Classification and States of Matter

Energy and States of Matter

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Particles moving at the same speed make up all matter.	
	The particles in a solid do not move.	

Key Conecpt

- How do properties affect a substance's state of matter?

Read to Learn

What gives each state of matter its unique properties?

Have you ever wondered what makes something a solid, a liquid, or a gas? Each state has its own unique properties. The particles that make up substances give each state its characteristic properties.

Properties of States of Matter A solid is matter that has a definite shape and a definite volume. Moving a solid from one place to another does not change its shape or volume. Putting a solid in a different container also does not change its shape or volume. Solids are difficult to compress, or squeeze into a smaller volume.

A liquid is matter with a definite volume but no definite shape. Moving a liquid to a different place or container can change its shape, but does not change its volume. Liquids are difficult to compress, or squeeze into a smaller volume.

A gas is matter that has no definite volume and no definite shape. Gases can flow from one container to another. Moving a gas to a different container changes its volume and shape. Gases are easy to compress. Both gases and liquids are fluids because they can flow from one container to another.

Study Coach

Ask Questions Read the headings in this lesson. Write questions about the information given under each heading. Take turns with a partner asking and answering the questions. Use the questions as a study guide.

Academic Vocabulary

unique
(adjective) very special or unusual

Academic Vocabulary

definite
(adjective) certain, clear, or specific

Scientific Vocabulary

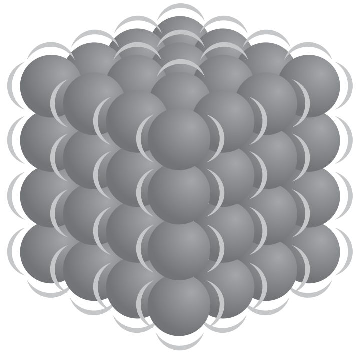
particle
(noun) a small piece of matter

Scientific Vocabulary

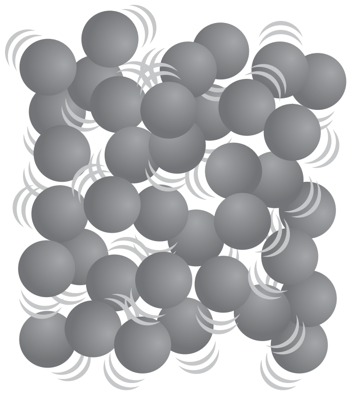
vibrate
(noun) to move back and forth with very short, quick movements

Particle Movement The particles that make up each state of matter act differently. For example, the particles of a gas act different from those in a liquid or a gas. The particles of two solids share characteristics.

The particles in a solid are close together, as shown in the figure below. The particles are touching and they are in a rigid structure. The particles still move, but they do not get away from each other. They simply vibrate back and forth in place.



The particles in liquids are close to one another. The particles move around randomly. The particles of a liquid can collide with one another, as shown in the figure below.



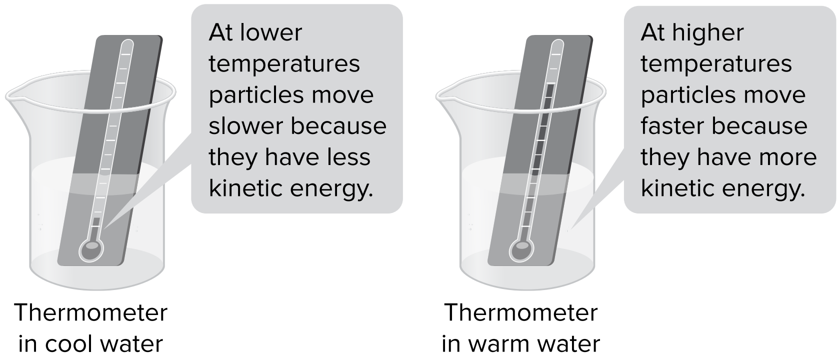
Compared to the particles in the solid and the liquid states, the particles in gases are very far apart, as shown in the figure below. They move around randomly. They move at high speeds.

What energy can a particle have?

All particles that make up matter are in constant motion. But the motion of the particles in solids, liquids, and gases is not the same. The particles of a solid vibrate in place. Liquid and gas particles move randomly. Particles will move in straight lines until they hit the container or collide with another particle. How does temperature play a role in the motion of particles in each state of matter?

Energy and Temperature Heating a substance adds energy to the particles. As energy is added, the particles move faster. The kinetic energy of the particles increases. **Kinetic energy** *is the energy an object has due to its motion*. The faster particles move, the more kinetic energy they have.

Heating a substance also increases its temperature. The temperature of a substance depends on how much kinetic energy the particles have. *The measure of the average kinetic energy of the particles in a material is* **temperature.** The higher the kinetic energy of the particles, the higher the temperature, as shown in the figure below.



