chapter 14

The History of Life

section 1 Fossil Evidence of Change

Before You Read

Throughout Earth's history, many species have become extinct. On the lines below, name some organisms that have become extinct. Then read the section to learn more about how scientists learn about extinct species.

MAIN Idea

Fossils provide evidence of the change in organisms over time.

What You'll Learn

- how a typical fossil is made
- techniques for dating fossils
- the major events using the geologic time scale

Read to Learn

Earth's Early History

How did life on Earth begin? Because there were no people around to record Earth's earliest history, the answer is a mystery. Scientists who study the beginning of life on Earth must look for clues that were left behind.

Some of the clues are found in rocks. Rocks give us clues about what Earth was like in the beginning and sometimes what species lived during that time. Scientists also study other planets to uncover clues about Earth's past.

What was Earth's early land environment like?

Earth formed about 4.6 billion years ago. At first, Earth was molten—melted rock. Gravity pulled the densest elements to the center of the planet, forming Earth's core. After about 500 million years, a solid crust formed on the surface. The crust was made mostly of lighter elements.

From clues found in rocks, scientists infer that Earth's early surface was hot. Volcanoes erupted and meteorites hit the surface. It is not likely that life could have survived the heat.

Mark the Text

Identify Definitions
As you read each section, highlight or underline the definition of each underlined term.

Reading Check

1. Explain What was Earth's early surface like?

What was Earth's early atmosphere like?

Earth's early atmosphere was probably made up of gases that were expelled by volcanoes. These gases might have been similar to those that are expelled by volcanoes today. Minerals in the oldest known rocks suggest that the early atmosphere had little or no free oxygen. Gases expelled by volcanoes do not include free oxygen.

Clues in Rocks

Earth eventually cooled, and liquid water formed on the surface, forming the first oceans. A short time later, as little as 500 million years, life appeared. Rocks provide important clues about Earth's history. The oldest clues about life on Earth date to about 3.5 billion years ago.

Reading Check

2. Identify How old is the oldest evidence of life on Earth?

_____

_____

What is a fossil?

A **fossil** is any preserved evidence of an organism. Fossils are found in rock, ice, and amber. More than 99 percent of the species that have lived on Earth are now extinct. Only a small percentage of those species are preserved as fossils.

For an organism to be preserved as a fossil, it must be buried quickly in sediment. Organisms that live in water are more likely to form fossils than organisms that live on land because sediment in the water is constantly settling.

First the organism dies. Then sediment covers the organism. Layers of sediment build up over time. In most cases, minerals replace or fill in the pore space of the bones and hard parts of the organism. In some cases, the organism decays, leaving behind an impression of its body. The layers eventually harden into sedimentary rock, such as limestone, shale, or sandstone.

Picture This

3. Describe the events that happen to make a fossil in sedimentary rock.

_____

_____

_____

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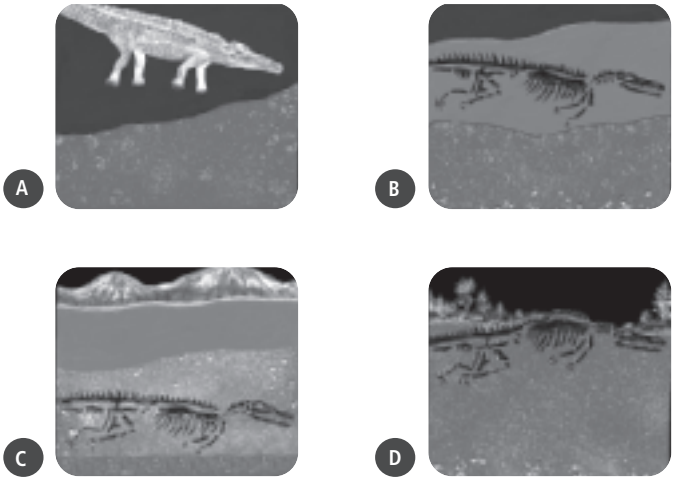
_____



What can scientists learn from studying fossils?

A **paleontologist** (pay lee ahn TAH luh jist) is a scientist who studies fossils. Paleontologists use fossils as clues to learn what an organism ate and the environment in which an organism lived. Paleontologists can use fossils to put together a picture of extinct communities as if they were alive today.

How do scientists find out a rock's age?

Paleontologists use different methods to find out the age of a rock or a fossil. **Relative dating** is a method that compares rocks with rocks in other layers. Relative dating is based on the law of superposition. The **law of superposition** states that rocks form in layers, with younger layers of rock deposited on top of older layers. The oldest rocks form the bottom layer and the youngest rocks form the top layer, as shown below.

