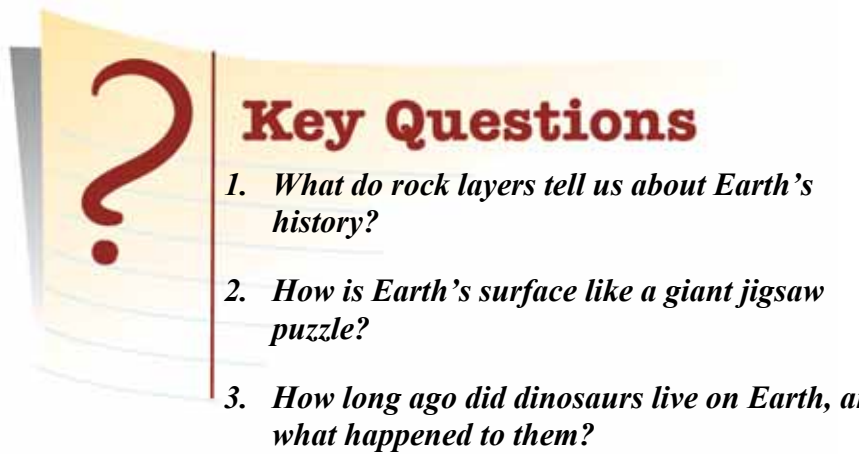
Chapter 12

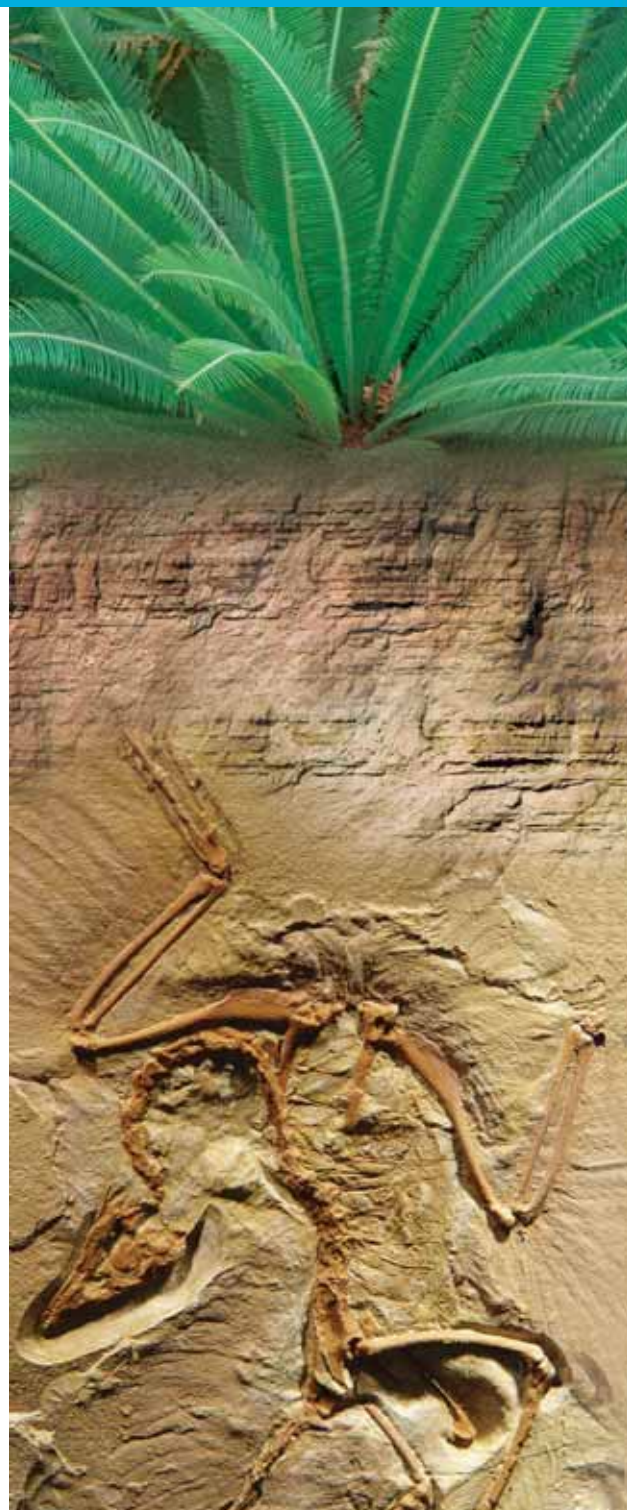
Earth and Life History

There was a time when Earth had a warm, tropical climate all over. Dinosaurs roamed Earth, and giant plants called cycads grew everywhere. Earth's land masses formed one giant continent. This might sound like science fiction, but it is actually a simple description of what geologists call the Mesozoic era in Earth's history. How do geologists know what Earth and its life forms were like millions of years ago? Explore this chapter to find out!



Key Questions

1. ***What do rock layers tell us about Earth's history?***
2. ***How is Earth's surface like a giant jigsaw puzzle?***
3. ***How long ago did dinosaurs live on Earth, and what happened to them?***



12.1 Evidence from Rocks

Earth's environment has been changing slowly since it was formed 4.6 billion years ago. These changes are the driving force behind evolution. **Geology** is the study of Earth's formation and structure. Geologists study rocks to find clues to Earth's formation. **Evidence from rocks and fossils allows us to understand the evolution of life on Earth.**

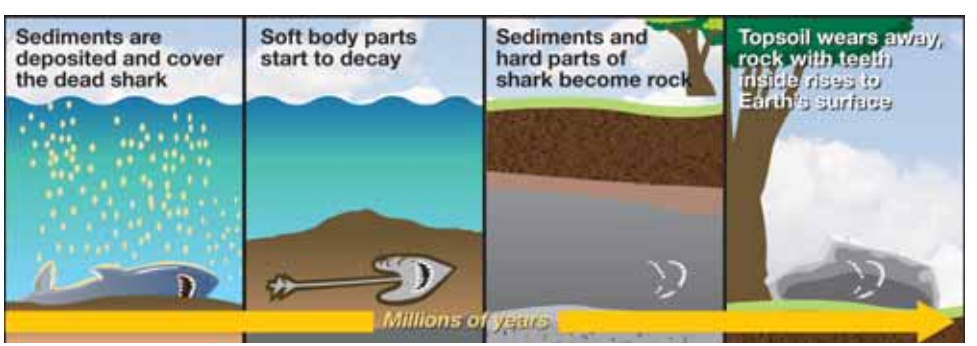
Fossil formation

Tonguestones and shark's teeth

In 1666, Nicholas Steno, a Danish anatomist, studied a shark's head and noticed that the shark's teeth resembled mysterious stones called "tonguestones" that were found inside of local rocks. At this time, people believed that tonguestones had either fallen from the moon, or that they grew inside the rocks. Steno theorized that tonguestones looked like shark's teeth because they actually *were* shark's teeth that had been buried and became fossils.

Fossil formation

Steno concluded that when a shark dies, sediments are deposited over its body. After a short time, the shark's soft parts decay, but the teeth do not. Over many years, layers of sediment cover the teeth. Over many more years, the layers of sediment are pressed together and become sedimentary rock. The shark's teeth become part of the rock. Steno's work led him to develop some important principles in geology, explained in this section.



VOCABULARY

geology - the study of Earth's formation and structure.

