High School Biology

Science course from Educational Options

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Lesson 10: The Theory of Evolution

Objectives

By the end of this lesson, students will be able to:

- outline the development of evolutionary theory
- explain Darwin's theories of evolution and adaptation
- explain how fossils support the theory of evolution
- give examples of evidence of evolution
- relate extinction to the concepts of adaptation and survival of the fittest

Click here for the course glossary

Introduction

Humans have always wondered about life on Earth. How did it get here? Why does it change? Today, scientists still debate these topics. Most of evolutionary science is based on the start of life *after* the creation of the universe and Earth.

This lesson will guide you through philosophers, scientists, events, and theories that led to Darwin's Theory of Evolution. You will explore how evolution works. You will also learn how natural selection plays a part in organisms' survival.

Early Thoughts on Life

Ancient Greek philosophers had different theories about the origin of life. Many believed in **evolution**, or slow change over many generations of living organisms.

However, the philosophers who were the greatest influences on Western culture felt differently. Plato and his student Aristotle

believed in a world of perfect creatures. These creatures each had a certain place in the world. Aristotle ordered them from simplest to most complex. He called this the Scale of Nature. To find out more about Aristotle's Scale of Nature, click **here**.

Natural Theology

As the world changed, Plato and Aristotle's theories stayed popular. The rise of modern religions had little effect on those theories. In fact, the Old Testament supported the idea that living things are created in one way and stay that way. People still believed a Creator made the world just as it is. Science supported this view.

By the 1700s, the study of nature focused on learning the Creator's plan. This was called *natural theology*. Natural theologists believed that the Creator had designed each animal for a special purpose. As the purpose differed from one animal to the next, so did the animal. To natural theologists, this explained the slight differences between some species. Early classification systems came from the desire to map what they called the *scale of life*. This scale was thought to be outlined by the Creator.

Early Study of Fossils

The study of **fossils** helped form the current theory of evolution. Over time, as organisms died, they sank to the bottom of oceans or decayed on land. Sand and mud covered the remains of the organisms. This pushed them deep into the soil or soft rock. In many cases, this preserved the hard parts of life forms. Sediment kept covering the rock and soil. The remains of life were compressed into layers of rock called **strata**.

Years later, **erosion** wore down the rock. Old layers of strata became visible. So did fossils. Looking at fossils and where they are found tells the history of Earth and its life forms.

Paleontology

A French scientist named Georges Cuvier (1769-1832) developed the study of *paleontology*. This is the study of early life from fossils.

Cuvier mapped the different species he found. The deeper he went into the rock, the less the plant and animal life looked like current plants and animals. He also found evidence that species appeared and disappeared from the area.

Cuvier did not believe in evolution. Like many, he thought a Creator made all life forms. When he found fossils of extinct

animals, he thought a great event must have killed all life in that area. This event could have been something such as a flood or drought. He concluded that the layer of rock with the extinct animals must have formed during that event. Then the region was repopulated with life forms from other parts of the world.

This theory was compatible with religious thinking. It was popular well before Cuvier. It is called **catastrophism**. The term comes from the word *catastrophe*, meaning a destructive event. A catastrophe, such as a flood, could cause a mass extinction of species. Later, new species would move into the area.

As the flow of a river cuts through ancient rock, the *strata*, or layers of rock, become visible.

Paving the Way for Evolutionary Theory

While Cuvier was writing about fossils, another theory was forming. Scientists realized life on Earth was not new. They began to think life evolved with Earth.

A group of Scottish geologists studied how canyons and rivers were formed. They found these landforms formed over long periods of time by a series of slow processes. They called this theory **gradualism**. More scientists began to accept this theory and its popularity grew. Gradualism laid the path for Darwin's theory of evolution.

The First Theory of Evolution

Jean Baptiste Lamarck (1744-1829)

In 1809, a naturalist named Jean Baptiste Lamarck published his theory of evolution. He said that living things went through constant change, and that this change would not end until the organism was perfect for its environment. Then the organism would stop changing and remain that way.

Lamarck believed that change came from special skills animals learned. When an animal learned something, its offspring would be born with that information or skill. These new traits were passed from parent to offspring. This made the next generation more perfect.

