Chapter 7 • Lesson 26

Plate Tectonics

Key Words • lithosphere • tectonic plate • plate boundary • folding • crust • uplift • magma • volcano • lava • sea-floor spreading • mid-ocean ridge • fault

Getting the Idea

Earth's land surface looks solid. But it is actually made up of huge sections, which are in slow, constant motion. These sections interact with each other in different ways, creating new mountains and other landforms.

Theory of Plate Tectonics

The **lithosphere** is the outer part of Earth, made up of solid rock. The lithosphere is broken up into sections called **tectonic plates**. They sit on a layer of soft, semifluid rock. Temperature differences in this soft rock create slow-moving currents in the rock. The motion of these currents causes the plates above to move as well.

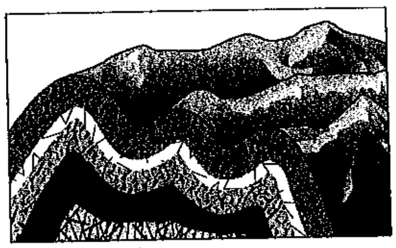
Scientist can identify the edges of Earth's plates and how they are moving by studying events and landforms on Earth's surface. There are seven main plates and six or seven smaller ones. Plates that are mainly covered by continents are continental plates. Plates that are mainly covered by ocean are oceanic plates.

As Earth's plates move, they interact, causing geologic events such as mountain formation, volcanic eruptions, and earthquakes. The region where two tectonic plates meet is called a **plate boundary**. At plate boundaries, plates can push against each other, move apart, or slide past each other. What happens at a plate boundary depends on how the plates are moving.

Mountains and Volcanoes

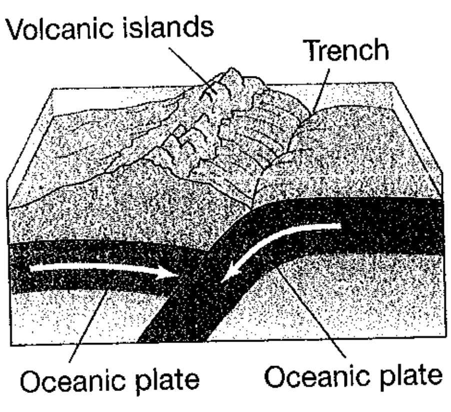
The highest mountains in the world were formed by **folding**. In this process, rock layers are squeezed together and pushed upward to form folds, or ripples in the crust. Earth's **crust** is the outer layer of the lithosphere. Where two continental plates collide, the plates buckle and thicken. Then the crust is pushed upward, and folded mountains form. The upward movement of rock layers is called **uplift**. Folded mountains include the Himalayas, the Alps in central Europe, and the Ural Mountains in Russia. The Appalachian Mountains of the United States were also formed by folding and uplift.

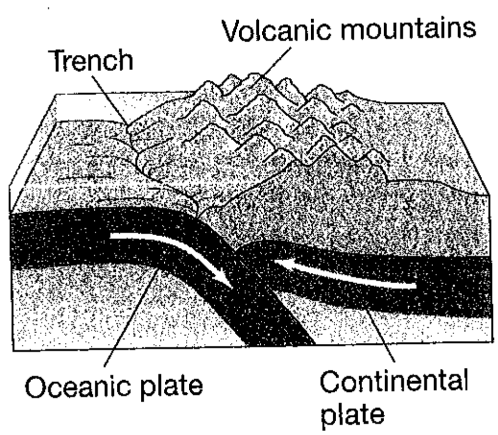
Folded Mountains



Two oceanic plates may collide. When that happens, one plate is pushed under the other. A deep canyon, called a *trench*, forms under the ocean where the plates meet. The plate that is pushed down sinks into the hot mantle, melting to form magma. **Magma** is melted rock beneath Earth's surface.

A **volcano** is an opening in Earth's surface through which magma is released. Melted rock that reaches Earth's surface is called **lava**. As newly formed magma rises and erupts as lava on the ocean floor, it cools and hardens. The result is a chain of volcanic mountains on the ocean floor. The mountains run parallel to the trench. As more material erupts and accumulates, the volcanic mountains grow. Some may reach the ocean's surface, forming volcanic islands such as the Mariana Islands in the western Pacific Ocean.





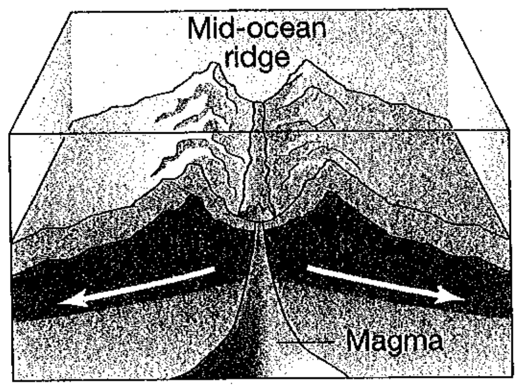
Continental plates collide with oceanic plates at continental-oceanic boundaries. At these boundaries, the oceanic plate slides under the continental plate. Chains of volcanic mountains can form on the edge of the continental plate. The western coast of South America has many volcanoes that formed in this way.

Sea-Floor Spreading

Where two oceanic plates move apart, magma flows up into the space between the plates. The magma hardens to form new oceanic crust. This process is called **sea-floor spreading.** As the spreading continues, magma continues to form new crust.

The oceans are widened by the process of sea-floor spreading. Long, continuous chains of volcanic mountains form along a boundary where oceanic plates move apart. These long chains of underwater mountains are called **mid-ocean ridges.** The Mid-Atlantic Ridge is the mid-ocean ridge in the center of the Atlantic Ocean. Sea-floor spreading is actively occurring there.

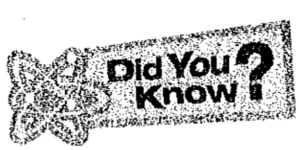
Formation of a Mid-Ocean Ridge



Earthquakes

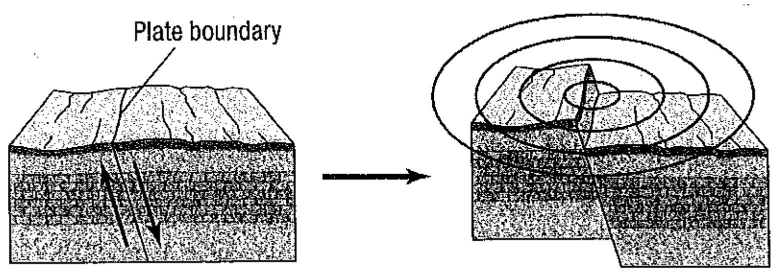
An earthquake is the shaking of the ground that occurs when rock in Earth's crust breaks or slips and quickly releases pressure. Pressure can build up as plates press together, slide by each other, or stretch and move away from each other. Rocks break or slip when they cannot withstand the pressure, and this movement releases energy that causes the ground to shake.

The break, or crack, in Earth's surface along which movement occurs is called a **fault.** There are different kinds of faults, and rocks move differently at each kind. At some faults, one side of the fault moves downward in relation to the other. At another kind of fault, one side of the fault moves upward in relation to the other. At a third kind of fault, the plates slide past each other sideways. The San Andreas Fault in California is the third type of fault.



Earthquakes can be felt in North Carolina, and records of earthquakes in the state date back nearly three centuries. One of the largest earthquakes on record in the state occurred in 1916. Damage caused by the earthquake included broken windows and fallen chimneys.

Earthquakes are also associated with the folding that occurs when rock layers crumple during plate collisions. Earthquakes can happen near Earth's surface or far below it. Most earthquakes happen in areas along tectonic plate boundaries where a large number of faults are located.



Mountains and volcanoes can form at boundaries where plates push together or pull apart, but they do not form where plates slide by each other sideways. In contrast, earthquakes can occur at any type of boundary, but they commonly occur at boundaries where plates slide by each other. Earthquakes rarely occur in the middle of a plate, but they do occur when cracks form in the middle of a plate. The movement of magma in and around a volcano can also trigger an earthquake.