Figure 12.1: *This illustration is from Nicolas Steno's 1667 paper titled "The Head of a Shark Dissected."*

STUDY SKILLS

Make a concept map out of the following terms. The terms come from this chapter and Chapter 11.

evolution, adaptation, fossil, fossil record, natural selection, geology, rock, sedimentary rock, superposition, paleontologist, relative dating

The formation of sedimentary rock

The rock cycle

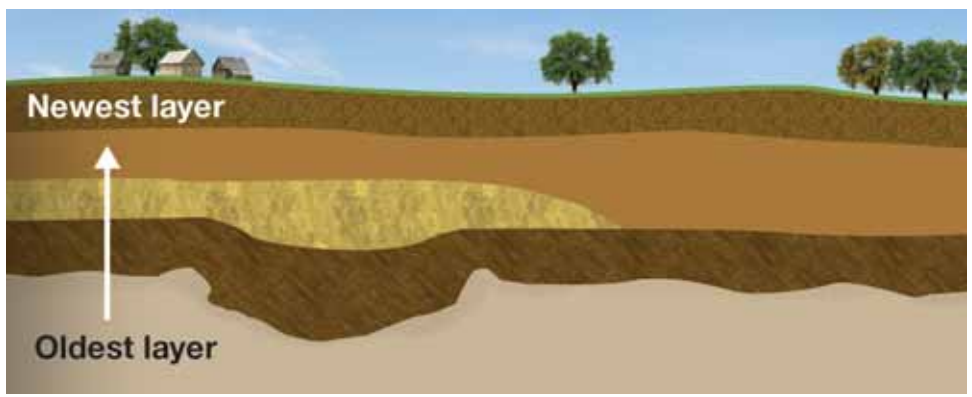
The **rock cycle** is the process of rock formation and recycling. Sedimentary rock formation is part of the rock cycle. (The other two types of rocks are *igneous* and *metamorphic*.) When rocks are unearthed and exposed to Earth's atmosphere, they are subject to weathering and erosion. This breaks rocks up into sediments.

Sedimentary rock layers form horizontally

Sediments are washed from the land and transported into bodies of water. They settle to the bottom because of gravity. Any change in the composition of material being deposited shows up as a distinct *horizontal* layer. Over time, those layers of sediment become layers of rock. Parts of organisms that do not decompose may become fossils within the layers (Figure 12.2).

Rock layers form from the bottom up

The relative age of each layer of sedimentary rock can be determined by applying an idea called superposition. **Superposition** states that the bottom layer of sedimentary rock is older than the layer on top because the bottom layer formed first. Stacking old newspapers in the order in which you received them illustrates superposition (Figure 12.3). The oldest newspaper will be on the bottom, and the newest on top.



VOCABULARY

rock cycle - the process of rock formation and recycling.

superposition - the principle that states that in layers of sedimentary rocks the lowest layers were the earliest to be deposited.

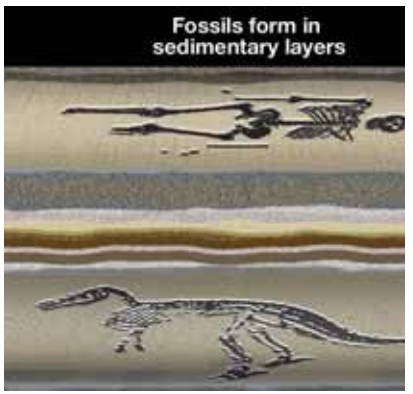


Figure 12.2: *Fossil formation.*

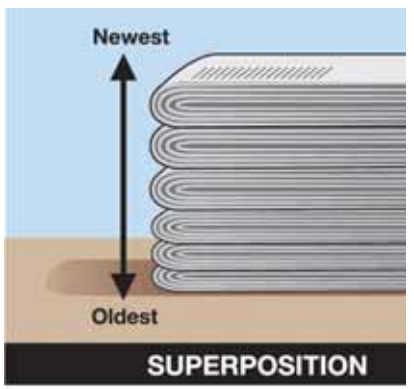


Figure 12.3: *A stack of newspapers illustrates superposition.*

Rock layers are bent or shifted by forces

Rock layers may bend and shift. Sometimes rock layers are found standing vertically, or tilted, or rolled into curves. Slow movements of Earth's crust create very powerful forces. Those forces can move and twist horizontal rock layers into different positions. The photo in Figure 12.4 shows what curved layers of sedimentary rock look like.

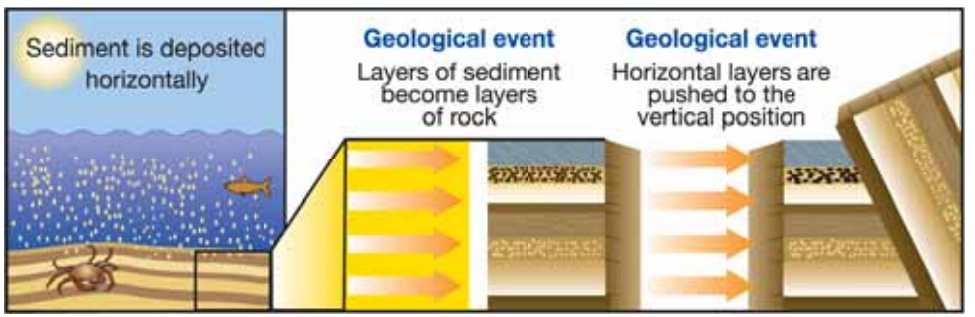
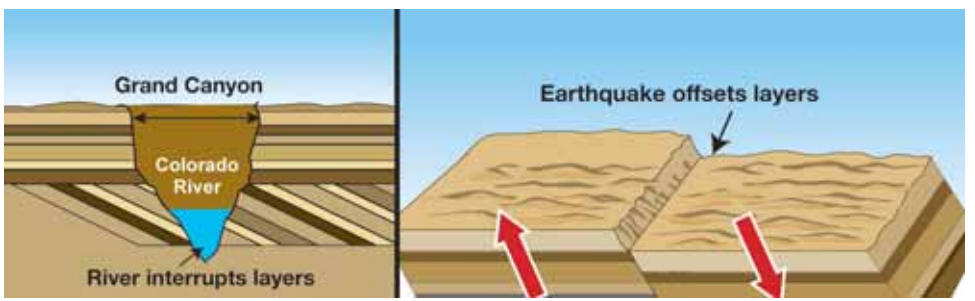


Figure 12.4: *Curved layers of sedimentary rock.*

Layers of rock are continuous

Horizontal layers of rock are continuous. When layers of sediment form, they extend in all directions. By comparing rock layers in the Grand Canyon, geologists have found that the layers on one side of the canyon more or less match up with the layers on the other side. A flowing river can interrupt layers or an earthquake can offset them. The Colorado River formed the gap that is now the Grand Canyon.



MY JOURNAL

Rock formations include mountains, boulders, cliffs, or anything made of rock that is too big for humans to move. Find a rock formation near your school or home. Sketch the formation and identify its features. Make a list of questions you would ask a geologist about the formation.

Relative dating

Relative dating

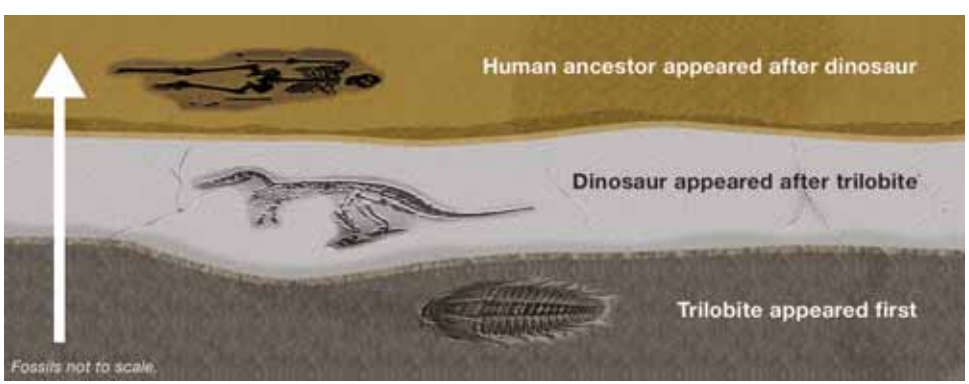
Steno's principles are used by geologists to determine the age of fossils and rocks in a process called relative dating. **Relative dating** is a method of sequencing events in the order they happened.

What is relative dating?

Figure 12.5 shows an example of relative dating. When you use relative dating, you are not trying to determine the exact age of an object. Instead, you use clues to sequence the order of events that occurred around it. Then you determine the age of the object *relative* to the other objects or events in the sequence. Can you list the three events shown in Figure 12.5 in order of occurrence?