What is radiometric dating?

Radiometric dating is a method used to determine the age of rocks using the decay of radioactive isotopes present in the rocks. Recall that an isotope is a form of an element that has the same atomic number but different mass number. The method requires that the **half-life** of the isotope, which is the amount of time it takes for half of the original isotope to decay, is known. The relative amounts of the isotope and its decay product must also be known.

Picture This

4. Identify Label the oldest and the youngest rock layers in the picture.

Reading Check

5. Identify What three things must be known to perform radiometric dating?

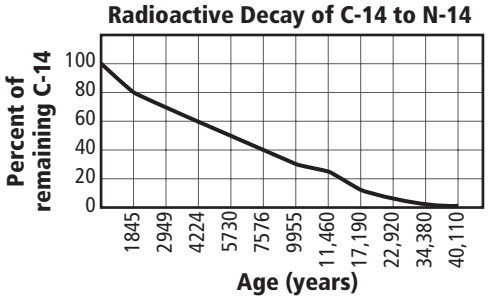
How does radiometric dating work?

Items such as mummies and frozen mammoths can be dated directly using carbon-14. Only materials less than 60,000 years old can be dated accurately with this isotope. Older materials do not have enough radio-isotope left.

Carbon-14 is a commonly used isotope. The decay of carbon-14 is shown in the graph below. The half-life of carbon-14 is 5730 years. After 5730 years, half of the original carbon-14 will remain. The other half will have decayed to nitrogen-14. At the half-life, there is a one-to-one ratio, or equal amounts, of carbon-14 and nitrogen-14. Scientists can determine the age of a sample by calculating the ratio of carbon-14 to nitrogen-14 in the rock.

Picture This

6. Estimate About what percent of carbon-14 is left after 11,460 y?



How is radiometric dating used for rocks?

Useful radioactive isotopes are found in igneous and metamorphic rocks. Sedimentary rocks are made from igneous and metamorphic sediments so they cannot be measured accurately. Scientists can determine the relative age of fossils by measuring nearby igneous and metamorphic rock in layers closely associated with them.

Reading Check

7. Describe How is radiometric dating used to find the age of sedimentary rock?

The Geologic Time Scale

The **geologic time scale** is a model that shows the major geological and biological events of Earth's history. These events include changes to Earth and to organisms.

The geologic time scale has two major divisions—Precambrian time and the Phanerozoic (fan eh roh ZOH ihk) eon. An **eon** is the longest unit of time and can include billions of years. An **era** lasts hundreds of millions of years. Eras include the Precambrian, Paleozoic, Mesozoic, and Cenozoic. Each era is further divided into one or more **periods** which last tens of millions of years. **Epochs**, which last several million years, are the smallest units of geologic time.

What occurred during the Precambrian?

The first 4 m of the geologic time ribbon makes up the Precambrian (pree KAM bree un). During the Precambrian nearly 90 percent of Earth's history occurred. It began with the formation of Earth, 4.6 billion years ago, and ended about 542 million years ago with the beginning of the Paleozoic era.

Many important events occurred during the Precambrian. Earth formed and life first appeared. Autotrophic prokaryotes, such as bacteria that make organic compounds using carbon dioxide and energy from the sun or inorganic sources, enriched the atmosphere by releasing oxygen. Eukaryotic cells emerged. By the end of the Precambrian, the first animals had appeared.

During the second half of the Precambrian, glaciers might have delayed the further evolution of life. After the glaciers receded, simple organisms lived in marine ecosystems.

Reading Check

8. Sequence What marked the beginning of the Precambrian?

How did life change during the Paleozoic era?

A drastic change in the history of animal life on Earth came at the start of the Paleozoic (pay lee uh ZOH ihk) era. In just a few million years, the ancestors of most major animal groups diversified in what scientists call the **Cambrian explosion**. Fish, land plants, and insects appeared. The swampy forests were home to many types of organisms, including huge insects. The first tetrapods—animals that walk on four legs—which were the first land vertebrates, appeared. By the end of the era, reptiles appeared.

What event ended the Paleozoic era?

The Paleozoic era ended with a mass extinction. Recall that a mass extinction is an event in which many species become extinct in a short amount of time. In the mass extinction that ended the Paleozoic era, 90 percent of marine organisms disappeared. Scientists do not know why the mass extinction occurred. Most scientists agree that geological forces, including increased volcano activity, would have disrupted ecosystems or changed the climate.