In Lamarck's time, scientific knowledge was still limited. There was little evidence to support evolution. Many scientists dismissed any theory of it. The most important scientists of that time still believed in divine creation. They believed this for almost another fifty years.

Think About It

To find out more about Lamarck and his theory of evolution, click **here**.

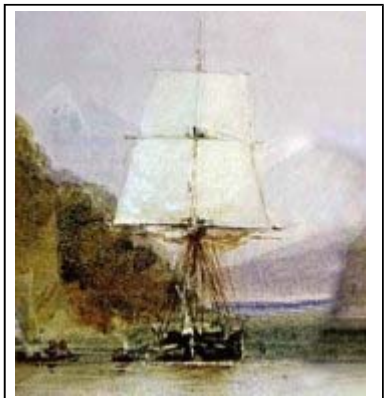
Suppose a farmer lost his right hand in an accident when he was young. As a result, he learned to do everything with his left hand. According to Lamarck's theory, how would that affect the farmer's children?

The Rise of Darwin's Theory

The divine creation theory held well into the 19th century. It was rarely challenged. Over time however, science began to emerge as its own subject of study. People began to see science as separate from religion. More people were open to new ideas. This change in attitude soon affected scientific study.

Charles Darwin and The Voyage of the *Beagle*

In 1830, Charles Darwin was a young naturalist. He was invited to join a survey ship on its trip around the world. To learn more about Darwin's life before this voyage, click **here**.



Detail of *HMS Beagle at Tierra del Fuego* by Conrad Martins

The HMS *Beagle* began its voyage on December 1831. Its purpose was to map the South American coastline, and then to continue on to sail around the world. During the trip, Darwin spent much of his time on land. He explored plant and animal life in the jungles of Brazil and on nearby islands. He gathered samples and kept records.

Darwin noticed differences between the life forms. His teachers had taught him that all life in tropical areas was the same. But when Darwin saw tropical animals in South America, they did not look like tropical animals around the world. Instead, they looked more like animals in other parts of South America. This puzzled Darwin.

Darwin was especially interested in organisms on the Galapagos Islands. The Galapagos are a group of islands off the west coast of Ecuador. The species that live there are unique. Still, Darwin noted they looked most like the life forms in South America.

Darwin guessed that these species had moved from South America and somehow changed once they reached the Galapagos. He collected birds from a few of the islands and took them back to England to study.

Darwin's Study of Fossils

Darwin observed fossils while on South American coasts. In his journal, Darwin reported seeing fossils of giant extinct animals. One example was the megatheria, an elephant-sized ground sloth. Another was the glyptodon, a huge armadillo-like creature.

Darwin noticed the rock around the fossils did not show signs of a catastrophe. According to popular belief, Darwin should have seen evidence of flood water on the strata. If there were no flood, how would the animals have become extinct?

After South America, the *Beagle* continued on around the world. Darwin continued to keep detailed records about the life forms he saw. By the end of his voyage, Darwin was doubting what he had been taught about the origin of life. He now believed Earth was much older than a few thousand years and had collected evidence to prove his theory.

Darwin's Finches

In the Galapagos, Darwin collected several species of wildlife. Back in England, he classified them into species. Darwin gave his bird samples to one of England's most famous ornithologists, John Gould. Gould found Darwin was wrong. The birds were not different species. They were different types of one species: the finch. Darwin looked back at his and his shipmates' journals from the voyage. He found that each finch came from a different island in the Galapagos.

Darwin guessed that one species made the journey to the island from South America. Later, the bird population spread to other

islands. In a new area, the birds had to find a way to survive. The slight differences in species supported Darwin's theory. Darwin's theory was that living things change to be better suited to live in a new place. He studied each bird's features to find how each changed.

The Galapagos Islands

Darwin concluded that each bird's appearance was a reaction to its environment. Examine how each bird's beak has adapted to its habitat:

Darwin's Finches

1. Large ground finch
Its large beak helps it break open seeds faster than smaller finches. It has little competition for food. Its control of the food source may have been why other finches developed more specialized beaks.

2. Medium ground finch
It developed a smaller beak from fighting for food. The smaller beak allows it to grasp big and small seeds easily.

3. Small tree finch
It feeds mostly on insects. Its sharp, narrow beak is good for grasping small prey.

4. Warbler finch
Its small beak is suited to its diet of small seeds and vegetation. This finch is found on almost all the Galapagos Islands. This could be because it adapted its diet to many different types of food.