Thermometers Thermometers measure the speed, or kinetic energy, of the particles in a material. A temperature scale uses a number to describe average particle speed. Temperature scales include Celsius, Fahrenheit, and Kelvin. You might be familiar with temperatures using the Fahrenheit scale in weather forecasts. The Celsius scale is the temperature scale used by scientists around the world.

The Kelvin scale was developed by scientists to predict the temperature at which particles would stop moving. At absolute zero, or 0 K, particles of matter would have no kinetic energy. They would not move. Scientists have not yet cooled any material to 0 K.

Scientific Vocabulary

absolute zero
(noun) −273°C, the temperature at which particles would stop all motion

Attraction and Energy Particles of matter that are close together pull on one another. This attractive force pulls particles toward one another. Solids have the greatest attractive forces between their particles. The particles are very close together. Gases have the smallest attractive force between their particles. The particles of gases are far apart.

In addition to kinetic energy, particles have potential energy. **Potential energy** *is stored energy due to the interactions between particles or objects*. The potential energy of a particle is due to its position compared to other particles. Potential energy typically increases when objects or particles get farther apart. Gases have more potential energy than liquids or solids.

Imagine a glass of carbonated water. The particles in the bubbles in the carbonated water have more potential energy than the particles in the liquid water. That is because they are further apart from one another. The state of matter determines the amount of potential energy contained in a substance.

Thermal Energy Which has more energy—a glass of water at 20°C or a bathtub full of water at 20°C? Often you need to know the total amount of energy a substance contains. *The result of the motion of all the particles, and the distance and attractions between those particles in the system, is known as* **thermal energy.**

Thermal energy of a substance depends on temperature. However, temperature is not a direct measure of thermal energy. That is because thermal energy also depends on the state of a substance. Thermal energy includes both the potential energy and the kinetic energy of the substance.

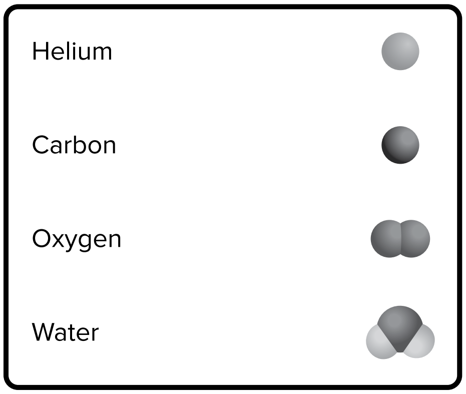
Imagine a pot of boiling water with pasta in it. The water in the pot has more thermal energy than it did before it was heated, because the water in the pot is now at a higher temperature. The water in the pot also has more thermal energy than the same mass of pasta because the water is in the liquid state.

Additionally, the larger the sample of matter you have, the more thermal energy it contains. So, a bathtub full of water at 20°C has more thermal energy than a glass of water at 20°C, even though they have the same temperature.

Substances also contain different amounts of thermal energy because they are made up of different types of particles. That is why different kinds of matter can be in different states at the same temperature.

What makes up a substance?

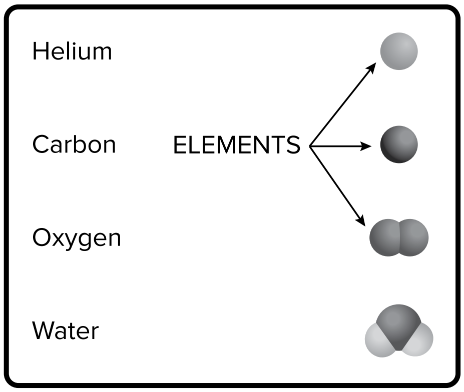
Thermal energy depends on the type of matter in a substance. Not all particles are the same. The figure below shows one way to represent different kinds of particles.



Matter and Atoms All matter is made up of particles called atoms. *An* **atom** *is a small particle that is the building block of matter*. There are many kinds of atoms. Hydrogen atoms and oxygens atoms are two examples. They combine to form water. Different types of matter are formed when particles combine.

Substances Atoms make up different types of substances. *A* **substance** *is matter with a composition that is always the same*. Substances are different from one another because they are made up of different types of atoms. Substances have their own properties, such as their melting points and boiling points.

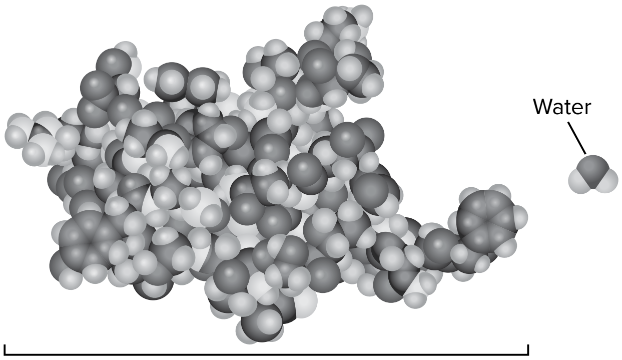
Elements One type of substance is an element. *An* **element** *is a substance made of only one type of atom*. Elements are often shown by using circles of one color. Look at the figure below. The helium, carbon, and oxygen shown in the figure are elements. Scientists have known about some elements for thousands of years. Some elements are still being discovered.