Using relative dating to sequence fossils

Paleontologists use relative dating to determine the sequence of fossils in the order that each species existed. A **paleontologist** is a scientist who studies fossils. A cross section of sedimentary rock has many different layers. The oldest layers are found at the bottom and the newest at the top. Suppose fossils were found in the layers shown below. A paleontologist could sequence the organisms found according to their location in the layers. The organisms found in the top layers appeared after the organisms found in the layers below them.



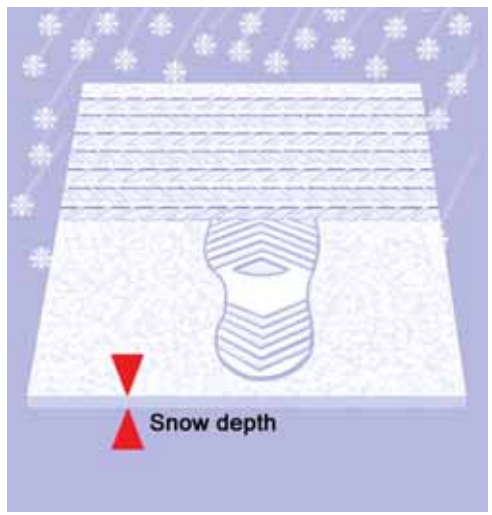


Figure 12.5: *This graphic illustrates three events: a footstep, a tire track, and snowfall. Which event happened first? Sequencing these events in the correct order is a form of relative dating.*

VOCABULARY

relative dating - a method of sequencing events in the order in which they happened.

paleontologist - a scientist who studies fossils.

More relative dating

Cross-cutting relationships

The idea of *cross-cutting relationships* states that a vein of rock that cuts across a rock's layers is younger than the layers. Figure 12.6 shows a rock formation with three layers and a cross-cutting vein. The rock layers formed first. The vein formed in a crack in the original rock. The bottom layer is the oldest part of the rock formation and the vein is the newest. The middle and top layers formed after the bottom layer but before the vein.

Inclusions

Sometimes rock pieces called *inclusions* are found inside another rock. During the formation of a rock with inclusions, sediments or melted rock surrounded the inclusion and then solidified. Therefore, the inclusions are older than the surrounding rock (Figure 12.6). A rock with inclusions is like a chocolate chip cookie. The chocolate chips (inclusions) are made first. Then they are added to the batter (melted rock or sediment) before being baked (hardened) into a cookie (rock).

Faunal succession

Faunal succession means that fossils can be used to identify the relative age of the layers of sedimentary rock (Figure 12.7). For example, dinosaur fossils are found in rock that is about 65 to 200 million years old because these animals lived that long ago. The fossils of modern human beings (*Homo sapiens*) are found in rock that is about 40,000 years old, but not in rock that is 65 to 251 million years old. And dinosaur fossils are not found in rock that is 40,000 years old. This means that human beings did not live at the same time as the dinosaurs. How might you learn which plants and animals *did* live at the same time as the dinosaurs?

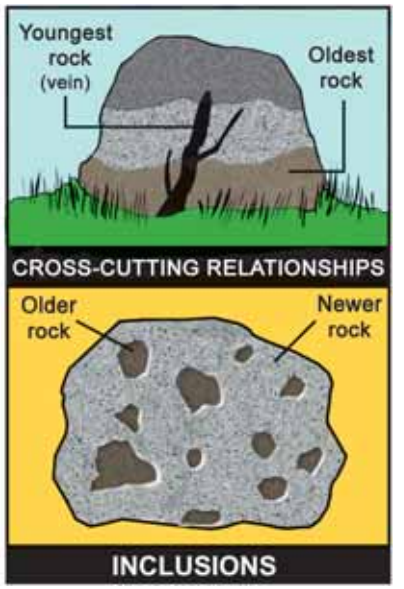
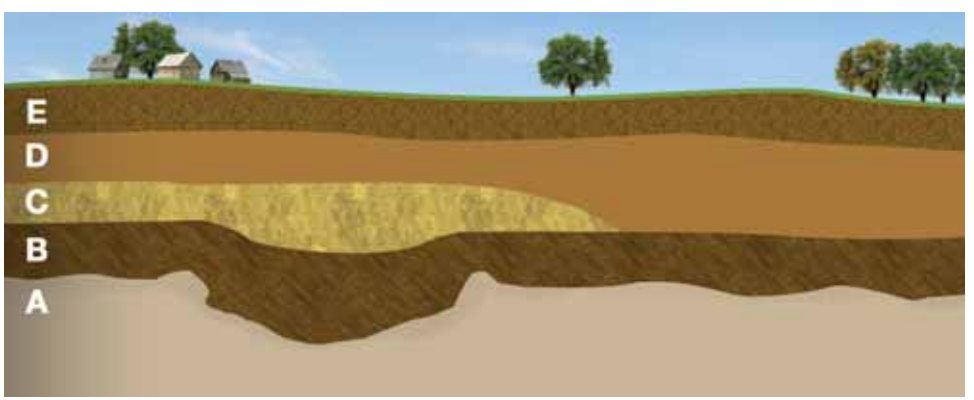


Figure 12.6: *Cross-cutting relationships and inclusions.*

Figure 12.7: *Faunal succession.*

12.1 Section Review

1. Who is Nicolas Steno? What ideas did he come up with that have contributed to modern geology?
2. A river cuts through a canyon and exposes the rock layers. How would the rock layers on either side of the canyon compare? Explain your reasoning.
3. What idea is represented in Figure 12.8? Which fossil is the oldest? Which is the newest? How can you tell?
4. True or False: Superposition states that rock layers near the surface of Earth are more recent than rock layers further from the surface. Explain your reasoning.
5. Study the following picture. Which is the oldest layer of rock? Which layer is the newest?



6. The rock in Figure 12.9 has many features. Use what you know about relative dating to place the features in order of occurrence from oldest to newest.
7. What are inclusions? Which part of a chocolate chip cookie are similar to inclusions?

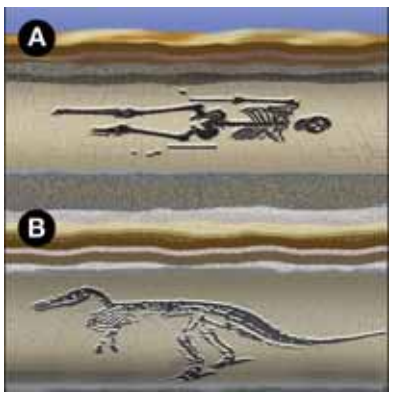


Figure 12.8: *Use the picture above to answer question 3.*

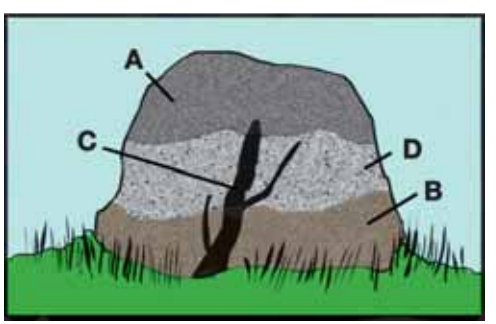


Figure 12.9: *Use the picture above to answer question 6.*

12.2 How Earth Changes

Geologists use an idea called uniformitarianism to piece together Earth's geologic history. **Uniformitarianism** refers to the use of features and process that are observable today, to interpret the ancient geologic record. For example, geologists have used the fossil record to determine how and why Earth's environments have been slowly changing over millions of years.