Hot Spots and the Ring of Fire

For many years, scientists observed that volcanoes cluster in certain geographic locations. An area of volcanic activity, generally in the middle of a plate, is known as a hot spot. A hot spot stays in the same place even though the plate above it moves. This can result in a chain of volcanoes, some of which are no longer active. For example, the Hawaiian Islands are a chain of islands that have formed as a tectonic plate has traveled over a hot spot. The island chain continues to form to this day.

Along the boundary of the Pacific plate is the Ring of Fire. It is a zone of frequent volcanic eruptions and earthquakes encircling the Pacific Ocean basin. The Ring of Fire contains more than 75 percent of all volcanoes on Earth. The ring is an arc that reaches from New Zealand, north along the eastern edge of Asia, across the Aleutian Islands, and south along the western coast of North and South America.

Discussion Question

Why do earthquakes often happen in areas where volcanoes are also found?

Lesson Review

1. Which landform is **most likely** to form where two oceanic plates push together?

   A. folded mountain
   B. mid-ocean ridge
   C. river valley
   D. volcanic island

2. A chain of mountains is located along the western coast of a continent next to a plate boundary. Which sentence describes how the mountains **most likely** formed?

   A. As a continental plate and an oceanic plate slid past each other, a fault formed, and mountains were produced by earthquake movement.
   B. As a continental plate and an oceanic plate collided, part of the oceanic plate was pushed under the continental plate, and volcanoes erupted, forming the mountains.
   C. As two oceanic plates collided, one of the oceanic plates was pushed under the other plate, which rose to the surface, forming folded mountains.
   D. As two oceanic plates moved apart, new seafloor was produced, forming a ridge.

3. Where does sea-floor spreading occur?

   A. where two oceanic plates collide
   B. where an oceanic plate and a continental plate collide
   C. where two oceanic plates move apart
   D. where two continental plates move apart

4. At which location are earthquakes **least likely** to occur?

   A. at a boundary where plates push together
   B. at a boundary where plates move apart
   C. at a boundary where plates slide by each other
   D. in the middle of a plate

5. A hot spot can produce

   A. a chain of islands.
   B. a mid-ocean ridge.
   C. a trench.
   D. a tectonic plate.

Objective: 8.E.2.2

Chapter 7 • Lesson 27

Earth's Changing Surface

Key Words • weathering • erosion • deposition • sediment • sedimentary rock • igneous rock • metamorphic rock • rock cycle

Getting the Idea

Earth's surface is always changing. You have learned about two processes that build up Earth's surface—the formation of folded mountains and volcanic eruptions. There are other processes that build up Earth's surface, and there are processes that wear it down. Earth changes inside, too. Processes inside Earth can change one kind of rock into another.

Weathering

One process that wears down Earth's surface is weathering. **Weathering** breaks rock down into smaller pieces. There are two types of weathering—mechanical weathering and chemical weathering.

The breaking down of rock into smaller pieces by physical means, without changing its chemical composition, is mechanical weathering. Wind and water cause mechanical weathering by causing small pieces of rock to scrape against the surfaces of other rocks.

Plants cause weathering by growing into rock. Plant roots may grow into tiny cracks in rocks. In time, the roots may exert enough force to break the rock. You may have seen cracks in sidewalks and streets that were made by tree roots. Water can also cause rock to crack. Water seeps into cracks in a rock and freezes as the temperature drops. As the water freezes, it expands and pushes on the rock. When the temperature rises again, the ice melts. This repeated freezing and melting of water can break rocks apart.

Chemical weathering breaks down rock as a result of chemical reactions. Substances in the environment can react with the minerals in rock to form new substances. As a result, the rock may dissolve or break. As runoff and groundwater flow over and through cracks in rocks, the water may slowly dissolve the rocks. Some rocks contain iron. This iron can react with oxygen in the air to form rust. Rusting makes rocks crumble.

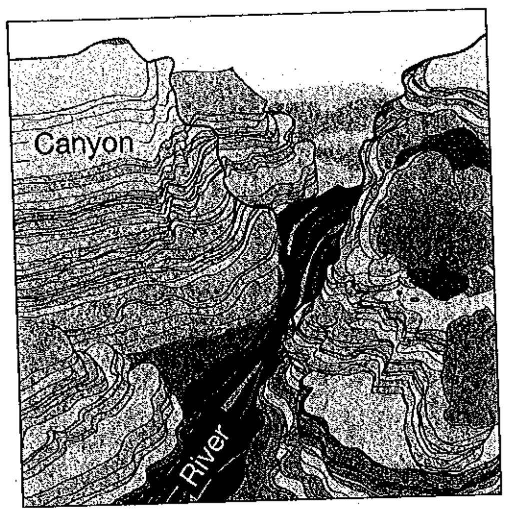
Acids can weather rocks. Some plant roots and lichens make acids that weaken and weather rocks. Acid rain can react with some minerals in rocks to cause rapid weathering.

Erosion

Erosion is a process by which weathered rock is picked up and moved to new places. Together, weathering and erosion change Earth's surface. Moving water, glaciers, wind, and gravity are agents of erosion.

Water is a major agent of erosion. Ocean waves pound against shorelines with great force. Wave action can carry sand away from beaches. Beach erosion is a problem on many coasts, including North Carolina's Outer Banks. On rocky coasts, ocean waves break down and erode rock that makes up cliffs.

As rivers flow, they carry away rock and soil. Over time, rivers carve out valleys. These valleys are often V-shaped because rivers cut downward. In some cases, rivers cut deep canyons. The Grand Canyon in Arizona is more than 1.6 kilometers deep in places. The Colorado River weathered and eroded rock for millions of years to form the Grand Canyon.



Wind erodes sand and other soil by lifting it and blowing it away. Wind is most likely to erode soil in areas with few plants to hold the soil in place. Gravity causes erosion by pulling pieces of rock downhill in landslides and rock falls.

Deposition

Weathering and erosion wear down Earth's surface. Deposition helps build it up again. **Deposition** is the dropping of pieces of weathered rock carried by water, wind, or ice. When wind and flowing water slow down, and when glaciers melt, they drop, or deposit, the rock materials they are carrying. Gravity overcomes the forces carrying the rock along. The deposited material is called **sediment**. Through deposition, sediment builds up into new landforms.

The flowing water in a river slows near its mouth, where it empties into an ocean or a lake. As the river slows, sediment in the water settles to the bottom. This sediment can build up to form a flat piece of land called a *delta*. A delta is usually shaped like a triangle or fan.

Heavy rainfall or melting snow can cause a river to overflow its banks. As the water spreads out over the land, the water slows down and drops the sediment it is carrying. With repeated floods, the sediment forms a wide, flat area of land called a *floodplain*.

Ocean water also deposits sediment. Much of the sand on beaches starts far inland. Rivers carry it to the ocean, where it sinks to the bottom, but ocean waves wash some sand back onshore. Over thousands of years, a beach forms.

A *dune* is a hill of sand deposited by wind. Dunes form along some ocean shores, in sandy deserts, and along the shores of the Great Lakes. Even a strong wind cannot carry sand very far. Wind blowing from the ocean toward land picks up sand along the shore and deposits it nearby. Sand dropped by the wind starts to build up around rocks or plants on the shore. As the wind deposits more sand, dunes form.

Classification of Rocks

Just as Earth's surface is constantly changing, rocks are always forming and changing too. Scientists classify rocks into three main groups based on how they form. The three kinds of rocks are sedimentary, igneous, and metamorphic.

When sediments are deposited, they may stay as loose sediments or form solid rock. Sediment deposited in rivers, lakes, and oceans sinks to the bottom. Over a very long time, layers of sediment build up. The weight of the layers compacts the sediments, or presses them together. Chemical changes cement the particles into a solid mass. Sediment that becomes compacted and cemented forms **sedimentary rock**. Limestone, sandstone, and shale are common types of sedimentary rock. Many sedimentary rocks have visible layers. These form as each new deposit of sediment is laid down. The oldest layers are usually at the bottom.

