Evolution and Genetics

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8.L.4 Understand the evolution of organisms and landforms based on evidence, theories and processes that impact the Earth over time.

8.L.4.1 Summarize the use of evidence drawn from geology, fossils, and comparative anatomy to form the basis for biological classification systems and the theory of evolution.

8.L.4.2 Explain the relationship between genetic variation and an organism’s ability to adapt to its environment.

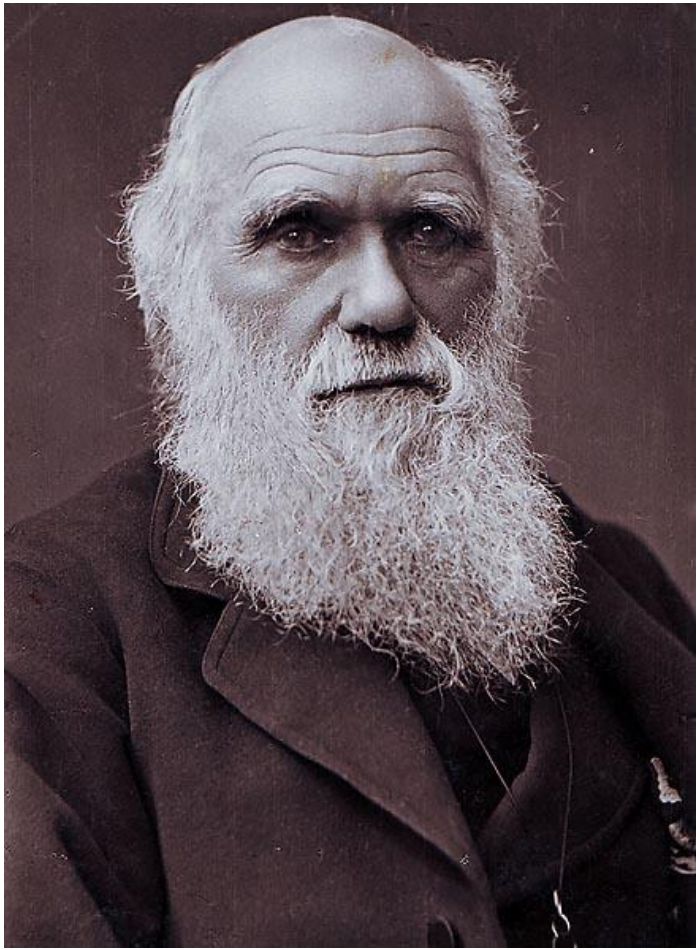
Darwin’s Voyage

What did Darwin observe?

- Charles Darwin became a naturalist, a scientist who studies nature, during a voyage on the British ship HMS Beagle.

- On his journey, Darwin observed and collected many living and fossil specimens.

- Darwin made his most important observations on the Galápagos Islands of South America.



What did Darwin observe?

- Darwin formed the theory of biological evolution using the observations that he had made during an almost five-year journey.

- **Evolution** is the process by which populations change over time.

What did Darwin observe?

- A population is all of the individuals of a species that live together in an area at the same time.

- A species is a group of closely related organisms that can produce fertile offspring.

What did Darwin observe?

- Darwin collected birds from the Galápagos Islands and nearby islands.

- The birds on each island were different from the birds on the other islands, and all were different from the birds on the mainland.