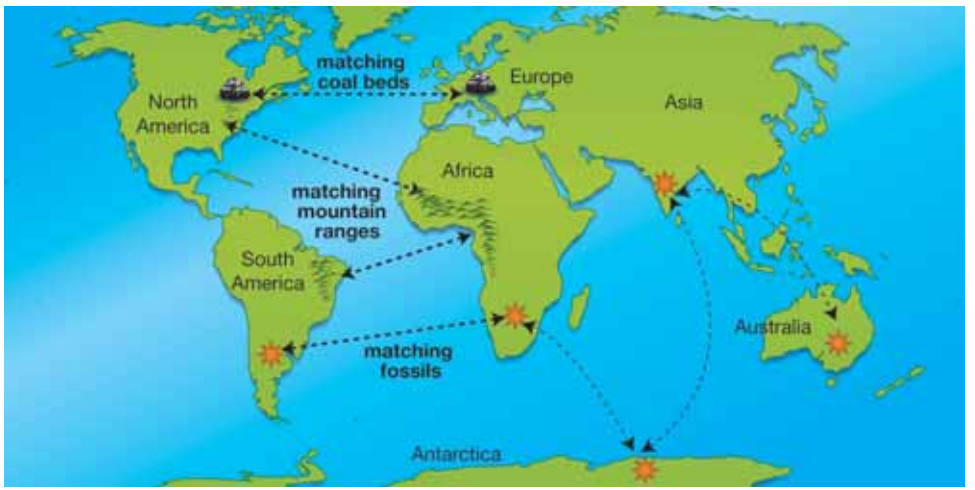
Pangaea

A supercontinent called Pangaea

In 1915, Alfred Wegener (1880–1930) theorized that the continents that we know today had been part of an earlier supercontinent. He called this great landmass **Pangaea**. According to his theory, Pangaea broke apart and the pieces drifted to their present places, becoming today's continents.

Evidence to support Wegener's theory

To support his theory, Wegener observed that fossils of plants and animals found on different continents were very similar. Also, there were matching geologic features on both sides of the Atlantic Ocean. Furthermore, the current shapes of the continents seemed to fit together like puzzle pieces (Figure 12.10).



VOCABULARY

uniformitarianism - using features and processes that are observable today to interpret the ancient geologic record.

Pangaea - an ancient supercontinent that broke apart to form today's continents.

Figure 12.10: *The continents on either side of the Atlantic Ocean fit together like puzzle pieces.*

Plate tectonics

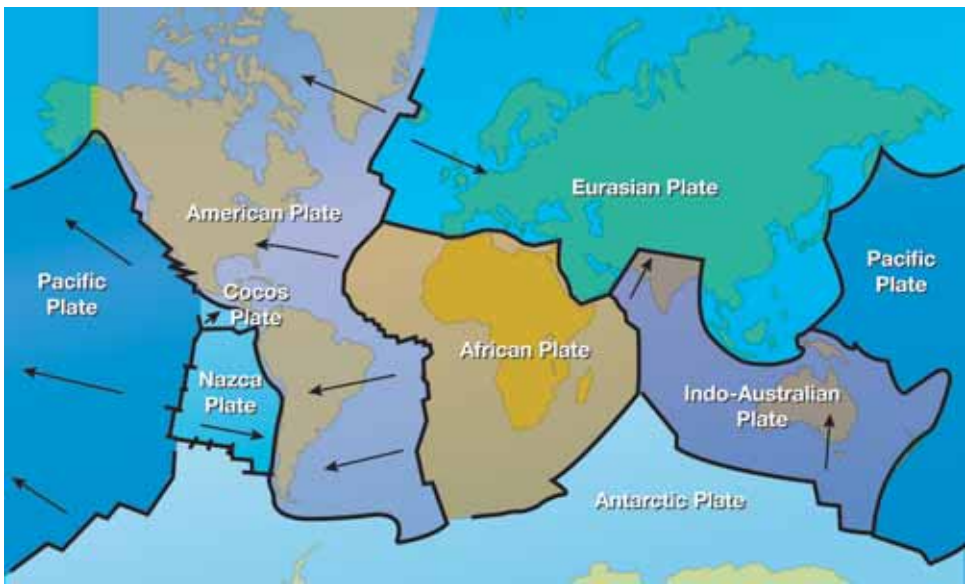
What is plate tectonics?

How the continents move is explained by a theory called **plate tectonics**. Earth's outer layers are called the *lithosphere*. The theory of plate tectonics, first stated in 1965, refers to the movement of giant pieces of the lithosphere called **lithospheric plates**. The movement of one plate causes the pulling or pushing of other plates, significantly affecting Earth's surface. There are seven large lithospheric plates and many smaller ones.

VOCABULARY

plate tectonics - a theory that describes how the continents move.

lithospheric plates - giant pieces of solid rock on Earth's surface.



Movement of tectonic plates

Forces beneath the lithosphere cause the plates to move. Some plates include continents (Figure 12.11). The continents move with their plates. The plates that include North America and Europe are moving apart at a rate of a little over 2 centimeters each year. By comparison, your fingernails grow at a rate of 2.5 centimeters a year. Though that rate may seem slow, it has produced enormous changes in Earth's surface over millions and millions of years.

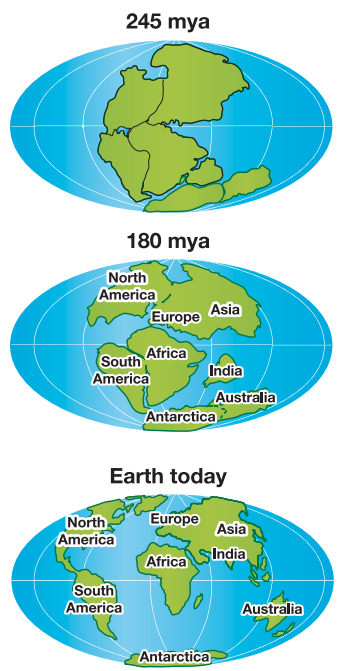
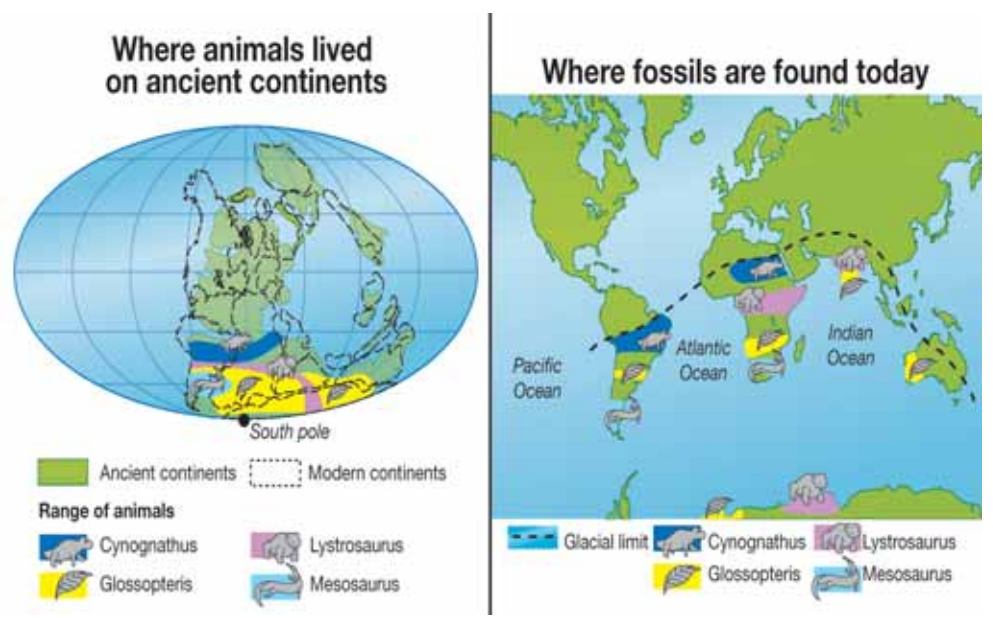


Figure 12.11: *The movement of tectonic plates causes the continents to move.*

Plate tectonics and fossil distribution

Fossil evidence for Pangaea The distribution of fossils provides evidence that the continents were once joined and have slowly separated over time. Fossils of the same species have been found on several different continents. If the continents had always been separated, we would not find these fossils on different continents.

Fossil distribution *Glossopteris*, an ancient plant species, was found on the continents of South America, Africa, India, and Australia (Figure 12.12). If the continents are reassembled into Pangaea, the distribution of glossopteris can be accounted for over a much smaller and connected geographic area. The distribution of other fossils can also be accounted for using the same method of analysis.