Darwin thought one bird population could split and grow to become very different. Environment caused bird populations to have different needs. Over many generations, the birds slowly changed. They did this to meet the needs of their environment. He called this **adaptation**.

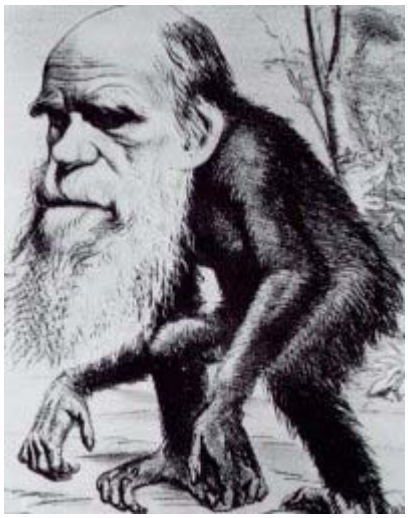
To explain evolution, Darwin needed to know why these adaptations happen. He would have to find the *mechanism of change*. In other words: why does evolution happen and what makes it happen?

The Theory of Evolution

Several theories of evolution were developed around the same time as Darwin's. A few authors published their work. None were in as much detail as Darwin's. His Theory of Evolution became the most famous document on the subject. The theory was proven again and again. Before long, scientists embraced it as the backbone of biology.

The Origin of Species

By the 1840s, Darwin worked out his theories on the evolution of organisms. He also talked with other scientists with similar theories. He explained his theories in his 1859 work *On the Origin of Species by Means of Natural Selection*. Darwin convinced his readers with logic and scientific evidence. He won the support of much of the scientific community and the general public.



Not everyone agreed with Darwin's theories, especially on the relationship between ape and man. Political cartoons from that time show Darwin living with apes, acting like an ape, and even as an ape, as in this cartoon from 1871.

In *The Origin of Species*, Darwin wrote on two main points:

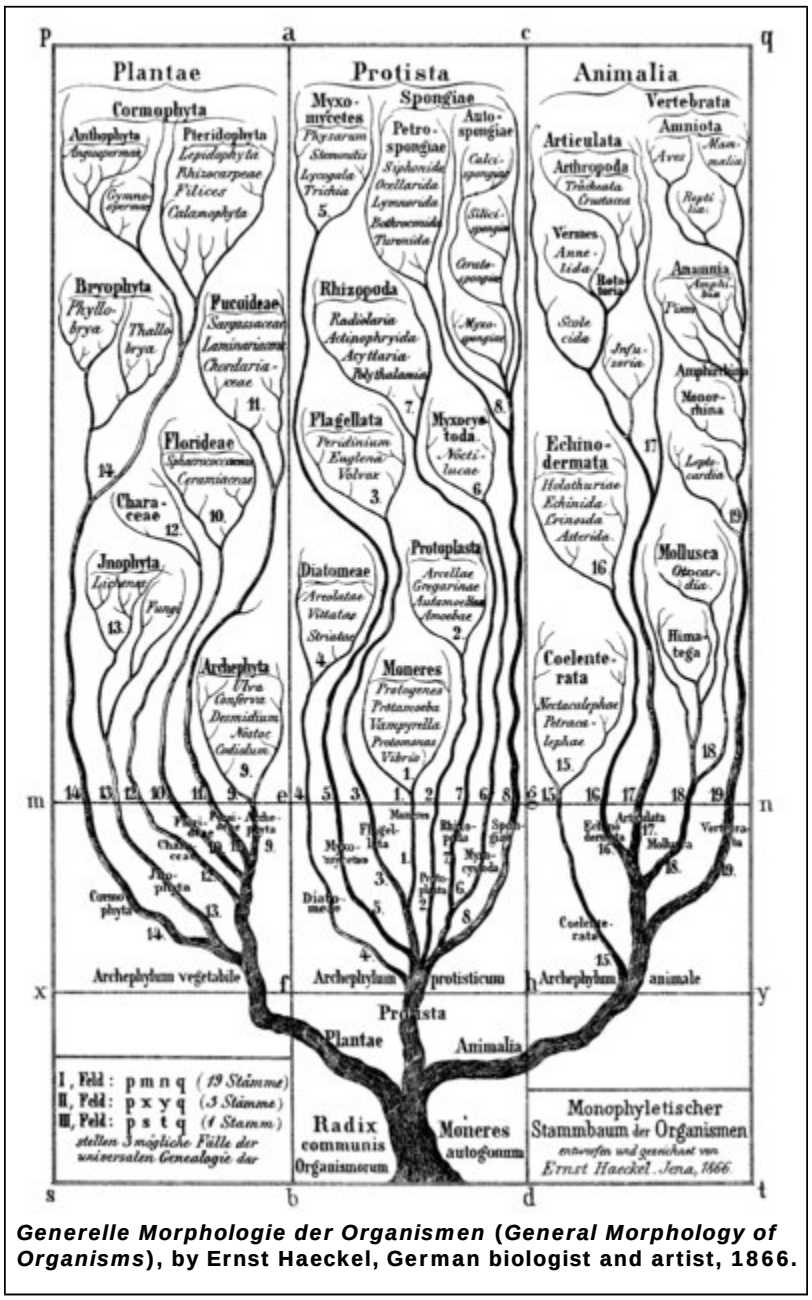
►Evolution happens.