Scientific Vocabulary

property
(noun) a quality or feature of something

Compounds *Another type of substance occurs when atoms of two or more different elements are bonded together to form a* **compound.** Water is an example of a compound. Compounds have different properties than the elements that make up the compound. Atoms can combine in many different ways to make millions of compounds. Compounds can vary in size. Some compounds are made up of just several atoms, like the water in the figure below. Other compounds are made up of hundreds of atoms, like the insulin shown in the figure.



Element Ratios Scientists know that every water molecule has one oxygen atom and two hydrogen atoms. So, the element ratio for water is 2 hydrogen : 1 oxygen. A water molecule is modeled with one oxygen atom attached to two carbon atoms, like the water particle in the figure above. Just like water, all compounds have a fixed ratio of atoms. No matter what size the sample is or what state it is in, the element ratio for a specific compound is always the same.

Scientific Vocabulary

ratio
(noun) the relationship between the sizes of two amounts or numbers

Same Elements, Different Ratios Sometimes the same elements combine to make different compounds. For example, nitrogen and oxygen can make six different compounds. The different compounds contain the same elements, but in different ratios.

Academic Vocabulary

combine
(verb) to put two or more things together

All elements and compounds are made up of different types of atoms. This gives each substance unique properties. This explains why some substances are solids at room temperature, while others are gases or liquids.

How else can the elements in a substance be represented?

Sometimes people use LOL to mean "laugh out loud." Scientists use abbreviations to represent elements. This system is used by all scientists around the world, so everyone knows what the symbols represent.

Element Symbols Element symbols are found on the periodic table of elements, shown in the figure below. The symbols for elements are one or two letters. They are often taken from the name of the element.

Metal
Metalloid
Nonmetal

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

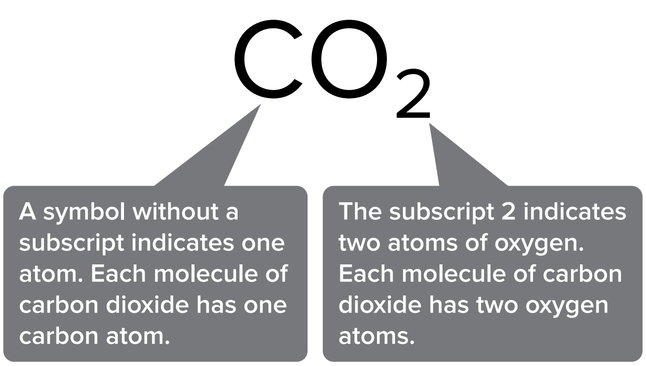
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Chemical Formulas Just as elements have chemical symbols, compounds have chemical formulas. *A* **chemical formula** *is a group of chemical symbols and numbers that represent the elements and the number of atoms of each element that make up a compound*. Just as a recipe lists ingredients, a chemical formula lists the elements in a compound. For example, the chemical formula for carbon dioxide is CO_2. The formula uses chemical symbols to identify the elements in the compound, as shown below. CO_2 is made up of carbon (C) and oxygen (O). The small number after a chemical symbol is a subscript. A subscript shows the number of atoms of that element in the compound. A symbol without a subscript means one atom. Carbon dioxide (CO_2) contains two atoms of oxygen bonded to one atom of carbon.

Scientific Vocabulary
formula
(noun) a group of letters or numbers that represent a science or math rule

Chemical Formula

A carbon dioxide molecule is made up of carbon (C) and oxygen (O) atoms.



After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Classification and States of Matter

Changes in Temperature

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Thermal energy moves from cooler objects to warmer objects.	
	A change in temperature can change the volume of a gas.	

Key Conecpt

- What happens to substances when their temperature changes?

Read to Learn

What happens to the volume of a gas when thermal energy changes?

Recall that adding energy to a substance increases the kinetic energy of the particles. Adding energy can also affect the volume of a substance.

History Connection Jacques Charles (1746–1823) was a French scientist who described the relationship between temperature and volume of a gas. Charles was interested in balloons. Because of this, Charles had practical experience with the behavior of gases.

Volume-Temperature Law Charles's law states that the volume of a gas increases with increasing temperature, if the pressure is constant. You have probably seen Charles's law in action if you have ever taken a mylar balloon outside on a cold winter day.