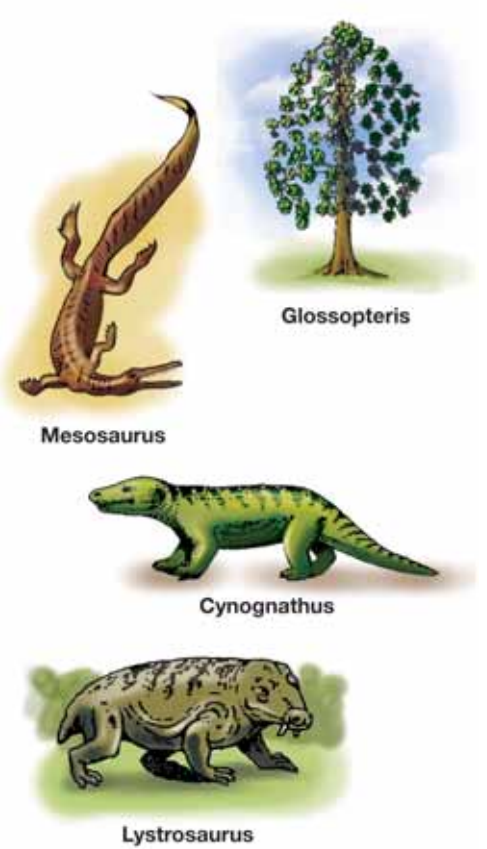


Figure 12.12: *Glossopteris was a woody, seed-bearing shrub or tree, 4–6 m in height. Glossopteris and the other fossil organisms shown have been found on different continents.*

Plate tectonics and evolution

Plate tectonics results in the formation of new species

One result of plate tectonics is the geographic separation of populations. Separation of lithospheric plates separated the continents and divided populations. Collision of plates pushed up mountain ranges which also divided populations (Figure 12.13). Once populations became geographically separated they could no longer interbreed. The separated populations evolved different adaptations. Eventually, they became different species.

Organisms adapt to their environments

Because the movement of plates is slow, organisms usually have time to adapt to changes in the environment. That is why organisms alive today are well adapted. But in the same location where well-adapted organisms thrive, scientists have discovered fossils of organisms that could not adapt to the changes. Dinosaur and plant fossils have been found on the continent of Antarctica. Today, Antarctica is permanently frozen and supports only species that have adapted to the gradual change in climate—like penguins (Figure 12.14).

Using fossils to interpret changes in the environment

Scientists use fossils to interpret environmental changes brought about by plate tectonics. To do this, they apply the principle of uniformitarianism. For example, ancient animals that resembled clams probably lived in the same type of environment as modern clams. If clam fossils are found on a mountain top, scientists assume that the mountain top may have once been part of an environment that supported a clam population. Geologic processes resulted in changes in that environment and the extinction of the clam population in that location. The fossils were probably brought to the surface by the collision of lithospheric plates.

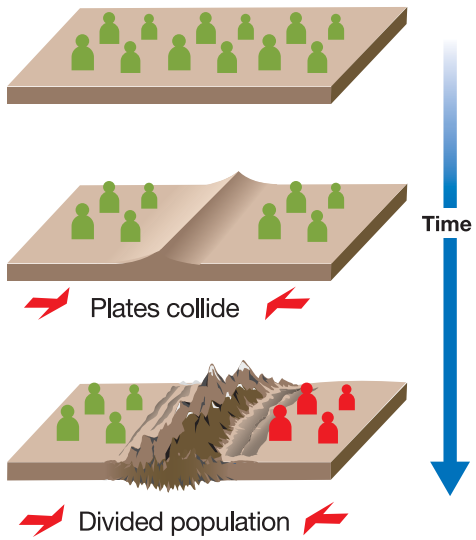
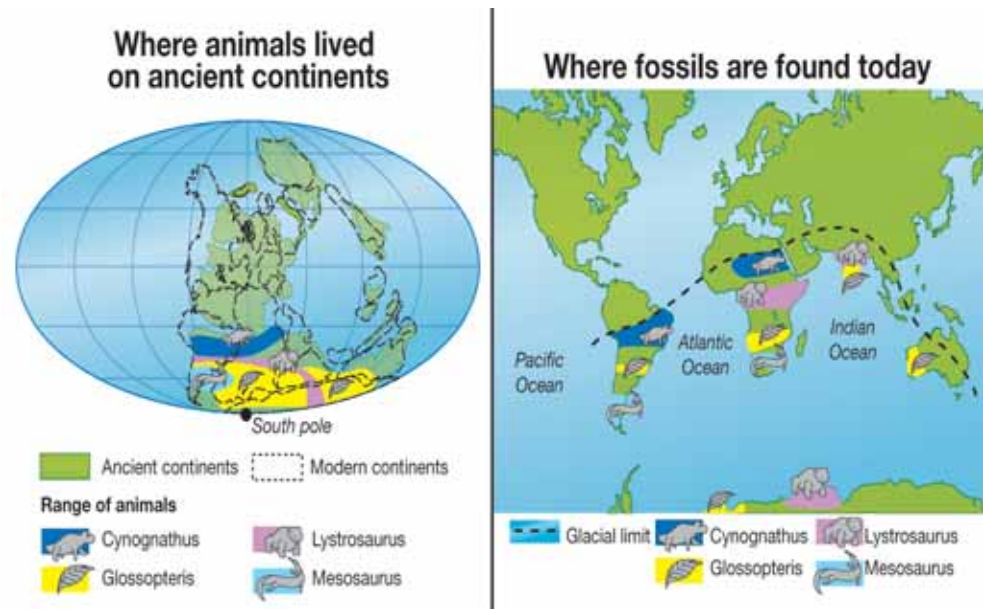


Figure 12.13: *Collision of plates may push up mountain ranges and divide populations.*

Figure 12.14: *A penguin.*

12.2 Section Review

1. How is Earth's surface like a giant jigsaw puzzle?
2. What was Pangaea? List three examples of evidence that Wegener used to support his idea of Pangaea.
3. Describe the theory of plate tectonics.
4. Write a paragraph describing the graphic below. Answer these questions in your paragraph.
   a. What does the left side of the graphic show?
   b. What does the right side of the graphic show?
   c. How does this graphic support the idea of plate tectonics?



5. How does plate tectonics contribute to the formation of new species?

MY JOURNAL

Imagine you are a penguin living in Antarctica. Write a short story describing a day in your life.

12.3 Life History

Scientists have developed a model of the history of life on Earth called the **geologic time scale** (Figure 12.15). It is based on studies of Earth's geology and the fossil record. Most of Earth's changes have occurred slowly, over millions of years. But occasionally, Earth's history has been interrupted by catastrophes such as massive volcanic eruptions or meteor impacts. These events had a significant effect in shaping Earth's surface and on the evolution of life. In this section you will read about the history of life on Earth as told by the fossil and geologic records.

VOCABULARY

geologic time scale - a model of the history of life on Earth.

The geologic time scale

Divisions of the geologic time scale

Paleontologists divide the geologic time scale into blocks of time called *eras* and *periods*. Eras are determined by the dominant life forms that were present at the time. Each era is divided into smaller blocks of time called periods. Periods are based on types of fossils found within each era.

Precambrian era

The Precambrian era lasted from Earth's formation 4.6 billion years ago until 542 million years ago (mya). The first prokaryotic cells appeared more than 3 billion years ago. Then, photosynthetic bacteria (cyanobacteria) evolved and began to add oxygen to Earth's atmosphere. Some of that oxygen reached Earth's upper atmosphere and formed the ozone layer. The ozone layer blocked harmful radiation from the sun. This allowed life to move out of the water and onto dry land. The first eukaryotic cells appeared in the Precambrian era, about 2 billion years after the first prokaryotic cells.