Igneous rock forms when melted rock cools and hardens. Some igneous rock, such as granite, forms from magma. Recall from Lesson 26 that magma is melted rock beneath Earth's surface. Other kinds of igneous rock, such as basalt, scoria, and pumice, form from lava. As you have learned, lava is melted rock that reaches Earth's surface. Lava flows from volcanoes when they erupt. The appearance of an igneous rock is often a clue about whether it formed from magma or lava. Igneous rock that formed from magma generally has large, or coarse, grains. This is because magma cools slowly and forms large crystals. By contrast, igneous rock formed from lava has small, or fine, grains because lava cools too quickly to form large crystals.

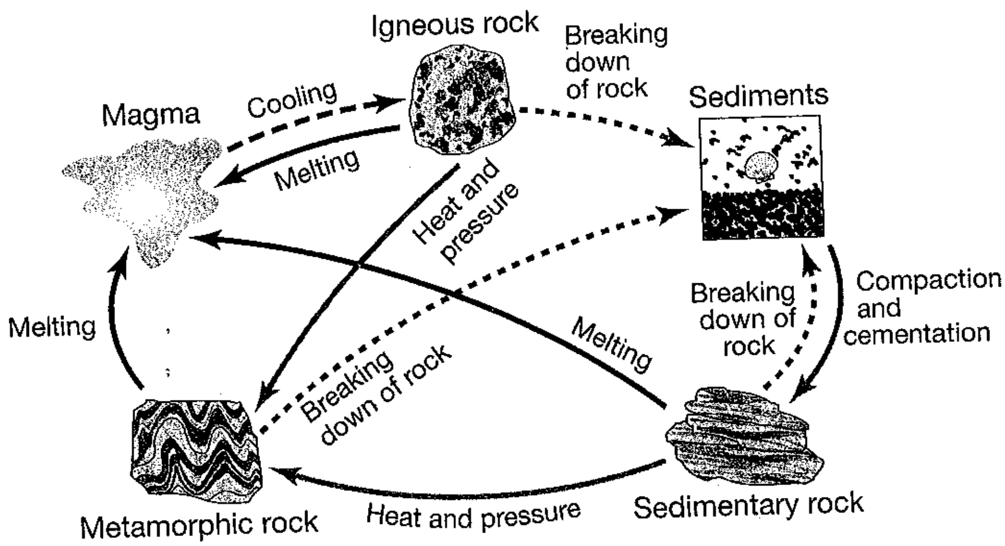
Metamorphic rock forms when existing rock is exposed to high heat, high pressure, or both. This happens mainly deep inside Earth and at plate boundaries. Chemical changes in the rock cause new minerals to form. Metamorphic rock can form from igneous rock or sedimentary rock. Metamorphic rock can also form from existing metamorphic rock. Different kinds of sedimentary and igneous rock become different kinds of metamorphic rock. Marble and gneiss are examples of metamorphic rock. Marble forms from the sedimentary rock limestone. Gneiss forms from granite, an igneous rock.

The Rock Cycle

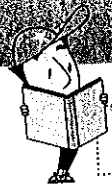
Processes that take place on and beneath Earth's surface can change rock. Weathering, erosion, and deposition change surface rock. Variations in temperature and pressure change rock inside Earth. At the same time, the movements of tectonic plates bring rock up to the surface and push rock down below it.

The **rock cycle** is the continual change of rock from one kind to another. The diagram below illustrates the rock cycle. Notice the arrows and labels. They describe the conditions and processes that drive the rock cycle.

The Rock Cycle



Any of the three major types of rock can change into one of the other types. Notice that the rock cycle includes many different pathways. For example, heat and pressure can change igneous rock into metamorphic rock. Igneous rock can also be broken down to become sediment, which can form sedimentary rock. Sedimentary rock can change into metamorphic rock or igneous rock. Some of these changes happen quickly, as when lava hardens after a volcanic eruption. But most happen very slowly, as when sedimentary rock forms over millions of years.Focus on Inquiry



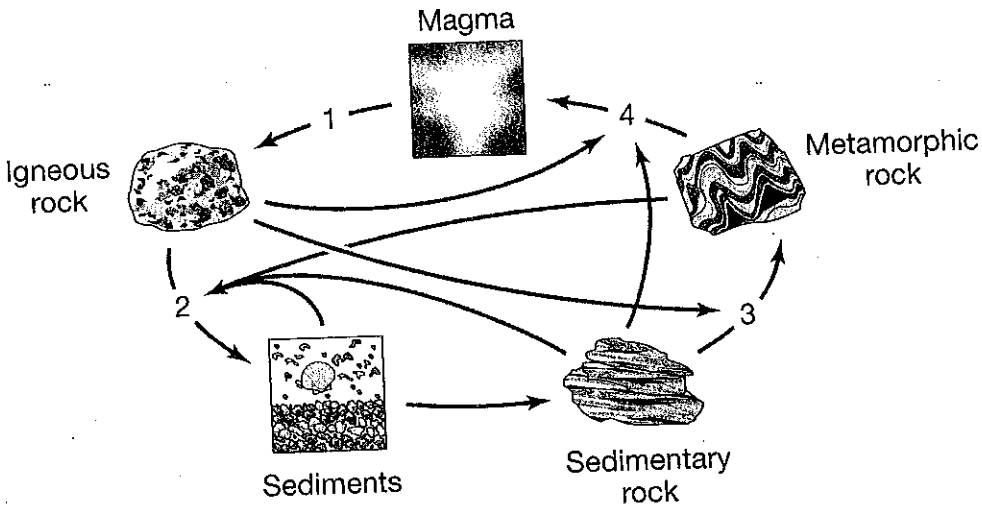
Lesson Review

1. Which of these is an example of chemical weathering?
   - **A.** Plants wedge their roots into cracks in rock and push it apart.
   - **B.** Acid rainwater seeps into the ground and dissolves limestone.
   - **C.** Gravitational force pulls rocks to the bottom of a mountain.
   - **D.** Rock pieces carried by river water wear away pieces of rock in the riverbed.

2. What does erosion do?
   - **A.** It changes rock chemically.
   - **B.** It changes rock particles into rock.
   - **C.** It breaks rock down physically.
   - **D.** It moves pieces of rock.

3. Deposition is a process that
   - **A.** dissolves sediment.
   - **B.** breaks down rock.
   - **C.** drops sediment.
   - **D.** moves rock particles.

Use the diagram of the rock cycle below to answer questions 4 and 5.



4. Which process does arrow 1 represent?
   - A. breaking down of rock
   - B. melting under very high pressure
   - C. chemical change due to heat and pressure
   - D. cooling and solidifying

5. Which process does arrow 3 represent?
   - A. breaking down of rock
   - B. melting under very high pressure
   - C. chemical change due to heat and pressure
   - D. cooling and solidifying

Objectives: 8.E.2.1; 8.E.2.2

Evidence of Earth's History

Key Words • fossil • extinct • ice core • geology • absolute age • radioactive dating • relative age • law of superposition • index fossil

Getting the Idea

You have seen that Earth's lithosphere has changed over time. Earth's climates and life-forms have also changed. Fossils, ice cores, and rocks provide scientists with valuable information about all of these changes. In some cases, they can provide details about what Earth was like millions or even billions of years ago.

Fossils and Ice Cores

Fossils are the preserved remains or evidence of organisms that lived in the distant past. Many of these species are now extinct. A species is **extinct** when there are no more individuals of that species living on Earth. Much evidence about past life-forms comes from fossils.

Many fossils were formed by a process in which an organism died and was covered over by sediment. Over time, the sediment was compacted and cemented into sedimentary rock around the organism's remains. In some cases, the remains of the organism decayed and left a mold, a hollow space in the rock. The mold shows the shape of the organism's remains. In other cases, the organism's remains were replaced by rock particles and other materials, which took on the shape of the remains. Sometimes hard parts of organisms, such as bones, teeth, or shells, are preserved in sedimentary rock.

Some fossils are evidence of the behaviors or actions of live organisms. Sometimes footprints left in mud were preserved when the mud dried. Sediments deposited over the footprints kept them from being destroyed by rain or other agents of weathering. As the sedimentary rock hardened, the footprints were preserved.