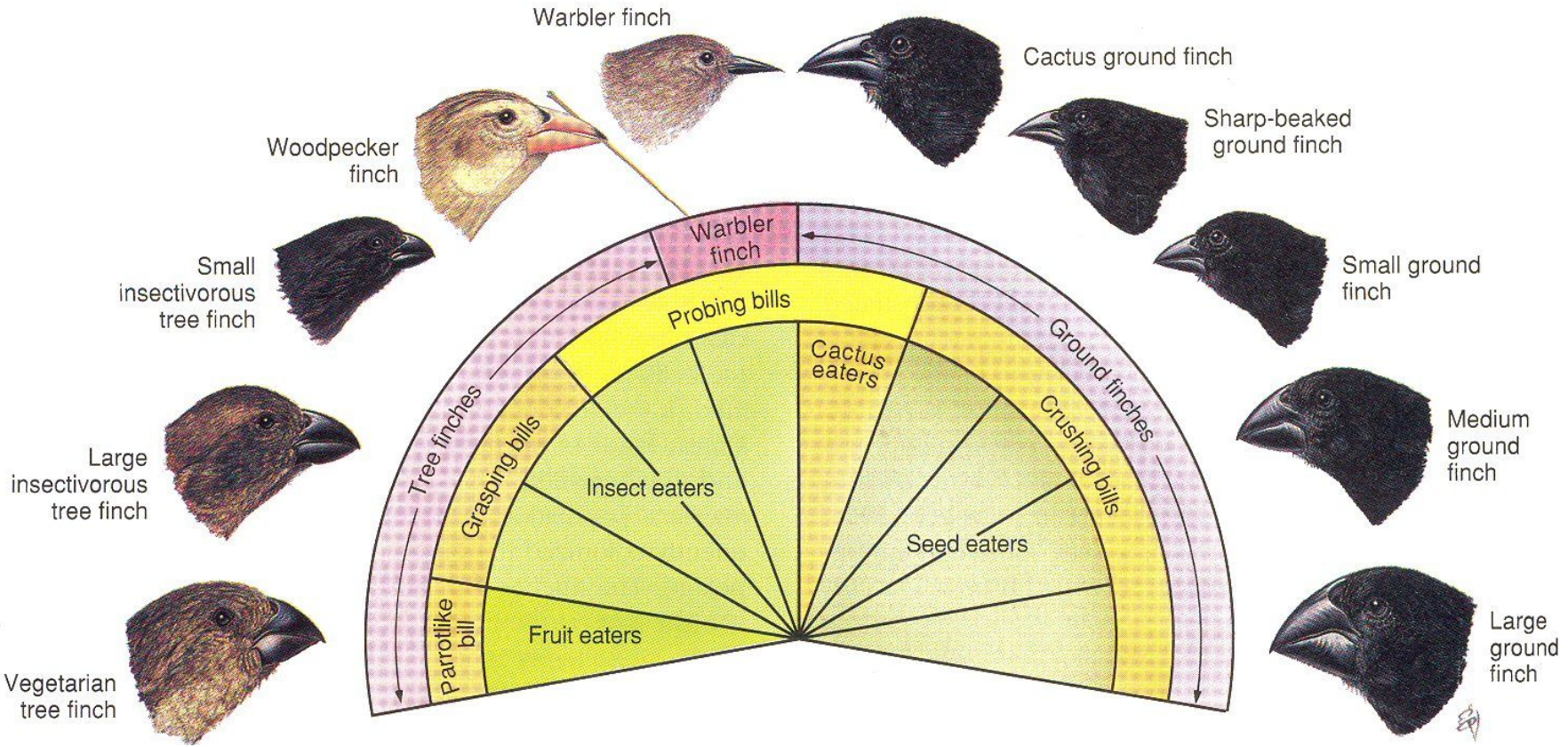
- Darwin wondered if the birds had evolved from one species of finch.

What did Darwin observe?

- Darwin observed differences in beak size among finches from different islands.

- Many years later, scientists confirmed that these differences related to the birds' diets.

- Birds with shorter, heavier beaks could eat harder foods than those with thinner beaks could eat.


Warbler finch
Cactus ground finch
Sharp-beaked ground finch
Woodpecker finch
Small insectivorous tree finch
Small ground finch
Large insectivorous tree finch
Medium ground finch
Vegetarian tree finch
Large ground finch
Warbler finch
Probing bills
Cactus eaters
Tree finches
Grasping bills
Insect eaters
Ground finches
Crushing bills
Seed eaters
Parrotlike bill
Fruit eaters

Darwin's Homework

What other ideas influenced Darwin?

- Darwin was influenced by the ideas of many scientists. These ideas helped him develop his theory about how populations change over time.

- Farmers and breeders select plants or animals for breeding based on desired traits. This is called **artificial selection**.

- A *trait* is a form of an inherited characteristic. Traits can spread through populations.

What other ideas influenced Darwin?

- Scientist Jean Baptiste Lamarck thought that organisms could acquire and pass on traits they needed to survive.

- He did not know that acquired traits do not become part of an organism's DNA and therefore cannot be passed to the offspring.