When the balloon is in cold air, the temperature of the gas inside the balloon decreases. Recall that a decrease in temperature is a decrease in the average kinetic energy of particles. As a result, the gas particles slow down. They begin to get closer together. Fewer particles hit the inside of the balloon. The balloon seems to be only partway filled. **Thermal contraction** *is a decrease in a volume as its temperature decreases.*

Study Coach

Make an outline as you read to summarize the information in the lesson. Use the main headings in the lesson as the main headings in your outline. Use your outline to review the lesson.

If the balloon is returned to a warm place, the kinetic energy of the particles increases. There are more collisions between the particles and the inside of the balloon. The collisions push outward on the balloon. The volume of the gas increases. *An increase in a volume as the temperature increases is called* **thermal expansion.** The number of particles in the balloon does not change. The object the particles are in changes size as the thermal energy changes. This happens because the space between the particles changes. The particles themselves do not change size. The volume the particles take up changes.

How does thermal energy transfer between objects?

Thermal energy can be added to substances. Thermal energy can be removed from substances. How do substances gain and lose thermal energy?

Heating Think about holding a warm cup of cocoa on a cold day. Thermal energy moves from the warm cup to your hands. *The transfer of thermal energy from a region of higher temperature to a region of lower temperature is called* **heat.** Heat can also refer to the amount of energy transferred during this process. Recall that temperature and thermal energy are not the same thing. Neither are heat and thermal energy. However, something is heated when thermal energy transfers from one object to another. How can you heat a material? You can heat a material by placing it in contact with a material that has a higher temperature. The material with the higher temperature can be a solid, liquid, or gas.

Scientific Vocabulary
region
(noun) a specific area

Systems The materials involved in a transfer of energy are part of a system. When you hold a cup of hot cocoa, your hands, the cup, the cocoa, and the air are parts of the system. This is an example of an open system. In an open system, energy is released into the environment. Scientists who study energy transfer use the idea of a closed system. In a closed system no matter or energy moves between the system and the environment. Closed systems do not actually happen in the real world, but they can be used to study energy transfer.

How can air hold up water?

Think about what would happen if you placed an index card over the opening of a cup that is half-full of water and turn the cup upside down. Could the air under the index card hold the water inside the cup?

Particle Collisions Particles in gases are always moving. As a result of this movement, gas particles are always bumping into other particles and into their container. When particles collide with their container, pressure results. **Pressure** *is the amount of force per unit of area applied to an object's surface.* This also explains why when you place a finger over a straw full of liquid and pull the straw out of the glass, the liquid stays in the straw rather than falling back into the glass. Your finger on the top of the straw reduces the air pressure on top of the liquid. When the straw is pulled out of the glass, there is more air pressure on the bottom of the liquid in the straw than on the top of the liquid. Once the finger is removed, there is equal air pressure at the top and bottom of the straw. The liquid falls out of the straw. Think back to the glass of water with an index card to top. When the glass is turned over the air pressure on the outside of the index card is larger than the pressure inside the glass. It's not magic that keeps in water from spilling out, but science!

Scientific Vocabulary

unit
(noun) an amount of something used as a standard for measuring, like meters

Units of Pressure The pressure of gases is measured by the number of collisions of particles with the container. The higher the pressure, the more times particles collide with the container. The lower the pressure, the fewer the collisions.

One way to describe pressure is by relating the pressure of the substance to the pressure that exists due to the atmosphere. Sometimes scientists use the unit atmospheres (atm). The pressure at sea level is 1 atm. A pressure of 4 atm is four times the pressure at sea level.

How does pressure change when temperature changes?

Temperature can affect the pressure of a substance. When conditions cause the pressure of a substance to change, containers must be strong enough to withstand the pressure. If the container is not strong enough, it could pop like a burst beach ball. A flexible container can appear to be crushed if the pressure inside decreases.

Academic Vocabulary

flexible
(verb) to able to be easily changed

Temperature and Pressure Changing the temperature of a gas affects its behavior. A decrease in temperature decreases the pressure of a gas. This happens because the speed of the particles decreases, and the particles collide with the container less often.

Academic Vocabulary

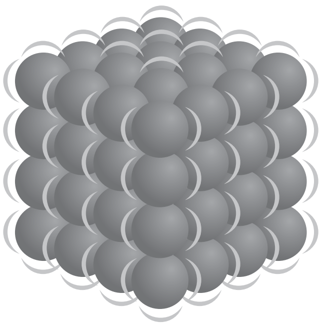
affect
(verb) to cause a change in something

When the thermal energy of a gas increases, the motion of the particles speeds up. As the particles move faster, they collide with their container more often. The pressure inside the container increases.