An **ice core** is a cylinder of ice removed from an ice sheet, a deep deposit of ice and snow. In an area where snow does not melt each summer, deposits of snow build up in layers, somewhat like those found in sedimentary rock. The texture of the snow is different in summer and winter, forming distinct layers in the ice core. Scientists can count the layers to find out how old part of an ice core is. Ice cores from Antarctica contain information going back 750,000 years.

Ice cores do not contain fossils, but ice cores do provide a lot of data. Air bubbles trapped in the ice can be analyzed to see how Earth's atmosphere has changed. Different amounts of dust, ash from volcanoes, and carbon dioxide show changes in Earth's atmosphere. Pollen can be studied to find out what kinds of plants lived hundreds of thousands of years ago.

Determining the Age of Rocks

The study of Earth's history, processes, and structures is called **geology.** Scientists can use rocks and fossils to create a timeline of Earth's geologic history. When studying rocks and fossils, scientists consider absolute and relative ages. **Absolute age** is the actual age, in years, of a rock or fossil. It tells how many years ago a rock or fossil formed.

Scientists find absolute age using a technique called radioactive dating. Radioactive substances give off high-energy radiation. This causes them to decay, or change into different substances called decay products. **Radioactive dating** measures the age of a material by comparing the amount of a radioactive substance with the amount of its decay product. The decay process happens at predictable rates. So radioactive dating tells scientists how old something is within a certain number of years.

Uranium is a radioactive element that decays into lead. The decay process takes place very slowly, over billions of years. This makes uranium a good choice for finding the age of rocks. Carbon-14 is another radioactive substance used for finding age. However, it decays much faster than uranium does. Carbon-14 can be used to date organic materials from the past 50,000 years or so, but it is not useful for dating rocks or most fossils.

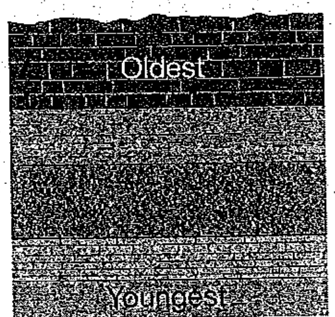
Radioactive dating is used to estimate Earth's age. However, Earth rocks are not completely reliable because they constantly change through the rock cycle. For this reason, scientists use rocks from the moon and meteorites, which scientists think formed at the same time as Earth. Using radioactive dating, scientists estimate Earth to be 4.5 billion years old.

When absolute dating is not possible, scientists try to find the relative age of an object. **Relative age** is the age of an object or event in comparison to another object or event. Relative-age information helps scientists put events in order without giving a specific date. Using relative age to determine the age of a rock or fossil is called relative dating. Geologists often use the law of superposition to find relative age. The **law of superposition** states that in undisturbed sedimentary rock layers, older layers of rock lie under younger rock layers. This idea makes sense because newer sediments are laid down on top of older ones.

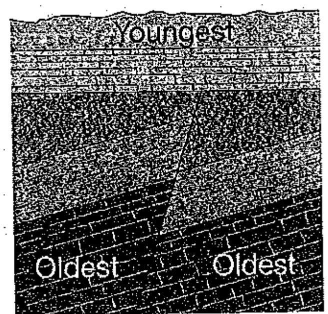
Sometimes rock layers become disturbed or even overturned. Then older layers of rock may lie above or beside younger rock layers. Plate movements can disturb rock layers through processes such as folding and faulting.

Recall from Lesson 26 that when tectonic plates collide, rock layers are squeezed together and form folds, or ripples, in the crust. Folds in rock layers can arch upward, downward, or sideways. Faulting can occur when pressure builds up as plates press together, slide by each other, or move away from each other. When the rocks cannot tolerate the pressure, they break and slip, forming a fault.

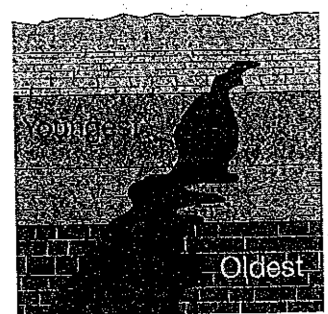
Magma can also affect rock layers. Magma can move upward and push into existing rock layers. When the magma cools and hardens, it forms a mass of igneous rock called an *intrusion*. An intrusion is always younger than any rock layer through which it cuts. Understanding how rock beds have been disturbed is important for finding the relative ages of the rocks. The diagrams below help explain how disturbances in rock layers affect relative dating.



Overturned bed—rocks on the bottom are now the youngest



Angular bed—horizontal rocks are younger than the tilted rocks



Intrusion—igneous rocks are younger than any sedimentary rocks they cut

Other processes also affect the rock record, or sequence of rock layers. Weathering and erosion can wear away rock, exposing older layers below. If new layers are later deposited, there will be a gap between the older and newer layers. Gaps like this can make it hard to figure out how Earth changed during a specific time period.

Using Fossil Evidence

Fossils are very useful in finding the age or geologic history of the rocks that contain them. Sometimes rocks in different locations contain the same kinds of fossils. This may indicate that the rocks were laid down in a similar place and time.

The law of superposition can be used to find the relative ages of fossils in a rock formation. Once the relative ages of those fossils are known, they can be used to determine the relative ages of other rock layers that contain those kinds of fossils. In some cases, the absolute age of a fossil can be determined. Then the fossil can be used to tell the absolute age of the rock layer in which it was found.

Some fossils are more useful than others for finding the age of rock layers. An **index fossil** is a fossil of an organism that existed for only a short period of geologic time and lived in many places. Index fossils can provide fairly precise information about the age of a rock layer. Suppose scientists study a rock layer and find a fossil from a species that existed for only a few hundred thousand years. The fossil shows that the rock layer was forming during that short time period. If the same index fossil is found in rock layers in different areas, scientists can conclude that those rock layers were all laid down during the same short period of time.

Fossils can provide evidence of major changes in the climate or surface features of an area. For example, fossils of marine organisms have been found in deserts. Fossils of tropical plants have been found in Antarctica. These fossils show that the areas in which they were found were once quite different.

Many of these changes are related to the movement of tectonic plates. Recall from Lesson 26 that tectonic plates are sections of the lithosphere that are in constant motion. Tectonic plates pass through different climates as they move across Earth's surface. Also, as tectonic plates interact with one another, landforms change. Areas that were once covered by water may rise above the surface.

Fossil evidence can also point to periods of widespread climate change. During Earth's ice ages, much of Earth's surface was covered with ice, and sea levels dropped. The fossil record shows that these changes affected the habitats of many organisms.

Discussion Question

List five events from your life on a sheet of paper. Then add your birthday to the list, as well as two events that you remember happening when you were a specific age. Rewrite your list so that all the events appear in the order in which they occurred (from earliest to most recent). Describe two of the items on your list in terms of relative age. Then, describe two events in terms of absolute age.

Lesson Review

1. To learn how Earth's atmosphere has changed over time, scientists study air bubbles in which of the following?

   A. ice cores

   B. pollen

   C. rocks containing uranium

   D. fossils in sedimentary rock

2. In which situation will older rock layers lie above younger rock layers?

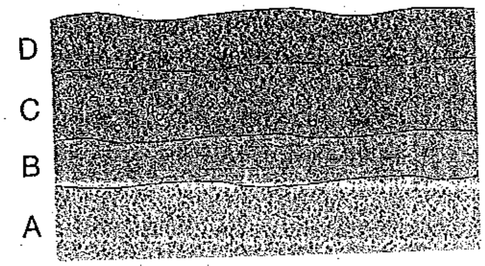
   A. Erosion has exposed older rocks, and new layers have been deposited.

   B. Rock layers have been overturned by folding.

   C. Sedimentary rock layers have remained undisturbed after deposition.

   D. Igneous intrusions have cut through layers of sedimentary rock.

3. The diagram below shows layers of sedimentary rock.



Assuming that this rock formation is undisturbed, what is the relative age of layer C?