- Lamarck's idea that organisms' traits help them survive influenced Darwin's theory.

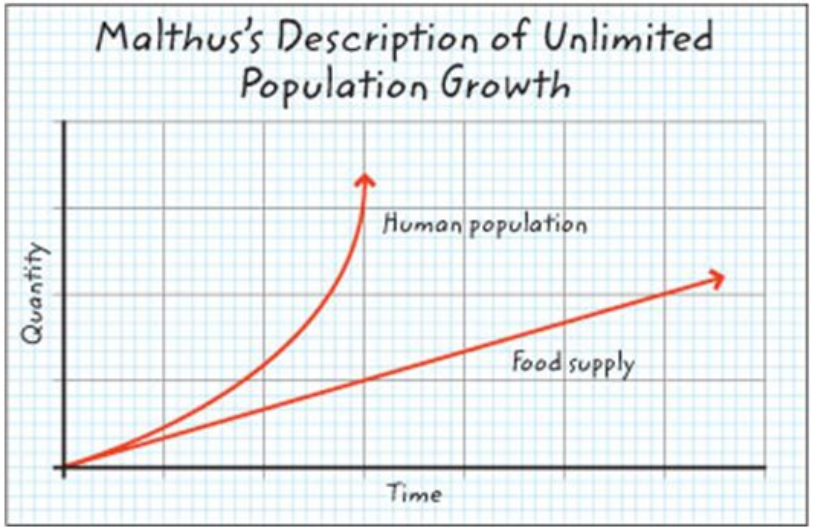
What other ideas influenced Darwin?

- Geologist Charles Lyell hypothesized that small changes in rocks have collected over hundreds of millions of years.

- Darwin reasoned that if Earth were very old, there would have been enough time for very small changes in life forms to add up.

What other ideas influenced Darwin?

- Darwin read an essay by Thomas Malthus that suggested populations are limited by food resources, disease, competition, and predation.



What other ideas influenced Darwin?

- Darwin reasoned that survivors probably have traits that help them survive.

- Darwin thought that some of these traits could be passed on from parent to offspring.

What are the four parts of natural selection?

- Within a species there are natural differences, or **variations**, in traits.

- Variations come from differences in genetic material. Genetic variations can be passed on from parent to offspring.

- An important source of variation is a **mutation**, or change in genetic material.

What are the four parts of natural selection?

- As each new generation is produced, new genetic differences may be introduced into a population.

- In this way, genetic variation can increase in a population.

- The more genetic variation, the more likely that some individuals might have traits that will be advantageous if the environment changes.

What are the four parts of natural selection?

- Individuals try to get the resources that they need to survive, including food, water, space, and, in most cases, mates for reproduction.

- Darwin reasoned that individuals with a particular trait are more likely to survive long enough to reproduce.

- As a result, the trait is “selected,” becoming more common in the next generation of offspring.

What are the four parts of natural selection?

- An **adaptation** is an inherited trait that helps an organism survive and reproduce in its environment.

- As natural selection repeats from generation to generation, these adaptations become more common, and new adaptations may arise.

- Over time, the population becomes better adapted to the environment.

Well-adapted

How do species change over time?

- Adaptations are variations that help a species survive and reproduce.

- At first, adaptations are rare. As more of the species survive and reproduce, the number of individuals with the adaptation will increase.

- Other adaptations are inherited behaviors that help an organism find food, protect itself, or reproduce.

How do species change over time?

- Parents and offspring often have small differences in genetic material, but over many generations, these differences add up.

- These differences accumulate so that organisms alive now are often very different from their ancestors.

What happens to species as the environment changes?

- All organisms have traits that allow them to survive in specific environments.

- If the environment changes, a species is more likely to survive if it has genetic variation, which results in a variation of traits.

What happens to species as the environment changes?

- If no individuals have traits that help them to survive and reproduce in the changed environment, a species will become extinct.

- **Extinction** occurs when all members of a species have died.

- Greater competition, new predators, and the loss of habitat are examples of environmental changes that can lead to extinction.

What happens to species as the environment changes?

- Because a natural disaster can destroy resources quickly, organisms may die no matter what adaptations they have.

- The fossil record shows that many species have become extinct in the history of life on Earth.