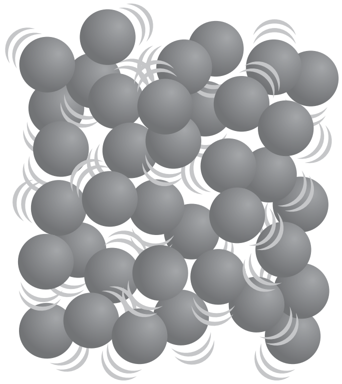
What happens to states of matter as temperature changes?

When seasons change, you might see ice and snow melt away. Water is one of the few substances that you frequently observe in three states of matter (solid, liquid, and gas) at Earth's temperatures.

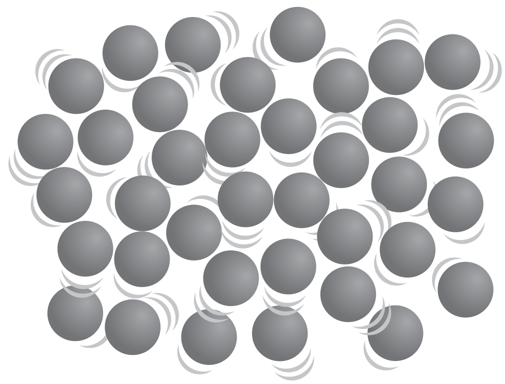
Melting Matter can change state when it gains or loses enough thermal energy. Recall that particles speed up when their temperature increases. When the particles speed up, they move further away from each other. As they gain more and more thermal energy, they break away from the other particles, as shown below. This is the melting point of the substance.



As energy is added, solid particles vibrate faster and temperature increases.



As particles move farther apart, the solids becomes a liquid. Temperature remains constant at the melting point.



Once all particles are in a liquid state, any additional energy increases the speed on the particles. Temperature increases.

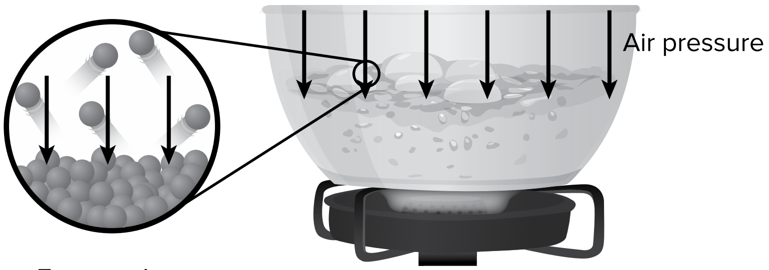
What happens when a solid reaches its melting point? The temperature stops rising when it reaches the melting point of the matter, as shown in the figure above. Additional thermal energy causes the particles to overcome their attractive forces. The particles move farther apart and potential energy increases. Once a solid completely melts, the addition of thermal energy will cause the kinetic energy of the particles to increase again, and the temperature will start to increase.

Vaporization When you heat water, do you ever notice how bubbles begin to form at the bottom and rise to the surface? The bubbles contain water vapor, a gas. As the water heats, it changes from the liquid state to the gaseous state. *The change in state of a liquid into a gas is* **vaporization.**

Vaporization that occurs within a liquid is called boiling. During boiling, vaporization takes place throughout the liquid. The temperature at which boiling occurs in a liquid is called its boiling point. The kinetic energy of particles increases until the liquid reaches its boiling point. At the boiling point, the potential energy of particles begins increasing. The particles move farther apart until attractive forces no longer hold them together. At this point, the liquid changes to a gas. The temperature stays at the boiling point until all of the particles have changed from liquid to gas.

Evaporation You may have seen a puddle disappear, or evaporate, slowly on a sunny day. Unlike boiling, evaporation is vaporization that occurs only at the surface of a liquid. A small amount of liquid in an open container will seem to disappear after several days due to evaporation.

Pressure and Evaporation Pressure also plays a role in evaporation. When a substance evaporates, the particles must overcome the force of air pressure. Air pressure is always pressing down on the liquid's surface. For a particle to evaporate it must overcome the force of air pressure.



Evaporation

Freezing Freezing is a process that is the opposite of melting—liquid changes to solid. The temperature at which matter changes from the liquid state to the solid state is its freezing point. The freezing point of a substance is the same as its melting point. Freezing requires the removal of thermal energy. As energy is removed, the particles slow down. They start to form an organized structure. As a liquid becomes a solid, the temperature remains the same until all of the liquid becomes a solid. Then the temperature will start to decrease again.

Condensation When a gas loses enough thermal energy, the gas changes to a liquid, or condenses. The change of state from a gas to a liquid is called condensation.

Earth Science Connection Water continually changes phase on Earth's surface. The Sun transfers energy to Earth. That energy powers the processes that cycle water through Earth's systems.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Classification and States of Matter

Changes in Pressure

Before You Read

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Before	Statement	After
	If the pressure on a gas increases, the volume of the gas also increases.	
	Changes in temperature and pressure affect the state of matter of a substance.	