►Evolution happens by natural selection.

Darwin did not use the word "evolution." He called it "descent with modification." This meant all life forms came from a single organism. Over time, an organism's offspring developed into many different organisms. As they spilled into new environments and climates, they continued to change. They changed until they had diverse characteristics. These allowed them to thrive in their environment.

Darwin compared life to a tree. On a tree, many branches come from one trunk. The trunk represents the oldest organism, where life started. The tips of the smallest branches are the youngest organisms. They are far away and very different from the base of the trunk. However, they are still part of a common line. Each place where a limb or branch splits represents a common ancestor.

The picture below is a tree of life drawn during Darwin's time. It is modeled after *The Origin of Species* and is labeled in German and Latin. Near the base of the trunk, you can see where plants, **protists**, and animals branch off from a common ancestor (the trunk).



***Generelle Morphologie der Organismen* (*General Morphology of Organisms*), by Ernst Haeckel, German biologist and artist, 1866.**

Darwin's main point in *The Origin of Species* was that evolution happens by **natural selection**. He said that an organism's response to nature controls how it acts in its environment. He also said that an organism's environment affects its ability to survive. Organisms that live in certain areas slowly change. They take on traits that help them succeed. These **adaptations** are passed from parent to offspring. The organisms that are the best fit for that environment will succeed in getting food, reproducing, and using resources. Those that do not adapt are not as suited to their environment and will soon die off. Thus, over time, more and more organisms have the changed traits.

It is important to understand that Darwin's theories are two separate ideas. The fact that evolution happens is different from describing *how* it happens. It is a common misunderstanding that evolution and natural selection are the same thing, or even the same theory. In fact, the two are not necessarily tied together. Science does not question the fact that evolution happens. But *how* it happens is still a topic of much debate.

Darwin's theories became wildly popular. Not everyone agreed with him though. In fact, he had as many critics as followers. His critics challenged him to prove his work by finding what caused life forms to change. Darwin did not have the technology or scientific knowledge to do this. Since he could not prove it, Darwin's Theory of Evolution remained in question. Later work revealed that the "mechanism of change" is located in the **genes**. Genes are contained inside cells. They determine how an organism is structured.

Survival of the Fittest

Natural selection favors certain traits for certain species. But how does that happen? According to Darwin, life is a struggle for survival. Organisms are in constant competition for the best food, the best space, and the best resources. Organisms that cannot keep up with the struggle are eliminated or die off quickly. This is often referred to as *survival of the fittest*. *Fittest* refers to the organism that is best *fit* for its environment.

Think back to Darwin's finches and follow the chart to see how this works.

Suppose a flock of finches spreads to the Galapagos from South America's mainland. These birds are used to eating small seeds and berries.

↓

On the island, they find fewer bushes with berries, larger seeds, and different predators. The birds struggle to survive in the new environment, and many die.

↓

Now suppose that, over many generations, a genetic difference causes some birds to be born with slightly larger beaks. Those birds find it easier to crack open large seeds. They become stronger and better able to defend themselves.