Fossil Hunt

How do fossils form?

- Evidence that organisms have changed over time can be found in amber, ice, or sedimentary rock.

- Sedimentary rock is formed when particles of sand or soil are deposited in horizontal layers. This often occurs as mud or silt hardens.

- The most basic principle of dating rocks and the remains of organisms inside is “the deeper it is, the older it is.”

How do fossils form?

- Many fossils form in sedimentary rock.

- **Fossils** are the remains or imprints of once-living organisms.

- Fossils form when a dead organism is covered by a layer of sediment or mud. Over time, more sediment settles on top of the organism.

How do fossils form?

- Minerals in the sediment replace the body's material with minerals that harden over time.

- This process produces a cast fossil.

- Most often, the dead organism is recycled back into the biological world by scavengers, decomposers, or the process of weathering.

How do fossils show change over time?

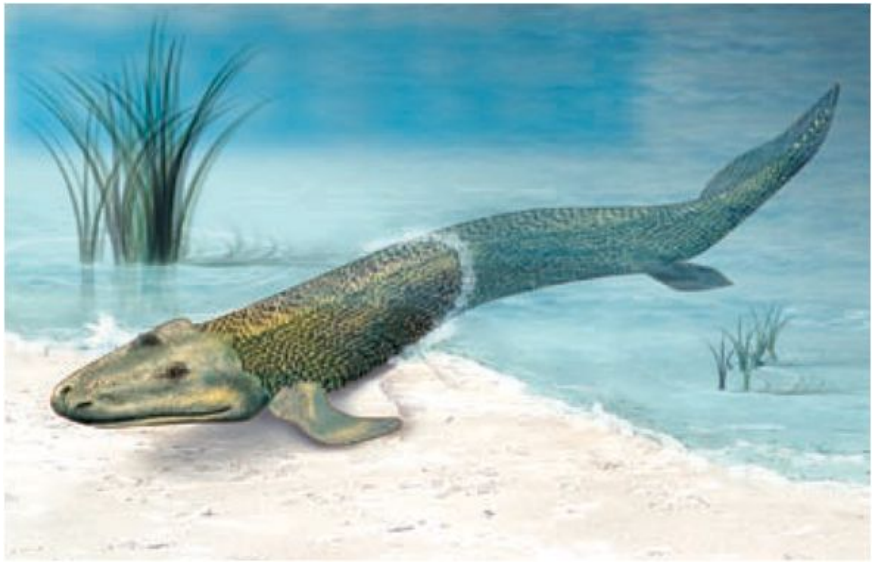
- All of the fossils that have been discovered make up the **fossil record**.

- By examining the fossil record, scientists can learn about the history of life on Earth.

- There are gaps in the fossil record in which a fossil has not been discovered.

How do fossils show change over time?

- Fossils that help fill in gaps in the fossil record are called *transitional fossils*.



How do fossils show change over time?

- Fossils found in newer layers of Earth's crust tend to have physical or molecular similarities to present-day organisms.

- Fossils from older layers are less similar to present-day organisms.

More clues …

What other evidence supports evolution?

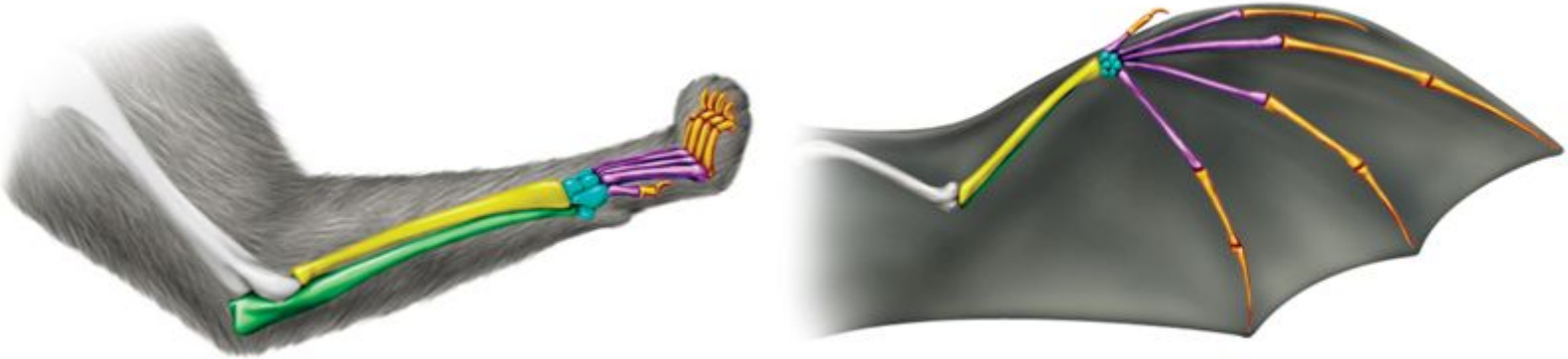
- Many fields of study provide evidence that modern species and extinct species share an ancestor.