A. It is the youngest rock layer.

B. It is the oldest rock layer.

C. It is older than B and younger than D.

D. It is younger than B and older than D.

4. Radioactive dating is used to find

A. the locations of index fossils.

B. the identities of index fossils.

C. the absolute ages of rocks and fossils.

D. the relative ages of rocks and fossils.

Chapter 7 • Lesson 29

The Geologic Time Scale

Key Words ◦ geologic time scale ◦ eon ◦ era ◦ extinction ◦ period ◦ epoch ◦ Precambrian ◦ Cambrian

Getting the Idea

Scientists have learned about Earth's history and its life-forms by studying rocks and the fossil record. Earth's history covers a long time span. By studying fossils, scientists have learned that Earth's life-forms have become more varied and more complex over time.

Organizing Earth's History

The **geologic time scale** is a timeline that organizes major events in Earth's history. It begins when Earth formed and continues to the present time. The chart on the next page shows how the geologic time scale is organized.

The geologic time scale shows that for more than a billion years, there were no life-forms on our planet. Fossils show that life started in the oceans around 3.5 billion years ago. Simple organisms such as algae and bacteria were the main life-forms during most of Earth's early history. Complex organisms such as land plants and fish appeared only within the last 500 million years. Humans did not appear until about 200,000 years ago. If the whole history of Earth were squeezed into a single day, humans would exist only for the last few seconds.

Geologic time is divided into eons, eras, periods, and epochs. An **eon** is the longest unit of time. Earth history is divided into four eons. Almost all known fossils come from the most recent eon, the Phanerozoic. This eon began about 550 million years ago, when the variety of life-forms suddenly increased.

Eons are divided into **eras**. Scientists have used evidence of mass extinctions as the dividing line between eras. **Extinction** is the permanent dying out of a species or a larger group of organisms. A *mass extinction* occurs when large numbers of species die out over a fairly short period of time. Mass extinctions have occurred many times in Earth's history. In the rock record, the sudden disappearance of many fossil species followed by the sudden appearance of new species marks a mass extinction.

A sudden, severe change in conditions on Earth is called a catastrophe. Such sudden changes can lead to mass extinctions. Scientists do not know the cause of each mass extinction in Earth's history. However, they do know the kinds of catastrophes that can cause a mass extinction. One event that could cause a mass extinction is an asteroid or comet crashing into Earth. Many scientists think that such an event helped cause extinction of the dinosaurs.

Eras are divided into periods. A **period** is a block of time during which unique rock layers were laid down. Specific fossils are often associated with individual periods. Periods are divided into **epochs**, which are the shortest divisions of geologic time.

The **Precambrian** consists of three eons and includes most of Earth's history. Although the Precambrian spans an extremely long time, very few fossils have been found from this period. The last eon of the Precambrian is the Proterozoic Eon. It ended with the appearance of many new life-forms.

Geologic Time Scale

Eon	Era	Period		Epoch	Millions of Years Ago	Events
Phanerozoic	Cenozoic	Quaternary		Holocene	11,000 yr–present	
				Pleistocene	1.6–11,000 yr	Humans
		Tertiary	Neogene	Pliocene	5.3–1.6	
				Miocene	23.7–5.3	
			Paleogene	Oligocene	36.6–23.7	
				Eocene	57.8–36.6	
				Paleocene	66.4–57.8	Rise of mammals
	Mesozoic	Cretaceous			146–66.4	Flowering plants
		Jurassic			208–146	Birds
		Triassic			245–208	First dinosaurs/ mammals
	Paleozoic	Permian			286–245	
		Carboniferous			360–286	First reptiles
		Devonian			408–360	First amphibians
		Silurian			438–408	First insects First land plants
		Ordovician			505–438	First fish
		Cambrian			570–505	Explosion of life-forms
Precambrian Proterozoic					2500–570	Multicelled organisms
Archaean					3800–2500	One-celled organisms
Hadean					4500–3800	

Geologic time after the Proterozoic Eon is called the Phanerozoic Eon. It is divided into three eras. These are the Paleozoic, Mesozoic, and Cenozoic eras. The Paleozoic era is the oldest. The first period of this era is the **Cambrian** period. The beginning of the Cambrian is marked by the Cambrian explosion, named because of the great variety of living things that developed during that time.

Paleontologists have found more fossils from the Cenozoic era than from earlier times. As a result, we know more about this time in Earth's history. It is important to remember that geologic time has not ended. Earth continues to change, and fossils continue to form. The Cenozoic era is still ongoing. You are living during the Holocene epoch.

Discussion Question

Dinosaurs first appeared on Earth during the Triassic period. They were all extinct by the end of the Cretaceous period. Use the geologic time scale to determine about how long dinosaurs existed on Earth. How does this compare to the length of time that humans have lived on Earth?

Lesson Review

1. The earliest part of Earth's history is called the

A. Cenozoic.

B. Cambrian.

C. Holocene.

D. Precambrian.

2. Which division of the geologic time scale is the longest?

A. eon

B. period

C. era

D. epoch

3. How do scientists know when a mass extinction took place?

   A. They find more fossils of plants.

   B. They find fossils of animals that died suddenly.

   C. They find a sudden disappearance of many fossil species.

   D. They find evidence of changes in Earth's atmosphere.

4. Which of these groups of animals appeared on Earth most recently?

   A. reptiles

   B. amphibians

   C. mammals

   D. fish

Objective: 8.L.4.2

Genetic Variation and Evolution

Key Words • evolution • adaptation • variations • mutation • natural selection

Getting the Idea

Evolution is the process by which species change over time. This very slow, gradual process usually occurs over long periods of time. Evolution is responsible for the similarities we see across all species. It is also responsible for the great variety of living things on Earth.

Adaptation and Genetic Variation

Think of an animal you have seen recently. You can describe it according to its traits. A trait is any characteristic of an organism, such as its body shape or what it eats. As species evolve, they develop new traits and lose others. The traits that help organisms survive in a given environment are called **adaptations.**

Organisms have many types of adaptations. Some are physical traits, such as the long neck of a giraffe or the needles on a pine tree. These adaptations are structural adaptations—part of the organism's body. Some adaptations are physiological, or having to do with how the body functions. The ability to regulate body temperature or to produce a toxic substance is such an adaptation. Other adaptations are behavioral adaptations. These include the ability to build a nest or recognize a predator. Adaptations allow groups of organisms to survive over long periods of time. These groups may be individual populations or entire species.

An organism that survives longer is more likely to produce offspring. Most adaptations that help an organism survive are passed from parent to offspring as inherited traits. Some adaptations of the giant panda are shown below.

Giant Panda Adaptations

Some adaptations help an organism protect itself from other organisms. Hedgehogs and sea urchins have sharp spines that keep predators away. Other animals sting or spray their predators. Roses have thorns and cactuses have sharp spines that keep many animals from eating them. Some plants and animals produce poisonous chemicals. Turtles and snails have shells in which they can hide.

For animals that cannot outrun their predators, color can be an adaptation if it helps them blend in with their environment and hide. For example, the color of the arctic hare's fur changes to blend into its surroundings as its environment changes with the seasons. Animals that blend in with their environment also stay still to avoid being noticed by predators.

Some mammals and many amphibians hibernate in response to cold weather and short supplies of food. Hibernation is a behavioral adaptation that conserves energy. This helps keep an animal from starving when food is scarce.

It is important to remember that an adaptation depends upon the environment in which an organism lives. A trait that is an adaptation in one environment may not be an adaptation in another environment. A polar bear has thick fur and a thick layer of fat under the skin. These traits keep the bear warm and are adaptations for a cold climate. They would not be adaptations for a hot climate. In fact, they would make a polar bear less likely to survive.

Variations and Survival

Variations are differences that exist naturally among members of a population or species. Sexual reproduction and mutations are the sources of variations and new traits in a population. Sexual reproduction results in offspring that are not exactly like their parents. The offspring inherit genes from both parents, and the genes combine in new ways. A **mutation** is a change in a gene or a chromosome. A mutation may result in an adaptation that improves an organism's ability to exist in an environment. Other mutations are harmful or even deadly. Most mutations have no effect on the organism. Mutations can be passed down to the next generation.