↓

When birds compete for mates, those with larger beaks overpower those with smaller beaks. The bird with the larger beak wins the mate. Then this bird passes the larger beak trait on to the next generation.

Slowly, the finches adapt to their environment. Birds with smaller beaks are not as successful. They find less food and fewer mates. These birds begin to disappear.

Nature rewarded the trait that was better suited to the environment, the bigger beak. This created a new species of finch with larger beaks.

It is a common misunderstanding that survival of the fittest and natural selection mean that the stronger organism survives. In fact, it is the organism that is *best suited* to the environment that survives. In the example above, the bigger beak happened to be the stronger beak. However, if a climate change caused more bushes with berries and fewer with large seeds, then a smaller beak would again be the best fit.

Think About It

Mountain goats mate in mid-winter. Male mountain goats must compete for the most desirable female goats. They fight each other with their horns and hooves. When one goat has had enough, he surrenders to the stronger goat. Female goats shun the weaker male goat. He may not be able to find a mate during that season. How does this fit in with Darwin's theory of natural selection?

Evidence of Evolution

Humans have always studied fossils. In ancient China, fossilized bones were thought to be dragon bones. They were ground up

and used in medicine. The discovery of fossils gave rise to myths about prehistoric beasts. Fossilized tails of sea animals found in Asia and Europe looked so much like wings that there were stories of stones rising up and flying during storms.

Fossilized trilobite tails

Amber necklace

For a long time, fossils have been used as jewelry. Skeletons from the Bronze Age (3500-1200 BCE) were buried with necklaces strung with sponge fossils. The sponge fossils have a natural hole through the middle like beads. Amber jewelry is still popular today. It often contains fossilized plant or insect life.

Fossils

The oldest known fossils are microscopic blue-green algae. They are about 3.5 billion years old. Scientists believe that they are from Earth's first life forms. The **fossil record** refers to the information scientists learn by looking at fossils. Studying the fossil record allows scientists to form theories about what Earth and organisms were like a long time ago.

The fossil record supports Darwin's theory of evolution. In Darwin's time, the fossil record was incomplete. It was easy to debate his theories. This was frustrating to Darwin. He referred to the fossil record as "extremely imperfect" in his last writings. Modern technology produces better dating and classification methods. These allow the fossil record to give a better picture of how life changed over time.

This chart shows the evolution of horses. Look carefully at the changes in the forefoot over the last 50 million years.