- A *common ancestor* is the most recent species from which two different species have evolved.

- Structural data, DNA, developmental patterns, and fossils all support the theory that populations change over time.

What other evidence supports evolution?

- Related organisms share structural traits.



What other evidence supports evolution?

- Scientists can compare the DNA from many organisms.

- The genetic information stored in an organism's DNA gives evidence that two species most likely share a common ancestor.

- If organisms develop in similar ways, they also likely share a common ancestor. The study of development is called *embryology*.

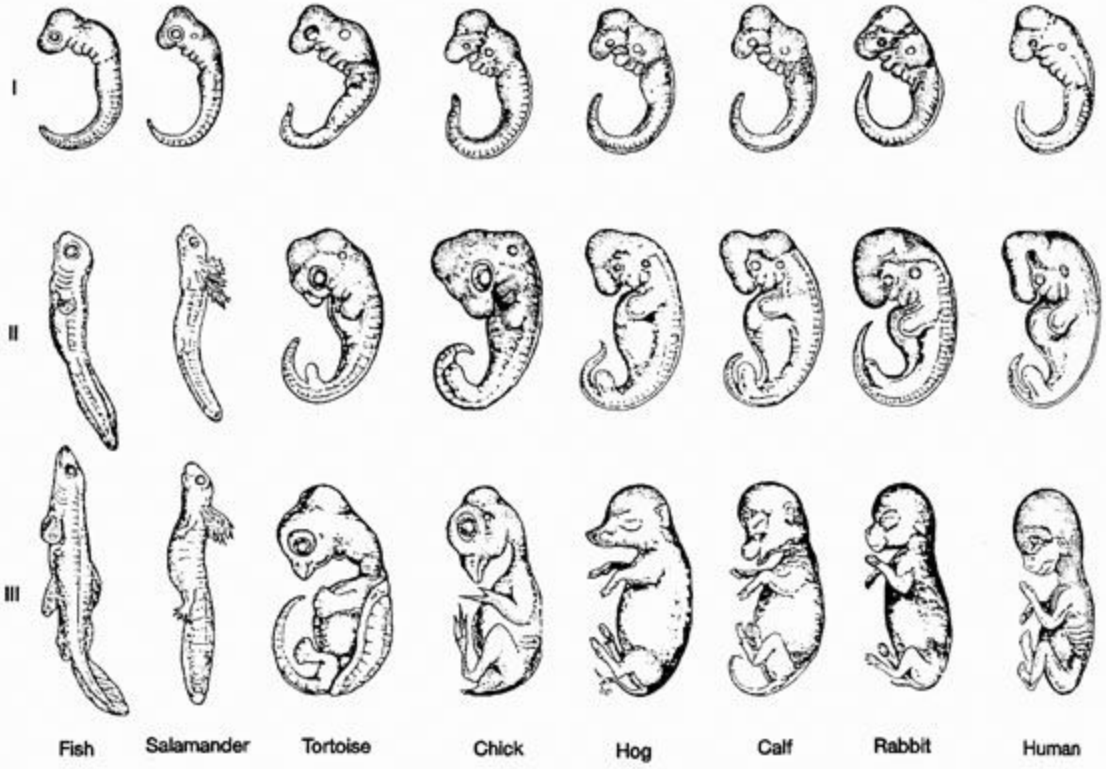


Figure 18.1 Vertebrate embryos illustrate the biogenetic 'law'. Modified from Ernst Haeckel (1874), *Anthropogenie*, Leipzig: Engelmann.