Because individual members of a species have variations, some are better suited than others to survive in their environment. Almost all populations have some variation. Species with more variation are more likely to have some members who can survive when conditions change.

For example, recall that antibiotics are medicines given to people who have bacterial infections. An antibiotic may kill the bacteria, but sometimes a few bacteria survive. These bacteria have a variation that makes them resistant to the antibiotic. When the resistant bacteria reproduce, they pass along their resistance as an inherited trait. This results in a population of bacteria that are resistant to that antibiotic. The next time the antibiotic is used, it may not kill the bacteria as well as it did before.

Notice that the bacteria's resistance to the antibiotic did not develop because of the antibiotic. The resistance existed as a variation in the population. This variation was not important until the antibiotic was used. The change in the bacteria's environment made the variation important to the survival of some bacteria. Over time, as the survivors reproduced, more bacteria had the variation. It became an adaptation to the new environment.

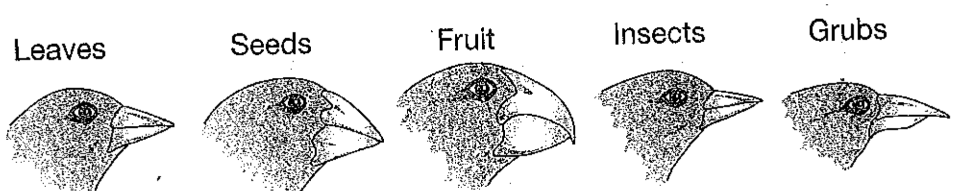
Natural Selection

Natural selection is the process by which organisms that are best suited to a particular environment survive and reproduce. In other words, nature "selects" these organisms for survival. Natural selection can work only with the genetic variation that already exists in a population. The fittest individuals live to pass on their traits to the next generation. By passing useful traits from generation to generation, a species develops adaptations to a new or changing environment.

A British naturalist named Charles Darwin developed the theory of evolution by natural selection. While traveling around the world in the 1830s, Darwin observed many species of plants and animals. Darwin noticed that many species had unique adaptations that helped them survive in a particular environment. He published his theory in his 1859 book *On the Origin of Species*.

Natural selection helps explain how a new species can develop from an existing species. As useful traits are passed from one generation to the next, differences among members of a species can grow. Over time, the differences may become so great that groups within a species can no longer breed with each other. When that happens, a new species has developed.

Darwin based his ideas about natural selection in part on his observations of finch species living on the Galápagos Islands. The Galápagos Islands are volcanic islands near the equator in the Pacific Ocean. The species of finches have beaks of different sizes and shapes, suited to gathering the types of food available on the islands on which they live. Darwin suggested that the different finch species evolved from a single species that came to the islands from the mainland. He thought the many different finch species evolved from the original species in response to different environmental conditions.



Darwin observed that beak shapes in finches varied according to the type of food the finches ate.

Evolution, Diversity, and Extinction

Evolution leads to diversity, or variety, of species. As species change, new species arise. Different species have different adaptations to their environments. But environments change, too. A species may not be suited to a changed environment and may not contain individuals that can survive in the new conditions. In that case, a species becomes extinct. Recall that extinction is the permanent dying out of a species or a larger group of organisms. Scientists estimate that the species that exist today are only a tiny fraction of the all the species that have ever lived on Earth.

Discussion Question

The distant ancestors of tigers may have had bodies without stripes. Use the theory of natural selection to explain how tigers may have evolved to have stripes.

Lesson Review

1. Which of the following **best** describes natural selection?

   A. Organisms compete for food and shelter.

   B. Organisms produce more offspring than can survive.

   C. Organisms vary in their physical traits, and some traits are inherited.

   D. Organisms best suited to their environment are most likely to survive and reproduce.

2. Some rattlesnakes in a population have markings that help the snakes hide. The snakes with these markings catch more prey, live longer, and have more offspring than the other snakes. What does the theory of natural selection predict about this population?

   A. It will not change.

   B. It will become extinct.

   C. Over time, more members will have the useful markings.

   D. Over time, fewer members will have the useful markings.

3. Which of these is a behavioral adaptation?

   A. swallows building nests out of mud

   B. cactus plants having long spines

   C. insects looking like leaves to blend in with real leaves

   D. butterflies producing a foul-tasting chemical

4. Which of the following is **most likely** to cause the extinction of a species?

   A. mutation

   B. a changing environment

   C. natural selection

   D. genetic variation

Evidence of Biological Evolution

Key Words • homologous structures • analogous structures • vestigial structure • embryology • embryo

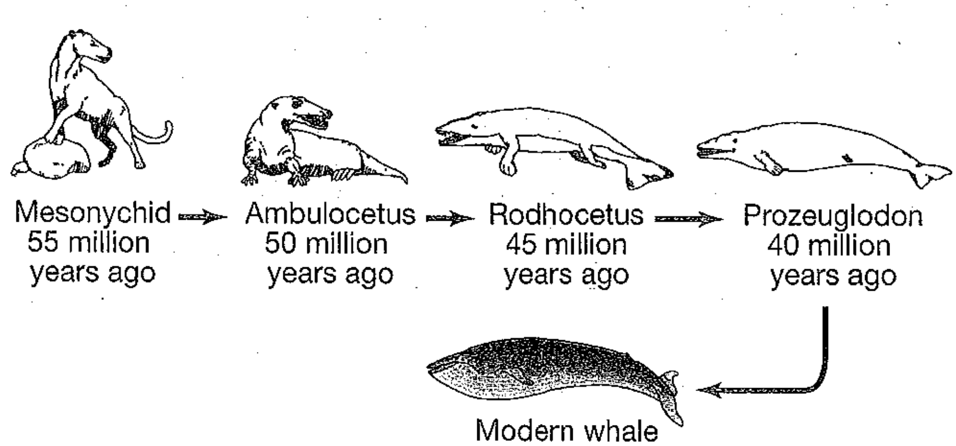
Getting the Idea

Scientists look at many kinds of data to try to piece together the evidence of the evolution of organisms. In part, these data come from observing fossils, examining genetic information, and studying different species. These data help scientists learn how and why adaptations arise, how new species develop, and why many species are now extinct.

Fossil Evidence for Evolution

Recall from Lesson 28 that fossils are the preserved remains or evidence of organisms that lived in the past. You learned that scientists often use fossils to determine when rock layers formed. The opposite is also true. If scientists know how old rock layers are, they can draw conclusions about the ages of fossils formed in those layers.

A series of related fossils found in different rock layers can show how organisms changed over time. Whales are descended from land animals related to deer and hippos. The fossil record shows how whales adapted to live in the water. Over many generations, their legs shrank and then disappeared. The legs were replaced by flukes, which whales use to swim. Whales also became more streamlined, which helps them move through water. Their nostrils moved toward the top of the head, so whales can breathe at the surface of the ocean.



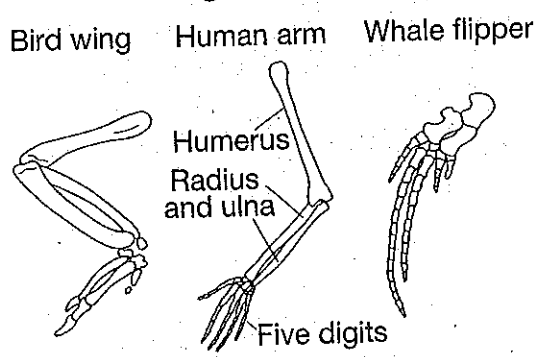
Fossil evidence also suggests an evolutionary relationship between birds and dinosaurs. Living birds, fossils of birds, and the fossils of a group of dinosaurs called *theropods* have some similar physical structures. Based on this evidence, most scientists have concluded that modern birds evolved from theropods.

Structural and Developmental Evidence for Evolution

Many species of organisms have similar structures. For example, both turkeys and blue jays have feathers. The presence of feathers suggests that the two animals are related in some way. Scientists often study the physical features and structures of organisms to try to discover how organisms are related.