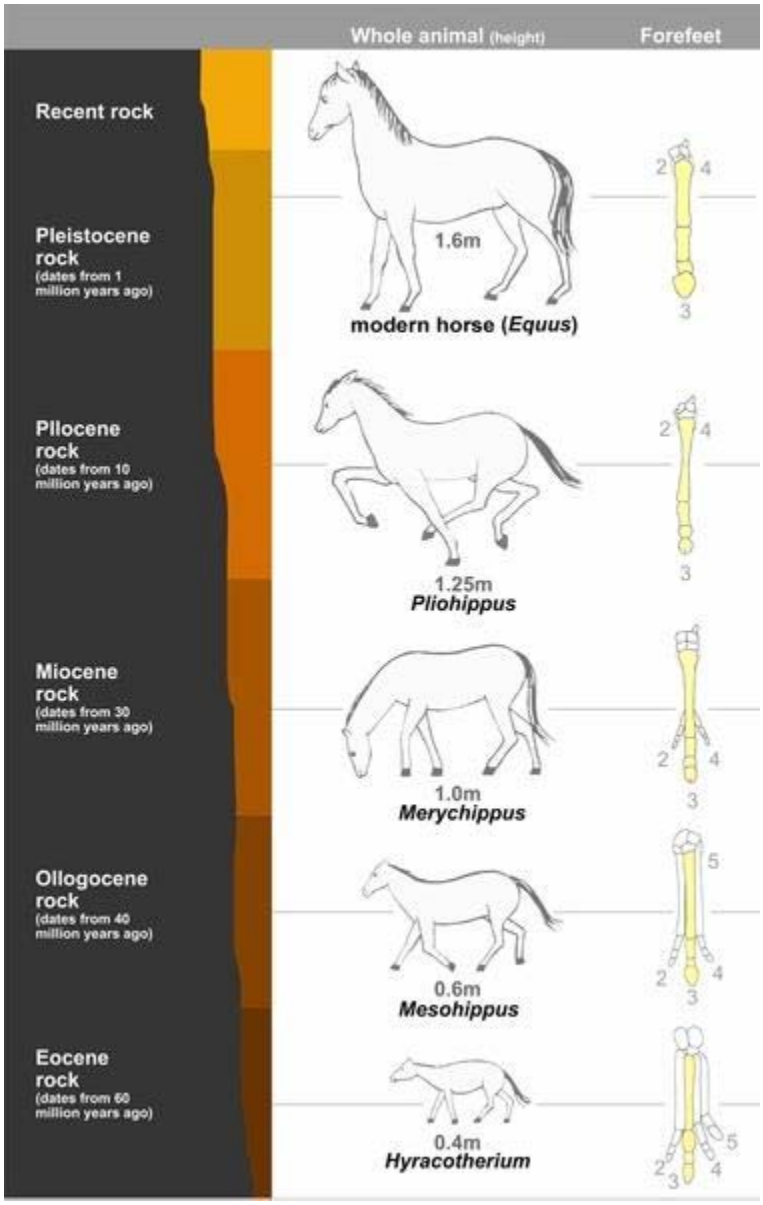
Real Life Scientist

Dr. Hopi Hoekstra is an Associate Professor of Biology at Harvard University. Her research is focused on how natural selection affects fur color in the oldfield mouse, *Peromyscus polionotus*. Many of these mice live on dunes on Barrier Islands in southeastern U.S. They have light fur. Other populations of these mice live inland in the southeastern U.S. They have darker fur. The association between fur color and habitat enables mice to hide from predators.

Dr. Hoekstra uses fieldwork and molecular tools to find the answers to her questions. Recently, she and her colleagues discovered that a single mutation in a DNA sequence of a

pigmentation gene affects the fur color of the oldfield mice in the southeastern U.S. These results show that adaptations can take place in large jumps, rather than gradually, as past research has suggested. They also show that a single mutation can affect the survival of wild organisms.

In addition to her professorship, Dr. Hoekstra is also the Curator of Mammals at the Museum of Comparative Zoology at Harvard University.

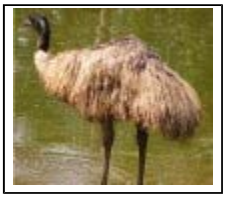


Evolution of the horse

Anatomy

Anatomy is often similar across species. Bat wings, whale flippers, and human arms all have similar bone structure. This implies there is a common ancestor millions or even billions of years ago. More proof of evolution is in **vestigial organs**. These are leftover organs. They had important functions in an organism's ancestors, but today they do not have the same purpose. Some have no purpose at all. Vestigial organs show how organisms have changed and developed over time. They appear in many living species. There are several in the human body.

Millions of years ago, whales lived on land. Now they live in the sea, but they still have pelvic bones. Whales have developed powerful tails for swimming. They have no use for legs. Pelvic bones are considered vestigial organs in whales.



Some birds have wings but cannot fly. Their wings now provide balance, but would not be able to hold the birds up in the air.

Goose bumps are a response to fear or alarm. In animals with fur, goose bumps puff up their hair to make them look larger. Humans are no longer covered in body hair. They have developed other means of communication and no longer have use for this response.

The human appendix is a vestigial organ. In larger animals, the appendix helps digest a diet of roughage, or plants. The appendix does not help digestion in humans. It is probably left over from a plant-eating ancestor.

The term *vestigial* does not necessarily mean useless in the same way that *evolution* does not always mean *better*. It refers to change that is *most suited* to specific conditions. The human appendix was meant for digestion of roughage. Humans might be better off with the ability to digest roughage. But many generations of a gentler diet has made the appendix useless.

Molecular Structure

Molecules can give information about evolution. Scientists want to learn how organisms are related on a molecular level. **DNA** information tells scientists about the evolutionary history of organisms. Closely related organisms have similar proteins. Distantly related organisms have proteins with less in common.