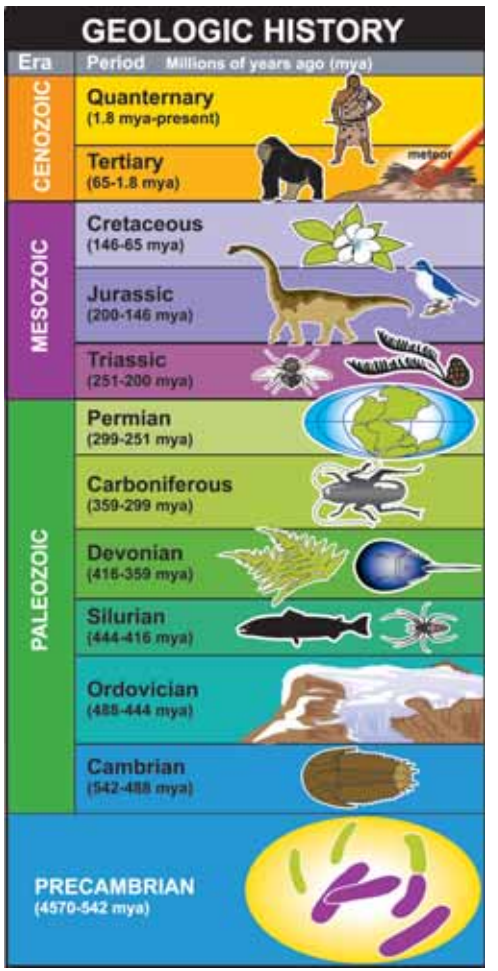


Figure 12.15: *The geologic time scale.*

Paleozoic era The Paleozoic era lasted from 542 to 251 mya. *Paleozoic* is a Greek word meaning "ancient life." Rocks dated from the Paleozoic era contain fossils of trilobites, snails, clams, and corals. Early in the era, many new, complex life forms developed, but glaciers covered the Earth in the Ordovician period, causing many of these new organisms to become extinct. In the Silurian period, fishes with backbones appeared. Next, plants and air-breathing animals began to populate the land. Toward the end of the Paleozoic era, much of the land was covered with forests of palm trees and giant ferns. Therapsids are a group of animals that dominated the land in the Permian period. Scientists believe that mammals evolved from therapsids.

Mesozoic era The Mesozoic era lasted from 251 to 65 mya. *Mesozoic* is a Greek word meaning "middle life." This era is often called the Age of Reptiles. Dinosaurs are the most well-known reptiles of the Mesozoic era and dominated Earth for about 150 million years (Figure 12.16). The Jurassic period was marked by the appearance of the first birds. Flowering plants evolved during the Cretaceous period. At the end of the Mesozoic era, 65 ya, dinosaurs and many other animal and plant species suddenly became extinct. Geologic evidence indicates that a giant meteor may have hit Earth. This may have been the cause of the extinctions.

Cenozoic era The Cenozoic era began 65 mya and is still going on. *Cenozoic* means "recent life." Fossils from the Cenozoic era are closest to Earth's surface, making them easier to find. Therefore, scientists have the most information about life in this era. The Cenozoic era is often called the Age of Mammals because many species of mammals appeared. Eohippus appeared in the Cenozoic era (Figure 12.17). The first human ancestors appeared about 4 million years ago. Modern humans appeared 40,000 years ago during the Quanternary period.

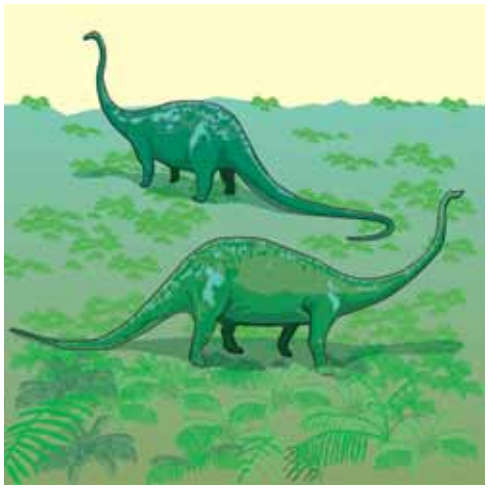


Figure 12.16: *Diplodocus is a dinosaur that lived in the Mesozoic era.*

Figure 12.17: *Eohippus appeared in the Cenozoic era.*

Mass extinctions

What are mass extinctions?

There have been at least five mass extinctions in which many types of plants and animals were wiped out. **Mass extinctions** are periods of large-scale extinction. They seem to be part of the evolutionary process because after each, new life forms emerge.

The greatest mass extinction

Scientists believe the greatest mass extinction was about 250 million years ago towards the end of the Paleozoic era. It is known as the Permian extinction, and it killed as many as 90 percent of all living things on Earth. Some scientists believe it was caused by an event such as a volcanic eruption or asteroid impact. That event sent particles of dust into the atmosphere and changed Earth's climate causing long- and short-term changes in the habitats of organisms living at that time. (Figure 12.18).

The most recent mass extinction

The Cretaceous-Tertiary extinction happened about 65 million years ago, ending the Mesozoic era. Many scientists believe a large asteroid hit Earth. The impact was so violent that once again, huge amounts of dust were thrown into the atmosphere. The sun was blocked out, possibly for years. Changes in climate and habitats caused the extinction of the dinosaurs. Afterwards, mammals became the dominant vertebrate life form on land.

A sixth mass extinction?

Today, some scientists think we are in the middle of a sixth mass extinction because many species have become extinct in the last few hundred years. This time, human impact may be the cause. But humans can also help prevent extinctions. The California condor is one example (Figure 12.19). A typical California condor has a 10-foot wingspan, making them the largest bird in North America. Government and private groups have created the California Condor Recovery Program. Because of the program, there are now almost 300 condors, over 100 of them in the wild in California, Baja California, and Arizona.

VOCABULARY

mass extinctions - periods of large-scale extinction.

Figure 12.18: *Scientists believe some mass extinctions were caused by an asteroid impact.*

Figure 12.19: *A California condor in flight.*

Absolute dating

What is absolute dating?

Relative dating provides information about the sequence of events in Earth's history. **Absolute dating** is a method of estimating the age of a fossil in *years*. Scientists use both absolute and relative dating to develop the geologic time scale. Absolute dating requires the use of a natural "clock." That clock is the *radioactive decay* of certain naturally-occurring elements like uranium and carbon.

What is radioactive decay?

Elements that undergo radioactive decay contain *unstable atoms*. All atoms are made of tiny particles held together by strong forces. Atoms of different elements contain different numbers of particles. Unstable atoms contain more particles than can be held together by the strong forces. They undergo radioactive decay by releasing some of those particles. In the process, they transform into different kinds of atoms. For example, when uranium atoms decay, one of the products is lead atoms (Figure 12.20).

What is half-life?

Half-life is the amount of time it takes for half of the unstable atoms in a sample to decay. Half-lives range from fractions of a second to billions of years. In a sample of uranium-238, it takes 4.5 billion years for half of the uranium atoms to transform into lead atoms. The half-life of carbon-14 is 5,730 years (Figure 12.20). One of the products of carbon-14 decay is nitrogen.

Using absolute dating

Scientists estimate the age of fossils by measuring the ratio of unstable to stable atoms in a sample of rock from a fossil. Earth's age is estimated by measuring the radioactive decay of uranium to lead. Scientists compared the amount of lead to uranium in a piece of uranium ore. With that measurement, the age of Earth was estimated to be about 4.6 billion years. The fossils of ancient bacteria, the first life forms, have been dated to be over 3 billion years old.

VOCABULARY

absolute dating - a method of estimating the age of a rock sample in years.

half-life - the amount of time it takes for half of the unstable atoms in a sample to decay.