Key Conecpt

- What happens to substances when the pressure changes?

Read to Learn

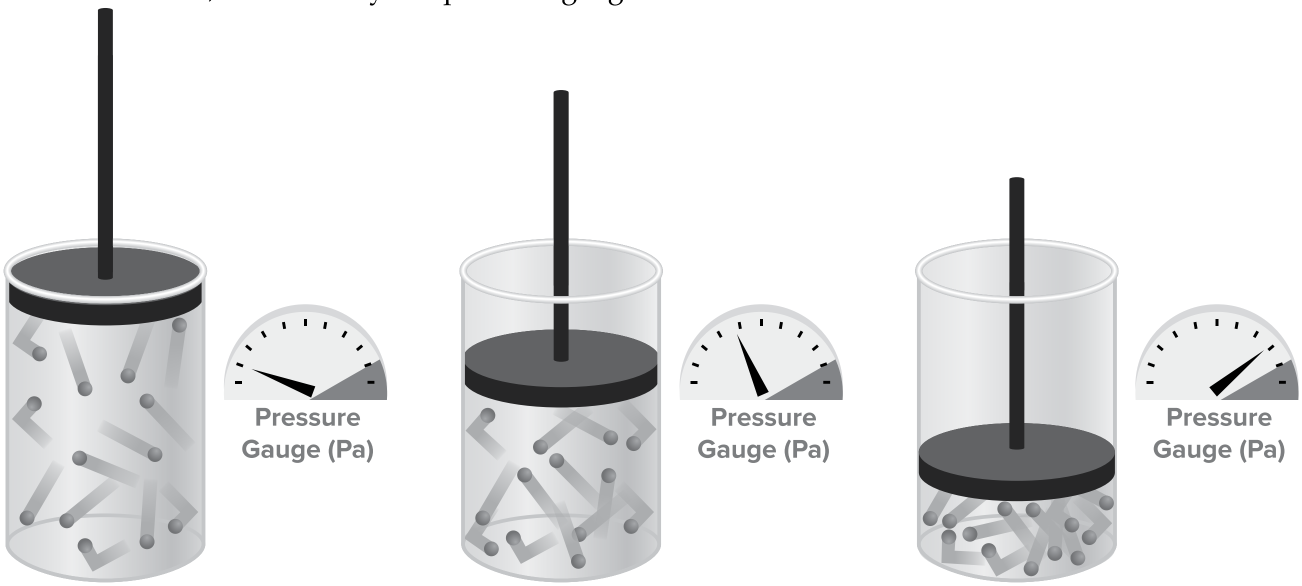
How can you change the pressure of a gas?

Scuba divers wear tanks of air to breathe. How can a small tank hold enough air for a diver?

Pressure and Volume Examine the figure below. When the plunger is pushed down, it decreases the volume of the container. The particles have less space. They bump into each other and the container more often. The pressure of the gas inside increases, as shown by the pressure gauge.

Mark the Text

Main Idea and Details Highlight the main idea of each paragraph. Highlight two details that support each main idea with a different color. Use your highlighted copy to review what you studied in this lesson.



When the volume of the container is greater, the particles have more room to move. That means the particles do not have as many collisions. The pressure of the gas decreases.

When a diver starts a dive, the pressure in the air tank is high. As the diver uses air, the pressure in the tank decreases. Scuba divers use a pressure gauge to track how much air they have left.

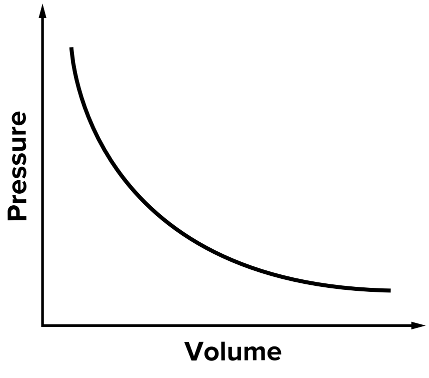
Scientific Vocabulary
gauge
(noun) something that is used for measuring something else

Scuba divers experience pressure in other ways. As they move deeper in the water, the water pressure surrounding the diver increases. Divers might feel the pressure increase in their ears. You too may have felt an increase in pressure in your ears when diving into a deep swimming pool.

History Connection You read that the pressure and volume of a gas are related. Robert Boyle (1627–1691), a British scientist, noticed this relationship. He was the first to describe this property of gases. Boyle measured the pressure of a gas in two different volumes. Using this data, he made a graph. No matter what kind of gas he tested, or what volume was used, he always saw the same result. Because the relationship between pressure and volume of a gas is a repeatable pattern, it is now defined as a scientific law. Boyle's law states that pressure of a gas increases if the volume decreases and pressure of a gas decreases if the volume increases, when temperature is constant.