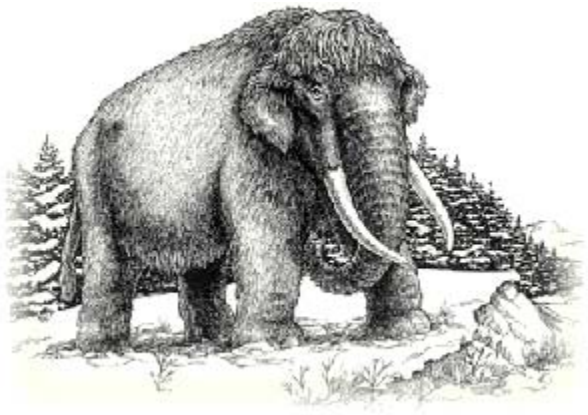
Paleontologists and molecular biologists have different, and sometimes conflicting, ways to date fossils.

Studying molecular structure has brought on new findings and debates about evolution. Molecular biologists have found that genes change, or **mutate**, often. When comparing organisms, scientists determine how long it took them to change. Then they can guess the age of the organism. This process is called the Molecular Clock.

Scientists that study and date fossils say this process is not accurate. The age of the organism from a molecular clock does not always match the age of the organism from the fossil record. Scientists continue to debate this topic.

Extinction

Adaptation is a slow process that happens over many generations. It is impossible for one species to adapt quickly. For this reason, animals tend to live only in specific environments where they fit best. For example, over thousands of years, polar bears have adapted to the arctic cold. A polar bear would not survive in a tropical rain forest. It would not be able to move around and catch food easily. Because of this, it would not survive.



Mastodon, an extinct member of the elephant family

A sudden loss of habitat can lead to the disappearance of a species. Animals are often forced from their habitats by pollution, humans, or environmental change. When animals lose their habitats, they must move. Sometimes they move to where they are not well adapted. This is stressful for a population. It may lead to **extinction**. Extinction occurs when all members of a species die.

The mastodon shown here is an example of an extinct species. Mastodons roamed North America about 4 million to 11,000 years ago. Scientists are not sure why this species became extinct. There are several theories. Early humans hunted the mastodon and other animals. Humans also brought new diseases. The native animals may not have been able to fight a new type of illness. Around the time of the mastodon's disappearance, the seasons became much warmer. This probably disrupted their birth cycles and food sources. It is most likely a combination of those factors that caused the mastodon's extinction.

Making Connections

Do you get a flu shot every winter? Why do we need a new vaccine every year?

Adaptation happens in places other than the animal kingdom. Viruses and diseases have the ability to change in response to their environment. This is called mutation. When viruses mutate, they find new ways to get into cells. Some viruses, such as polio, have been nearly wiped out from powerful vaccines. Still, even polio has not been completely eliminated because it has the ability to mutate. It may reappear in an altered form.

The flu is an example of a virus that changes very rapidly. The same flu virus does not return year after year. It mutates so quickly that scientists must create a new vaccine every year. New strains of the flu virus would not respond to the same old vaccine. New vaccines must continually be created.

Scientists believe that many of today's known viruses have evolved from other viruses. AIDS is one such virus. Scientists have found a very similar virus in monkeys. The monkey strain of the virus cannot be contracted by humans, but scientists believe that the monkey virus went through several mutations. It eventually evolved to the point where it could infect humans.

Practice Problems

Answer each question in your notebook. Click on the "Check Answers" button to check your answers.

1. Charles Darwin observed many different organisms while touring South American coasts. In his journal, Darwin reported seeing fossils of giant extinct animals such as megatheria (elephant-sized ground sloths) and glyptodons (armadillo-like creatures the size of a small car). He noted the preserved fossils showed no signs of catastrophe. Why is this relevant to his theory?

(a) Darwin's theory of evolution is based on one destructive event long ago that eliminated many species of animals.
(b) The fossil record had not been established yet, and Darwin did not understand what he was seeing.
(c) Other scientists wanted to discredit Darwin's work by proving a great flood wiped out the populations of giant animals.
(d) Most people still believed in divine creation and that world-wide catastrophes eliminated entire animal populations.

2. Compare Darwin's and Lamarck's theories. Where did Lamarck's theories go wrong?

3. How is virus mutation similar to Darwin's concept of biological adaptation?

(a) Viruses mutate in order to continue to survive in a new or changed environment.
(b) Viruses mutate in order to pass along adaptations to future generations.