to become more

\[\text{Photo by CK-12 / CC-BY-SA 3.0.}\]
common in a population and unfavorable heritable traits to become less common. For example, a giraffe’s neck is beneficial because it allows the giraffe to reach leaves high in trees. Natural selection caused this beneficial trait to become more common than short necks.

As new changes in the DNA sequence are constantly being generated in a population’s gene pool, some of these changes will be beneficial and result in traits that allow adaptation and survival. Natural selection causes evolution of a species as these beneficial traits become more common within a population.

Sexual Selection

But what about the Peacock? Why have these birds evolved to have such ornate, and cumbersome feathers? Wouldn’t these large, showy feathers hinder the organisms ability to survive? This was a questions that stumped Charles Darwin for many years. Until finally he came up with a theory that seemed to answer his questions, sexual selection.

Sexual selection is another mode of natural selection. Sexual selection also causes organisms to change and evolve over many generations. Instead of animals changing to better adapt to their surrounding environment animals are better adapted at securing a mate. As Charles Darwin said in his book, On The Origin of Species, “sexual selection depends, not on a struggle for existence, but on a struggle between the males for possession of the females; the result is not death to the unsuccessful competitor, but few or no offspring.”

Because the female peacocks prefer males with larger, more colorful feathers, the males with the largest, most colorful feathers were able to reproduce more than the males that did not have those traits. Therefor, the males with the larger, colorful feathers passed their traits onto the next generation and male
peacocks start to have larger, and more colorful feathers over the generations. There are many examples of sexual selection, this has not just occurred in peacocks. Other examples include: mains on lions, antlers on deer, the wattle and comb on a chicken, and many more.

Selective Breeding

Selective breeding occurs when humans select which plants or animals to breed in order to pass on specific traits to the next generation. For example, a farmer may choose to breed only cows that produce the best milk. Farmers would also avoid breeding cows that produce less milk. In this way, selective breeding of the cows would increase milk quality and quantity.

Humans have also artificially bred dogs to create new breeds (Figure below).

Artificial Selection: Humans used artificial selection to create these different breeds. Both dog breeds are descended from the same wolves, and their genes are almost identical.

Review

- Speciation, the creation of a new species, can happen through natural selection, sexual selection or artificial selection.

Vocabulary

Natural Selection

Process by which organisms with traits that better enable them to adapt to their environment will tend to survive and reproduce in greater numbers, causing beneficial heritable traits to become more common in a population.

Selective Breeding
Selection of plants or animals by humans to breed in order to pass specific traits on to the next generation.

**Sexual Selection**

Process by which organisms with traits that better help them secure a mate and reproduce will reproduce at a greater rates than males without those traits, and will pass those desirable traits along to subsequent generations.

**Speciation**

Creation of a new species.
6.6 Mass Extinctions

Learning Objectives
- Define mass extinction and give two examples.

Introduction

What happened to the dinosaurs?
Most of the dinosaurs disappeared from Earth about 65 million years ago. This is probably the most famous example of a mass extinction. So how do you define a mass extinction?

Guided Learning

Mass Extinctions

An organism goes extinct when all of the members of a species die out and no more members remain. Extinctions are part of natural selection. Species often go extinct when their environment changes, and they do not have the traits they need to survive. Only those individuals with the traits needed to live in a changed environment survive (Figure below).

Humans have caused many extinctions by introducing species to new places. For example, many of New Zealand’s birds have adapted to nesting on the ground. This was possible because there were no land mammals in New Zealand. Then Europeans arrived and brought cats, foxes, and other predators with them. Several of New Zealand’s ground nesting birds, such as this flightless kiwi, are now extinct or threatened because of these predators.

Mass extinctions, such as the extinction of dinosaurs and many marine mammals, happened after major catastrophes such as volcanic eruptions and earthquakes (Figure below).

19 Kiwi by G.D. ROWLEY / CK-12 / CC-BY-SA 3.0.
Since life began on Earth, there have been several major mass extinctions. If you look closely at the geological time scale, you will find that at least five major mass extinctions have occurred in the past 540 million years. In each mass extinction, over 50% of animal species died. The total number of mass extinctions could be as high as 20.

After each mass extinction, new species develop to fill the habitats where old species lived. This is well documented in the fossil record.

**Review**

- Extinctions, when a species entirely dies out, can happen when the environment changes, and the organisms do not have the traits they need to survive.
- Since life began on Earth, there have been at least five major mass extinctions.

**Vocabulary**

**Extinction**

Dying out of a species so that no members of the species exist anymore.

**Mass Extinction**

Dying out of a large number of species within a relatively short period of time, usually due to major catastrophes.