Scientific Vocabulary
constant
(adjective) remaining at the same level

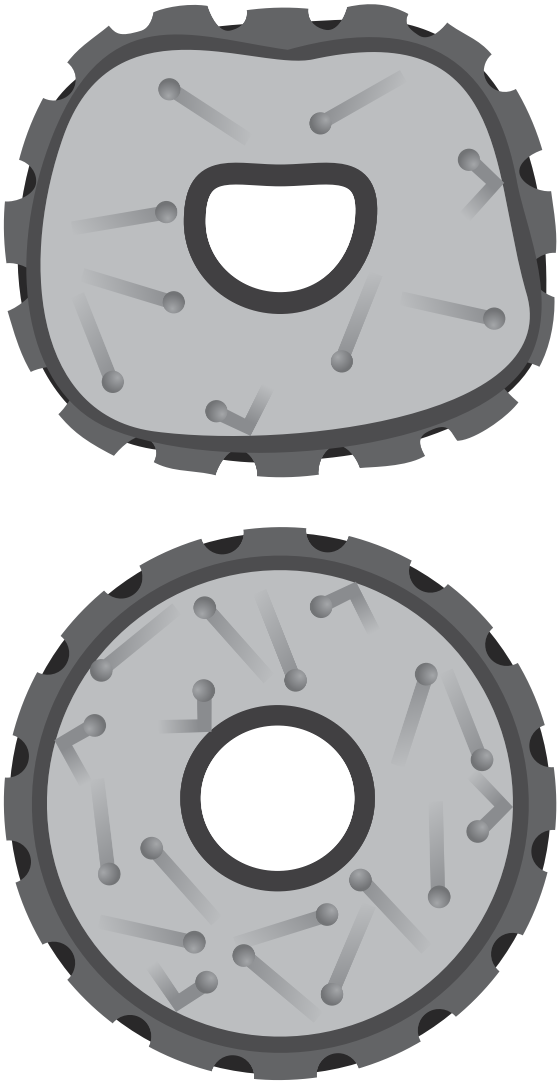
The graph in the figure below shows Boyle's law. Pressure is on the y-axis of the graph. Volume is shown on the graph's x-axis. The graph shows that pressure of a gas decreases as the volume increases.



Adding Particles A scuba diver's oxygen tank must be refilled before each new dive. Compressed air is added to the diver's air tank. Imagine the flow of millions of gas particles going into the tank. How do you think the pressure in the oxygen tank changes when more particles are added?

Pressure and Number of Particles In a system like a tire, particles can be added using an air pump. This changes the volume of the tire. Look at the figure below. The top image shows a tire that is partly deflated. Compare that to the tire shown at the bottom. The tire on the bottom has a greater volume. You can tell by the shape of the tire. The inside of the tire is being pushed on by many particles. There are more collisions in the tire on the bottom because there are more particles. The pressure in the bottom tire is greater.

A scuba tank is made of metal and will not change shape like the tire does. It does not deflate when the number of particles decreases. Scuba divers must use a pressure gauge to find out how much air is in their tank. As the number of particles in the tank decreases, the pressure decreases.



Scientific Vocabulary

air pump
(noun) a piece of equipment used to put air in a tire or ball

Academic Vocabulary

deflate
(verb) to release gas from something and make it smaller

Scientific Vocabulary

variable
(noun) a thing, factor, or condition that can be controlled or changed

Types of Relationships When one variable changes and the other variable changes in the same way, this is called a proportional relationship. For example, when the number of particles of a gas in a container increases, the pressure increases. When one variable changes and the other variable changes in the opposite way, it is an inversely proportional relationship. An example is when pressure on a gas decreases and its volume increases. Knowing the type of relationship between two variables can help you predict results in natural and designed systems.

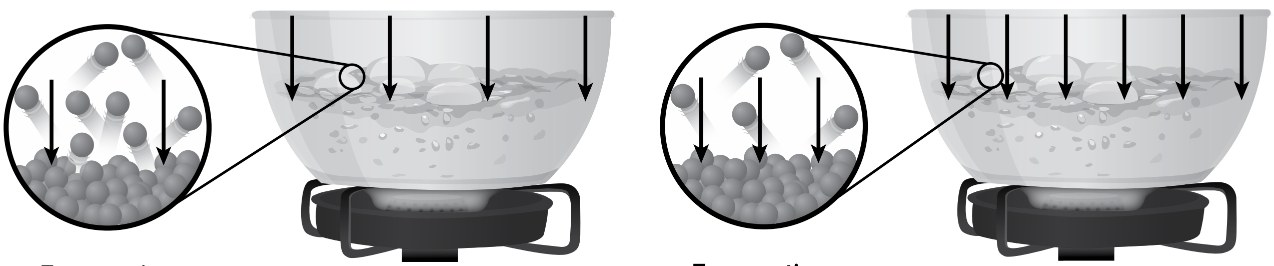
How does changing pressure affect a substance?