Reading Check

9. Identify What type of organisms became extinct during the mass extinction that ended the Paleozoic era?

How did life change during the Mesozoic era?

Life continued to change during the Mesozoic (mez uh ZOH ihk) era. Mammals and dinosaurs appeared. Flowering plants evolved from nonflowering plants. Birds evolved from dinosaurs. Reptiles, including dinosaurs, were the dominate animals.

What is the evidence of a meteor striking Earth?

Then, a meteorite struck Earth. The evidence for the meteorite comes from a layer of material between rocks of the Cretaceous (krih TAY shus) period and rocks of the Paleogene period. Scientists call this layer of material the **K-T boundary**.

In the K-T boundary, scientists have found high levels of iridium. Iridium is rare on Earth but common in meteorites. Iridium on Earth is evidence of a meteor impact.

Reading Check

10. Name the rock layer found between rocks of the Cretaceous period and rocks of the Paleogene period.

How might a meteor strike have led to a mass extinction?

Many scientists think this meteor impact is related to the mass extinction, which eliminated all dinosaurs except birds, most marine reptiles, many marine invertebrates, and many plant species. The meteor itself did not kill these organisms, but the debris from the impact probably stayed in the atmosphere for months or years. The debris would have affected the global climate. Those species that could not adjust to the changing climate disappeared.

How did Earth change during the Mesozoic era?

Evolution in the Mesozoic era was affected by the massive geological changes of the era. As shown in the figure below, at the beginning of the Mesozoic era, approximately 225 million years ago, the continents were joined into one landmass called Pangaea.

Plate tectonics describes the surface of Earth as being broken into several large plates. Some of the plates contain continents. The plates move over a partially molten layer of rock moving the continents with them. The continents have been moving since they formed. By the end of the Mesozoic era, approximately 65 million years ago, the continents had broken apart, moved, and were in roughly the position they are now.

Picture This

11. Label the landform known as Pangaea.

225 mya 135 mya 65 mya

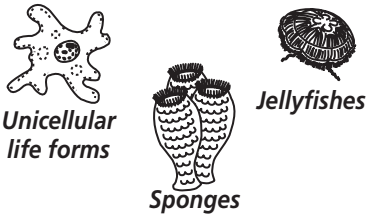
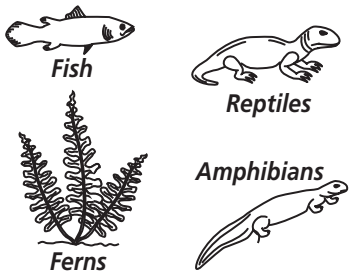
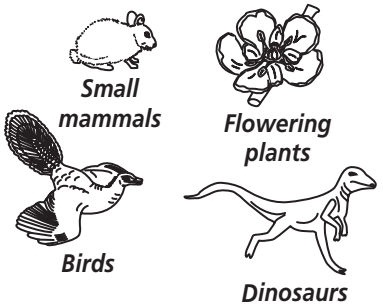
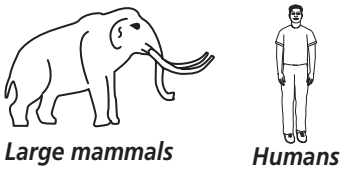
How did life change during the Cenozoic era?

The Cenozoic (sen uh ZOH ihk) era is the most recent era. Mammals became the dominant animals on land. At the beginning of the era, most mammals were small. After the mass extinction, at the end of the Mesozoic era, mammals, including primates, began to become more diverse.

When did present-day humans appear on Earth?

Present-day humans appeared near the end of the geologic time scale. Humans survived the last ice age, but many species of mammals did not. Think back to your time ribbon. The time that humans have lived on Earth takes up about two threads at the end of the ribbon.

The figure below shows the geologic time scale and gives examples of organisms that evolved during each era.

Geologic Era	Time Span	New Organisms
Precambrian	4.6 billion years ago to 542 million years ago	 *Unicellular life forms* *Jellyfishes* *Sponges*
Paleozoic	542 million years ago to 251 million years ago	 *Fish* *Reptiles* *Amphibians* *Ferns*
Mesozoic	251 million years ago to 65 million years ago	 *Small mammals* *Flowering plants* *Birds* *Dinosaurs*
Cenozoic	65 million years ago to present	 *Large mammals* *Humans*

Applying Math

12. Calculate What percentage of Earth's history has included present-day humans?

Picture This

13. Label Circle the era when Pangaea broke apart into individual continents.