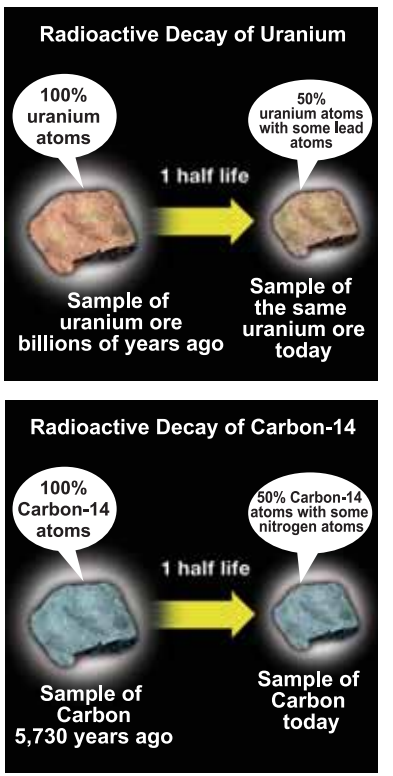


Figure 12.20: *The half-life of uranium-238 is 4.5 billion years. The half-life of carbon-14 is 5,730 years.*

12.3 Section Review

1. Explain how time is divided in the geologic time scale.
2. Match the organism or event to the time period in which it first appeared.
   a. dinosaur
   b. woolly mammoth
   c. archaebacteria
   d. human
   e. mass extinction of dinosaurs
   f. Pangaea
   g. plants
   h. fishes with backbones
3. What is a mass extinction?
4. How could a giant meteor impact change Earth's climate?
5. How have catastrophes contributed to the evolution of life on Earth?
6. Explain the difference between relative dating and absolute dating.
7. The age of a fossil is estimated to be about 280 million years old.
   a. Explain how scientists estimate the age, in years, of a fossil.
   b. To which era and period does the fossil belong? What are some organisms that lived during that time?

SOLVE IT!

1. A sample of rock contains 10 mg of carbon-14 atoms. The half-life of carbon-14 is 5,730 years. How many grams of carbon-14 will be in the sample after 11,460 years?
2. A sample of rock contains 4 mg of an unstable element. After 50 years, the sample contains 2 mg of the unstable element. What is the half-life of the element?

ARCHAEOLOGY CONNECTION

A Tiny Challenge to Human History

Imagine that an ancient band of humans had been found on a remote island. Imagine that these humans were only one meter tall - and that they hunted dwarf elephants that also lived on the island. Does that sound like the beginning of a science fiction movie? Well, this story is true.

In 2004, scientists made an amazing discovery. On the rugged, remote Pacific island of Flores, Indonesia, they found fossil bones of tiny humans. The scientists named this human *Homo floresiensis*, or Flores man. Adults of this ancient species were about as tall as today's 3-year-olds (who, like you, are *Homo sapiens*, or "wise man"). Flores man hunted dwarf elephants and other animals on the island. And the species disappeared about 13,000 years ago.

Archaeologists found stone tools made by these early humans. They know Flores man hunted, because burned bones have been found. Those bones show marks from the stone tools used by these small humans.

Small is the right size

The dwarf elephants were a type of stegodon. Stegodons are the largest of all the extinct elephants. They were 26 feet long and stood 13 feet high at the shoulder. But on Flores, they were small. Why? Often on an island there are few large predators. Food resources may be limited and large animals may run the risk of starvation. These evolutionary pressures can lead to small size, such as the dwarf stegodons. The same pressures may also have made Flores man small.

Earlier humans

It is not the small size of Flores man that is most fascinating. The remains are amazing because they are so young. The discovery has forced scientists to rethink the history of humans on Earth. It was believed that modern humans, *Homo sapiens*, had been the only humans on Earth for the last 30,000 years. Yet *H. floresiensis* was around 13,000 years ago.

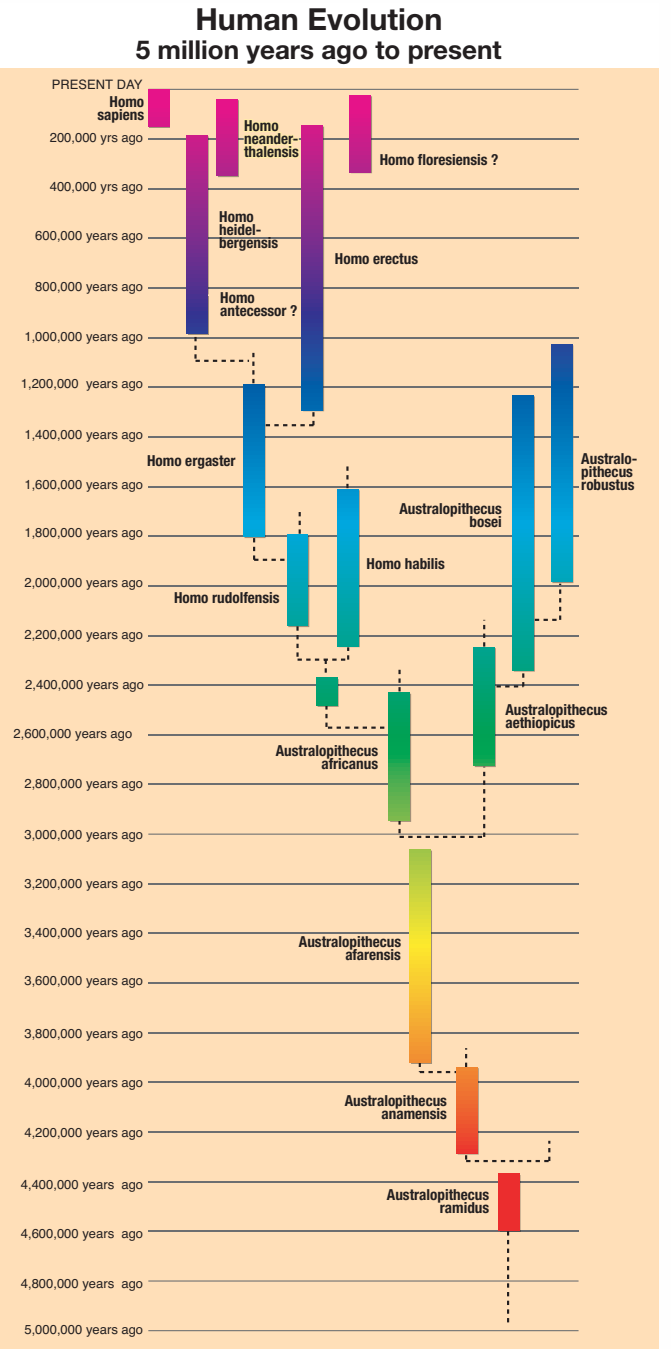
Scientists call the earliest humans *hominids*. One hominid was the ancestor of modern humans and Neanderthals. Primates are the order of mammals that includes humans, gorillas, chimpanzees, orangutans, and monkeys. Hominids and chimpanzees shared a common ancestor that lived about 6 million years ago. Long before that, about 65 million years ago, the earliest primates appeared. They lived in trees and were similar to the modern shrew, a tiny animal like a mouse, only smaller.

Scientists believe modern humans—that's us, *Homo sapiens*—first appeared about 195,000 years ago. At that time, another type of human, *Homo neanderthalensis*, also lived on Earth. The earliest Neanderthal fossils are 230,000 years old and were found in the Neanderthal, a valley in Germany. Neanderthals disappeared 30,000 years ago.

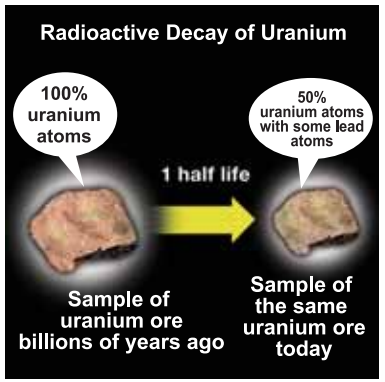
Now, Flores man makes it seem that yet another type of human was around for at least 17,000 more years. Archaeologists and anthropologists and many other scientists will study the Flores fossils. It may be years before they agree on where *H. floresiensis* should be placed on the human "family tree."

Questions:

1. How do archaeologists know that Flores man was a hunter?
2. Why might their home on an island have made Flores man small?
3. Why was the discovery of Flores man important? What effect did the discovery have on scientific understanding of human history?
4. How are modern humans and Neanderthals related?



CHAPTER ACTIVITY Radioactivity and Half-life



Scientists use absolute dating to estimate the age of a fossil in years. Absolute dating uses the decay of radioactive elements as a natural "clock." Uranium-238 decays naturally to lead-206 which is not radioactive. The time for half of the atoms in a sample of uranium-238 to perform this entire nuclear decay process takes about 4.5 billion years! In other words, the half-life of uranium-238 is 4.5 billion years. In this Investigation, you will simulate the radioactive decay of a fictional element.

What you will do

Your teacher has given you a can of pennies to represent the atoms of a sample of a fictional, radioactive element. To simulate the process of radioactive decay follow the steps below.