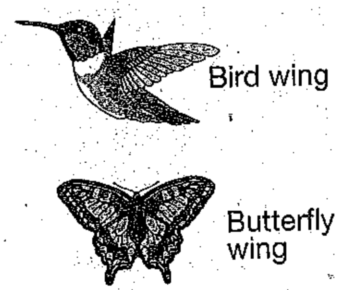
Homologous structures are body parts of different organisms that have a similar structure but not necessarily a similar function. Look at the left side of the diagram below. It shows that the human arm, the wing of a bird, and the flipper of a whale are homologous structures. Although they are used in different ways, they are all composed of very similar bones. Homologous structures indicate that organisms have evolved from a common ancestor.

Homologous Structures



Homologous structures indicate shared ancestry.

Analogous Structures

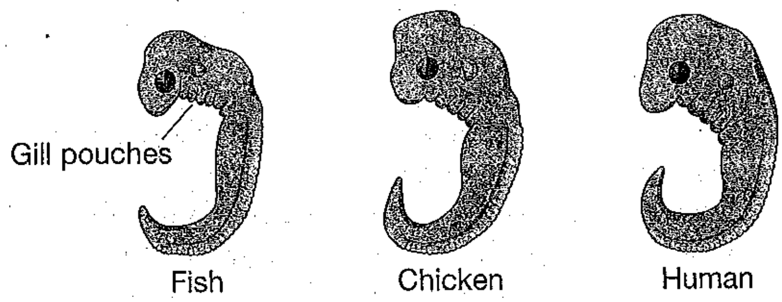


Analogous structures do not indicate shared ancestry.

Analogous structures are body parts that have a similar function but not a similar structure. Analogous structures, like those shown on the right side of the diagram above, do not indicate shared ancestry. The wing of a bird is supported by bones. The wing of a butterfly does not have any bones. This difference shows that flight evolved separately in unrelated organisms.

Scientists also examine vestigial structures. A **vestigial structure** is a body part that does not seem to play a role in the body functions of an organism. Rats have an appendix that appears to function in digestion. Humans also have an appendix, but its function is unknown and it is not essential for survival. The human appendix is an example of a vestigial structure. The presence of an appendix in both rats and humans suggests that these organisms evolved from a common ancestor.

Embryology is the study of embryos. An **embryo** is an early stage in the development of an organism. The embryos of related organisms develop in similar ways. Often, embryos have structures that are not present in the adult form of the organism. The diagram below shows that the embryos of fish, chickens, and humans look very similar. They all have folds called gill pouches in the neck region. These folds develop into gills in adult fish. Although adult chickens and humans do not have gills, the similarities in their embryos suggest that the organisms are related.



Genetic Evidence for Evolution

Scientists have also learned about evolution by analyzing DNA. You have learned that DNA is a very large molecule made of repeating units. The order of units is a code that determines an organism's traits. Similarities in DNA sequences can be used to show common ancestry. The more similarities found in the DNA sequences of two species, the more recently the species evolved from a common ancestor.

Distribution of Organisms

The places where related species are found are also evidence of evolution. When organisms travel to new environments, they may evolve into new species. The plants and animals of the Galápagos Islands are examples.

Recall that Darwin traveled to the Galápagos Islands. Many species of plants and animals he found closely resembled the ones on the nearest mainland. Darwin concluded that mainland species migrated to the islands, where they eventually evolved into new, distinct species. Only animals that could fly or survive in salt water could make the trip from the mainland. Seeds of mainland plants may have been carried to the islands by wind or water.

Scientists think that Earth's lithosphere was once one giant landmass. The movement of tectonic plates has resulted in the landmasses we know today. Many species on different landmasses once had a common ancestor. They evolved differently when they became separated.

Areas such as Australia, New Guinea, and New Zealand have been separated from other landmasses for millions of years. They have distinct sets of organisms not found in other areas of the world. Australia has large populations of egg-laying mammals, called *monotremes*, and pouched mammals, called *marsupials*. Monotremes and most species of marsupials are found only in Australia and New Guinea.

Discussion Question

A dolphin is a mammal that must come up to the water's surface to breathe. A shark is a fish that breathes underwater. Yet the dolphin and the shark have similar body shapes. Are these body shapes analogous or homologous? Explain your answer.

Lesson Review

1. Which of these would **not** be used by a scientist to determine the evolutionary relationship between two species?

   A. bone structure

   B. fossils

   C. DNA

   D. population size

2. Which of these are vestigial structures?

   A. the wings of a butterfly

   B. the hip bones found in some species of snake

   C. the thick fur and layer of fat of some mammals in cold climates

   D. the sharp spines of a cactus

3. What is the **most likely** result if two populations of the same species are separated for a long period of time?

   A. Neither population will change.

   B. Both populations will change in the same ways.

   C. The populations will change in different ways.

   D. Both populations will become extinct.

4. Which of these is **least likely** to show common ancestry?

   A. homologous structures

   B. vestigial structures

   C. DNA

   D. analogous structures

Chapter 7 • Lesson 32

Objective: 8.L.4.1

Biological Classification

Key Words • classification • taxonomy • domain • kingdom • phylum • class • genus • species • Bacteria • Archaea • Eukarya • fungus • protist • binomial nomenclature

Getting the Idea

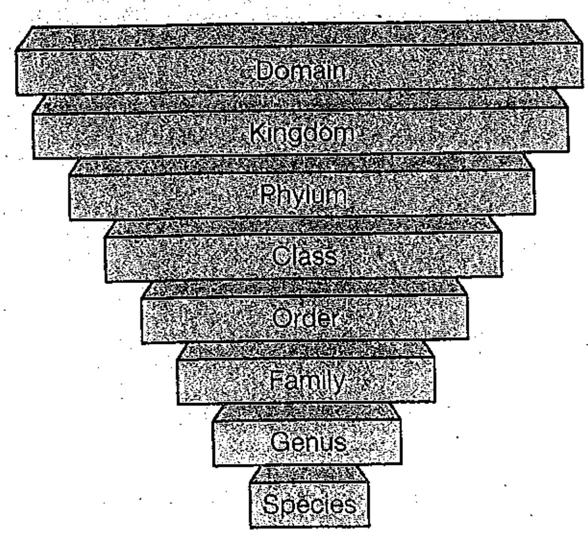
Scientists know of more than 1.5 million different kinds of organisms. To organize what they know about so many life forms, scientists have developed a method of classifying living things. **Classification** is the systematic grouping of organisms based on shared characteristics. The classification system shows how different species of organisms evolved and how they are related.

Classification of Organisms

Taxonomy is the branch of life science that names and groups organisms. New organisms are discovered every year. When scientists find an unfamiliar organism, they study it and try to determine where it fits in the classification system. Sometimes these discoveries lead scientists to change their current understanding of the relationships among living organisms. The list of known organisms continues to grow and undergo refinement.

Levels of Classification

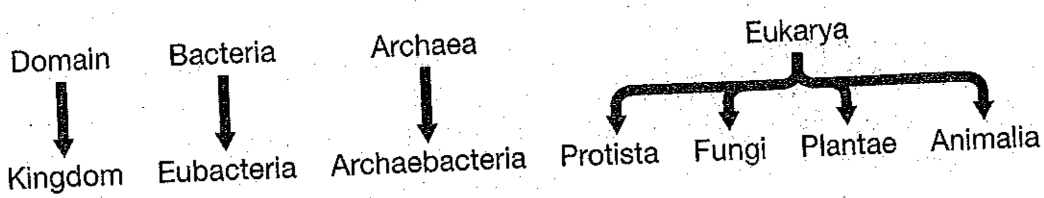
Some organisms are more alike than others. Scientists classify them by their similarities and differences. They use a system in which living things are classified into more and more specific groups. As the groups become more specific, the organisms become more alike. The diagram below shows the current recognized levels of classification.



The first classification level is **domain**. All living things are grouped into one of three domains. Each domain includes a huge variety of organisms. At the domain level, organisms may be very different from one another.