How do we know organisms are related?

- Fossils give evidence for how certain species changed gradually over time.

- Fossil and DNA evidence support the hypothesis that modern whales evolved from hoofed mammals that lived on land.

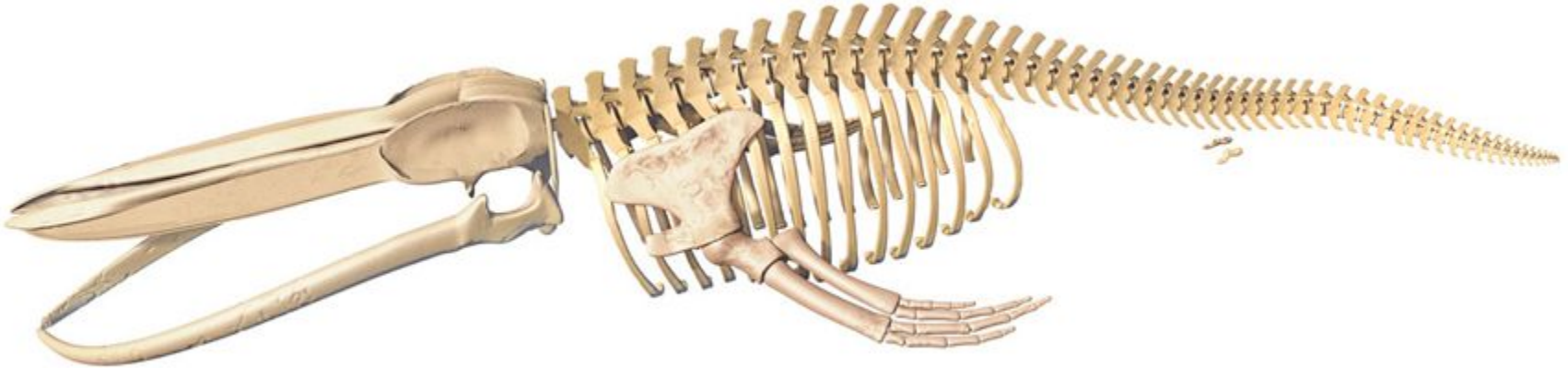
Scientists have examined *transitional characters* of extinct species to see how changes happened.

How do we know organisms are related?

- Fossil evidence and skeletons of fossils suggest how a land mammal might have gradually changed to an aquatic whale.

How do we know organisms are related?

- Molecular evidence also shows that the DNA of whales and hoofed mammals is very similar.



Uncovering Clues

How do we learn about ancient life?

- Paleontologists use fossils to reconstruct the history of life.

- A **fossil** is a trace or an imprint of a living thing that is preserved by geological processes.

- Fossils of single-celled organisms date as far back as 3.8 billion years.

What can we learn from fossils?

- All of the fossils that have been discovered worldwide make up the **fossil record**.

- Examining the fossil record helps scientists identify when different species lived and died.

- There are two ways to describe the ages of fossils.

What can we learn from fossils?

- *Relative dating* determines whether a fossil formed before or after another fossil formed. Newer fossils are found in layers of rock that are above older fossils.

- *Absolute dating* estimates the age of a fossil in years.

- Estimations are based on information from radioactive elements in certain rocks near the fossil.

What can we learn from fossils?

- What can relative dating and absolute dating tell us about these fossils?

What can we learn from fossils?

- The fossil record gives evidence of many of the different organisms that have lived during Earth's long history.

- Changes in population can be preserved in fossils over many generations.

- Some species are present in the fossil record for a short period of time, while others survive for long time spans without much change.

What can we learn from fossils?

- An **extinction** happens when every individual of a species dies.

- A mass extinction occurs when a large number of species go extinct during a relatively short amount of time.

- Gradual environmental changes and catastrophic events, such as the impact of an asteroid, can cause mass extinctions.

What can we learn from fossils?

- Extinctions and mass extinctions are documented in the fossil record.

- Fossils that were common in certain rock layers may decrease in frequency and eventually disappear altogether.

- Evidence in the fossil record helps scientists form hypotheses about how and when species went extinct.

Way Back When

What is the geologic time scale?