1. Make a data table in your notebook like the one shown at the left.
2. Shake your can of pennies and spill them out onto a tray or table.
3. Remove all pennies that are "heads" up and count them.
4. Record these as decayed atoms in your data table.
5. Put the rest of the pennies back into the can, shake them again.
6. Spill them out onto the tray or table, and again, remove and count the "heads."
7. Repeat this process until you have no more pennies left.
8. If necessary, add extra rows to your table.

Number of decayed atoms in each trial

sample number	number of decayed atoms	sample number	number of decayed atoms
1		8	
2		9	
3		10	
4		11	
5		12	
6		13	
7		14	

Questions

a. Graph your data for number of decayed atoms per sample vs. sample number. Sample number will be on the *x*-axis, and number of decayed atoms will be on the *y*-axis. Label the axes clearly. Be sure to provide a title for the graph. Be sure to use the entire graph in plotting your data.

b. Write a paragraph that describes what your graph looks like.

c. What part of this simulation represents the half-life of this new element? Explain your answer.

d. If the half-life of your element was 430 years and you had 2000 atoms of this element, how long would it take for the element to undergo complete radioactive decay to a stable isotope? What year would it be when the element finished decaying? Note: As you work through this problem, round the number of atoms left to a whole number. For example, round 62.5 to 63.

Chapter 12 Assessment

Vocabulary

Select the correct term to complete the sentences.

rock cycle	lithospheric plates	absolute dating
geologic time scale	paleontologists	pangaea
half-life	superposition	relative dating
geology	plate tectonics	uniformitarianism
mass extinctions		

Section 12.1

1. Understanding volcanoes, dinosaurs, earthquakes, rock cycles, and other Earth systems and the processes that act upon it is the study of _____.
2. Sedimentary, igneous, and metamorphic rocks are created, altered, and worn down in a process called the _____.
3. Estimating the age of fossils and rock layers from the arrangement of sedimentary layers is the principle of _____.
4. Before radioactive decay was understood, geologists were limited to _____ techniques to sequence geologic and prehistoric events.
5. Uncovering fossils in rock layers and conducting laboratory techniques that date specimens help _____ uncover the history of life on Earth.

Section 12.2

6. Using the present as keys to the past is consistent with the idea of _____.
7. Approximately 254 million years ago all major continents were fused into a massive landmass called _____.
8. _____ explains the changes and movement of lithospheric plates.
9. As _____ move slowly across the Earth's surface they sometimes collide and create huge mountain ranges.

Section 12.3

10. Earth's history is divided into eras and periods known as the _____.
11. Believed to have occurred at least five times in Earth's history, _____ seem to be a natural evolutionary process.
12. By comparing the amount of radioactive decay in a sample, _____ makes it possible to estimate the age of rock samples in years.
13. The _____ of radioactive isotope Potassium-40 is 1.3 billion years therefore it takes 1.3 billion years for half of its atoms to break down into argon-40.

Concepts

Section 12.1

1. The idea that sediments deposit and cover dead organisms in lakebeds, which eventually leads to fossilization, was introduced by
   a. Nicholas Steno
   b. Charles Darwin
   c. Alfred Wallace
   d. Alfred Wegener
2. Distinguish between the two terms: Superposition: Sedimentation
3. All of the following are used in relative dating except
   a. Superposition
   b. The fossil record
   c. Crosscutting and inclusions
   d. Radioactive Carbon-14 dating

4. Canyons and gorges are carved out of existing landmasses. The surrounding rock walls tell stories of the area's past history. What type of information can be revealed in canyon walls?

5. Describe in your own words the processes involved in the rock cycle.

6. Although sediments are deposited in even continuous layers, some sedimentary rocks exists in curved and interrupted forms. Explain two major reasons why this happens.

Section 12.2

7. The *coelacanth* is "living fossil" first caught off the coast of South Africa in 1939. Prior to this, it was believed to have lived 360 years ago and then suddenly become extinct approximately 70 million years ago. How can paleontologists use the coelacanth to understand life on Earth at the time of the dinosaurs?

8. How might the collision of two lithospheric plates contribute to the evolution of a species?

9. The movement of lithospheric plates helps explain all of the following except
   a. the distribution of fossils and living animals around the world.
   b. the occurrence of earthquakes and volcanic activity.
   c. the amount of solar radiation emitted from the sun.
   d. evidence of fossilized sea creatures found on high mountain ranges.

10. Australia is a unique continent with thriving marsupial populations like kangaroos. North America however has a thriving placental mammal population but only one known marsupial, the opossum. How might this be explained given what you know about plate tectonics?

11. The continents were once joined in a massive supercontinent called Pangaea and have slowly drifted over time. Which of the following statements does not support this idea?
   a. Fossils of the same species have been found on several different continents.
   b. Evidence from a meter impact broke apart the continent.
   c. Matching geological features such as mountain ranges and coal beds are distributed systematically across oceans.
   d. The shapes of today's continents fit together like a puzzle.

Section 12.3

12. Which of the following matches the geologic era with the correct historical event.
   a. Paleozoic- flowering plants and birds first appear.
   b. Cenozoic- evidence of the first human ancestors emerges.
   c. Mesozoic- fish with backbones appear.
   d. Precambrian- mammals became the dominant life form on land.

13. Why are the units of geologic eras not divided into equal time spans? What is the basis of division and how long did each era last? Provide an example.

14. After a mass extinction, species who survive
   a. Usually do not adapt to the new environmental conditions.
   b. Are usually only mammals.
   c. Frequently cannot survive and also become extinct.
   d. Often branch out into highly adapted species suited for the new environment.

15. Many theories exist about what caused the major mass extinctions throughout Earth's history. How might major changes in global temperature, sea level and atmospheric composition explain mass extinctions and the emergence of new life forms following such events?

16. Absolute dating
    a. Predicts the approximate age based upon position in sedimentary layers of rock.
    b. Can only be used to date animals and not other life such as plants and bacteria.
    c. Estimates the age of a fossil by measuring the decay of radioactive elements within the fossil.

Math and Writing Skills

1. Absolute dating using radioactive isotope Potassium-40 is used to date rocks millions of years old. The half life of Potassium-40 is 1.3 billion years. If sample of rock containing about 16g of radioactive Potassium-40 when it was formed now contains 4g of Potassium-40, how old is the rock?
2. What percentage of Carbon-14 will remain after 3 half lives?
3. If the amount of radioactive Carbon-14 left in a fossil indicates that the sample has decayed 85 half-lives, in what geologic time period did the organism live?

Chapter Project

Making a scaled timeline

A timeline is a visualization of a sequence of events. A scaled timeline is helpful when learning about historical events, because it gives you an idea of how much time it took for different events to occur. For example, how much time went by between the age of dinosaurs and when humans first appear in the fossil record? Reading the numbers of millions of years is one way to answer the question, but it is easier to visualize this amount of time if you can see it pictured on a relative time scale. For this project, you will construct your own scaled timeline of important events in the history of our changing Earth. You will need a roll of adding machine tape, colored pencils or markers, and a measuring tape. To make the timeline, follow these steps:

1. Measure out 20 feet of adding machine tape. Every inch equals 19 million years; every foot equals 230 million years
2. Using the scale described in step 1, place each event in the correct spot on the timeline. Use words and a sketch to represent each event on the timeline.
3. Use a lightly colored pencil to shade in the correct areas of the timeline that correspond to the Precambrian, Paleozoic, Mesozoic, and Cenozoic eras.
4. Stretch out the entire timeline and reflect on what this shows you about Earth's history.

Event	MYA
Human recorded history (5,000 yrs)	0.005
Earliest humans (Cro-Magnon)	0.1
Hominids (ancestors of humans)	3
Extinction of the Dinosaurs	66
First flowering plants	144
First mammals	200
First dinosaurs	230
Mass extinctions occurred	245
Forests that formed fossil fuels (coal and oil)	300
First vertebrates (fish)	400
Seedless land plants become common	400
First animals	600
First multicellular organisms	650
First eukaryotes	1500
Oldest fossils	3600
Formation of the earth	4600