The next level of classification below domain is **kingdom**. The classification group below kingdom is **phylum** (plural: *phyla*). Members of each phylum are then divided into different classes. A **class** is made up of different *orders*. An order consists of several *families*. Each family contains at least one **genus** (plural: *genera*). Each genus is divided into smaller groups called species. At each level, the groups contain fewer kinds of organisms, and the organisms are more and more alike. At the **species** level, the organisms are so similar that they are able to mate and produce fertile offspring.

Recall that all living things are either prokaryotes or eukaryotes. Prokaryotes make up two domains, Bacteria and Archaea. Each of these domains contains one kingdom. Eukaryotes make up the third domain, Eukarya. Eukarya is a very large and diverse group. It contains four kingdoms. The diagram below shows the three domains and the kingdoms they include.



The Kingdoms of the Domains Bacteria and Archaea

The organisms in domain **Bacteria** are one-celled bacteria. The only kingdom in this domain is Eubacteria. This name means "true bacteria." Recall that bacteria are prokaryotes, organisms whose cells lack a nucleus and membrane-bound organelles. Their cells have thick cell walls. Some bacteria are autotrophs. Recall from Lesson 18 that an autotroph is an organism that makes its own food. Other bacteria are heterotrophs. A heterotroph is an organism that gets nutrients from other organisms. The bacteria that cause food to spoil and cause infections in other organisms are heterotrophs.

The only kingdom in domain **Archaea** is kingdom Archaebacteria. Like bacteria, members of this kingdom are one-celled prokaryotes. Some archaea are autotrophs. Others are heterotrophs. These organisms resemble bacteria in many ways. In fact, they were once classified together with bacteria. Classification methods change, however, as scientists develop better tools and greater understanding. They study both physical and chemical characteristics of organisms. In the case of archaea, scientists learned that their genetic material and cell walls differ from those of bacteria. Scientists realized that these organisms belonged in a different kingdom. Many archaea live in extreme environments, such as thermal vents and salt lakes.

The Kingdoms of Domain Eukarya

The organisms of the domain **Eukarya** all share one important characteristic—their cells have an organized nucleus. Some organisms in domain Eukarya are one-celled, while others are multicelled. Humans, oak trees, amoebas, and mushrooms all belong to domain Eukarya. These four kinds of organisms are very different, so each belongs to a different kingdom.

You know organisms in the kingdom Animalia as animals. All animals are multicelled. All animals are also heterotrophs. Animals obtain nutrients by eating plants or other animals that have eaten plants. Most animals can move from place to place. Recall that animal cells lack cell walls and chloroplasts.

Kingdom Plantae is made up of plants. Plants are multicelled organisms that are able to make their own food. The cells of plants have cell walls that contain cellulose.

A **fungus** (plural: *fungi*) is a member of the kingdom Fungi. Fungi are heterotrophs. They obtain nutrients from other living organisms or their remains. The cells of fungi have cell walls that contain a substance called chitin. Mushrooms are examples of many-celled fungi. Yeasts are examples of one-celled fungi.

The organisms in the kingdom Protista, the **protists**, are very diverse. In fact, these organisms are classified more by what they are not than by what they are. Protists are members of domain Eukarya that cannot be classified as fungi, plants, or animals. Most protists, such as amoebas, are one-celled. Some protists have many cells. Some protists are heterotrophs, and others are autotrophs. Algae are an important group of protists that make their own food by photosynthesis.

The table below summarizes the main characteristics of the six kingdoms.

The Six Kingdoms

Kingdom	Main Characteristics
Eubacteria	Prokaryotic, one-celled, have thick cell walls, may be autotrophs or heterotrophs
Archaebacteria	Prokaryotic, one-celled, cell wall contains a complex molecule not found in cell walls of other organisms, may be autotrophs or heterotrophs
Protista	Eukaryotic, most are one-celled, have no cell wall, may be autotrophs or heterotrophs
Fungi	Eukaryotic, one-celled or many-celled, have cell walls, are heterotrophs
Plantae	Eukaryotic, many-celled, have cell walls, are autotrophs
Animalia	Eukaryotic, many-celled, have no cell walls, are heterotrophs

Scientific Names

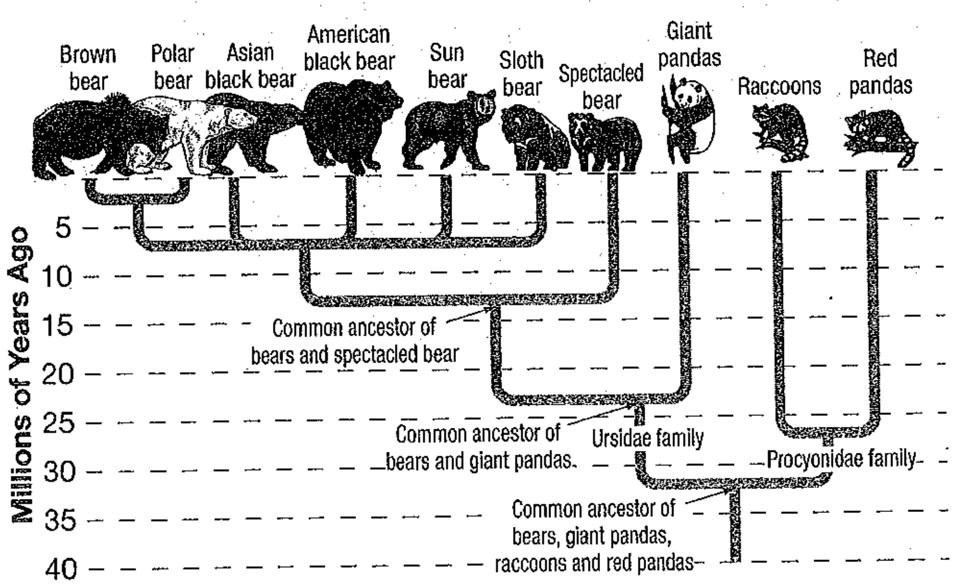
The last two levels of classification are used to give each organism a unique name. An organism's genus and species make up a two-part name. This system of two-part naming is called **binomial nomenclature**. The genus name is capitalized, and the entire two-part name is in italics.

The organism shown here is *Felix concolor*. The genus *Felix* includes all cats. The species *Felix concolor* is a particular species of cat. The advantage of using scientific names is that all scientists around the world use the same names for a species. Common names can be confusing because some organisms have several common names. You would probably call a *Felix concolor* a mountain lion. Someone else might call this animal a cougar or a puma. There are even more names for this animal in other languages, but its scientific name always remains the same.

Uses of Classification

Classification helps scientists understand and show how organisms are related. Modern bears and their relatives evolved from a common ancestor that lived 40 million years ago. Because of variations in the population of this species, two new species formed. One species evolved into a group including raccoons and red pandas. The other evolved into several other groups.

Scientists use diagrams to show how species have evolved. These diagrams are called evolutionary trees. Look at the evolutionary tree below. You can see that different species branched off from the rest of the species at different times.



Focus on Inquiry

Imagine you are a scientist who has been given a challenging task. You must classify the nonliving objects in the classroom. To do so, you will observe what makes them alike and different, and develop a classification system. List 50 items in the room. How will you classify them? You might consider their shape or the material they are made from. Or you might classify them according to function. Record the characteristics you use to classify them into two "domains." For each domain, again consider the characteristics of the objects. How can they be classified? Divide the items into "kingdoms." Continue classifying, until you reach the species level. Then give each object a scientific name.

Lesson Review

1. Which two kingdoms include both one-celled and many-celled organisms?

A. Eubacteria and Fungi

B. Archaebacteria and Protista

C. Fungi and Archaebacteria

D. Protista and Fungi

2. An organism is one-celled and has no cell wall. To which kingdom does it belong?

A. Eubacteria

B. Archaebacteria

C. Fungi

D. Protista

3. Which kingdom is made up only of autotrophs?

A. Protista

B. Animalia

C. Plantae

D. Fungi

4. In the scientific name *Limulus polyphemus*, which classification group is *polyphemus?*

A. species

B. genus

C. order

D. phylum