- The **geologic time scale** is the standard method used to divide Earth's 4.6-billion-year natural history into manageable parts.

- Paleontologists adjust and add details to the geologic time scale when new evidence is found.

- The early history of Earth has been poorly understood, because fossils from this time span are rare.

What is the geologic time scale?

- Boundaries between geologic time intervals correspond to significant changes in Earth's history.

- Some major boundaries are defined by mass extinctions or significant changes in the number of species.

- Some boundaries are defined by major changes in Earth's surface or climate.

What is the geologic time scale?

- The largest divisions of the geologic time scale are eons, which are divided into eras.

- Eras are characterized by the type of organism that dominated Earth at the time.

- Eras are further divided into periods, and periods are divided into epochs.

What is the geologic time scale?

- The four major divisions that make up the history of life on Earth are Precambrian time and the Paleozoic, Mesozoic, and Cenozoic eras.

Ancient Wisdom

What defined Precambrian time?

- Precambrian time started 4.6 billion years ago, when Earth formed, and is made up of the first three eons of Earth's history.

- *Prokaryotes*—single-celled organisms without a nucleus—were the dominant life form.

- They lived in the ocean, and the earliest prokaryotes lived without oxygen.

What defined Precambrian time?

- Fossil evidence suggests that prokaryotes called *cyanobacteria* appeared over 3 billion years ago.

- Cyanobacteria use sunlight to make their own food. This process releases oxygen, which did not exist in Earth's atmosphere at this time.

- Eventually, oxygen built up in the ocean and air and formed ozone, a gas layer in the upper atmosphere.

What defined Precambrian time?

- Increased oxygen allowed for the evolution of new species that used oxygen to live. After about 1 billion years, new types of organisms evolved.

- These organisms, called *eukaryotes*, have cells with a nucleus and other complex structures.

- Later, eukaryotic organisms evolved that were multicellular, or made up of more than one cell.

What defined Precambrian time?

- For some organisms, oxygen is toxic. Therefore, increased oxygen was also followed by the extinction of some organisms.

- Less is known about Precambrian life because microscopic organisms did not preserve well in the fossil record.

What defined the Paleozoic era?

- The Paleozoic era began about 542 million years ago.

- Rocks from this era are rich in fossils of animals such as sponges, corals, snails, and trilobites.

- Fish and sharks, the earliest animals with backbones, appeared during this era.

What defined the Paleozoic era?

- Plants, fungi, and air-breathing animals colonized land during the Paleozoic era.

- Land dwellers had adaptations that allowed them to survive in a drier environment, and plant groups appeared.

- Crawling insects were among the first animals to live on land, followed by large, salamander-like animals.

What defined the Paleozoic era?

- The Permian mass extinction took place at the end of the Paleozoic era and is the largest known mass extinction.

- By 251 million years ago, as many as 96% of marine species had become extinct.

- The mass extinction wiped out entire groups of marine organisms, oceans were completely changed, and many species became extinct.

Time Marches On

What defined the Mesozoic era?

- Scientists think the reptiles that survived the Paleozoic era evolved into many different species during the Mesozoic era.

- Dinosaurs are the best-known reptiles that evolved during the Mesozoic era.

- The first birds and mammals also appeared.

- The most important plants of this era were conifers, or cone-bearing plants, which formed large forests. Flowering plants appeared later.

What defined the Mesozoic era?

- Evidence shows that an asteroid hit Earth around the Mesozoic era. The impact caused giant dust clouds and worldwide fires.

- With sunlight blocked by dust, many plants would have died.

- Without plants, plant-eating dinosaurs also would have died, along with meat-eating dinosaurs that ate the other dinosaurs.

What defines the Cenozoic era?

- The Cenozoic era, in which mammals dominate, began 65 million years ago and continues today.

- Humans appeared during this era.

- The climate has changed many times during the Cenozoic. Organisms migrated toward the equator, adapted to the cold, or became extinct.

What defines the Cenozoic era?

- Primates are a group of mammals that includes humans, apes, and monkeys.

- Primates have eyes that are in the front of the head. Most primates have five flexible fingers, one of which is an opposable thumb.

- Primates' ancestors were probably nocturnal, mouse-like mammals. Millions of years after dinosaurs died out, primates with larger brains appeared.