Academic Vocabulary

remove
(verb) to take something away from a place

Scuba divers use filtered air in their tanks. The water vapor in the air has been removed. This keeps the inside of the tank from rusting. Imagine if unfiltered air was placed into a scuba tank. How would the water particles be affected by a change in pressure?

Pressure and State of Matter Examine the images below. In the figure on the left, air pressure on water is less then the figure on the right. The air particles collide less frequently with the surface of the water. The liquid particles can more easily overcome the attractions between one another. This means that the water can start changing to a gas at a lower temperature. Recall that standard pressure is 1 atm. The figure on the left models what happens when pressure is less than 1 atm. Compare that to the figure on the right, where pressure is 1 atm.



The opposite can also happen. If the air pressure on a liquid increases, more collisions will happen between the air and the surface of the liquid. The liquid will require more thermal energy than normal to change to a gas. Changing the pressure can affect the state of matter of a substance.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Classification and States of Matter

Molecular Structure

Key Conecpt

- How do atomic structures determine the properties of a substance?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	All compounds have high melting and boiling points.	
	Metal and nonmetals have the same properties.	

Study Coach

Make an Outline Outline the information in this lesson. Use the headings as the main divisions of your outline. Include important details under each heading. Use your outline to review the lesson.

Scientific Vocabulary

chemical bond
(noun) a force that holds two or more atoms together

Academic Vocabulary

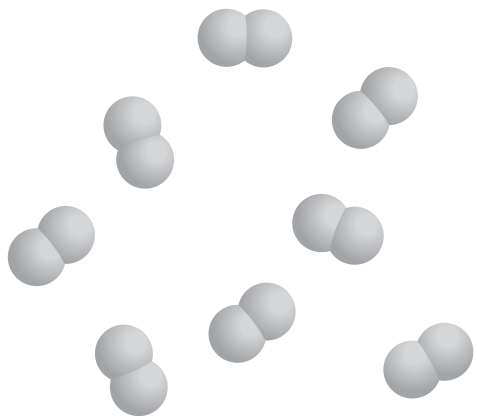
individual
(adjective) existing separately from others

Read to Learn

How do elements differ?

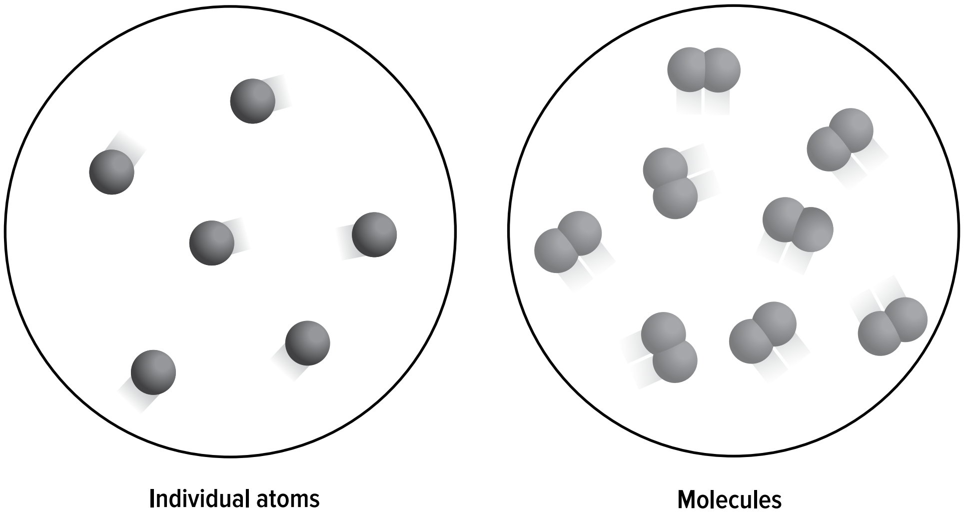
An element is a substance made of only one type of atom. Each element's name is found on the periodic table of elements.

Types of Elemental Substances Elements are made of individual atoms, but those atoms can be arranged into different kinds of structures. Some substances, such as helium and neon, are made up of individual atoms that are not attracted to one another. *Some substances are* **molecules,** *a group of atoms that are held together by chemical bonds and act as a unit.* Examples include hydrogen, oxygen, and chlorine. The figure below shows hydrogen molecules. A third type of substance is individual atoms of the same type connected to form extended structures.



Properties of Metal and Nonmetals The properties and behaviors of a substance can be observed. These observed properties are due to the structure of the atoms and molecules in the substance, which cannot be observed because atoms are too small to be seen with light microscopes. Elements can be classified into groups based on their structures and their properties.

Nonmetal Gases Many nonmetals are gases at room temperature. These gases are usually either individual atoms, shown below on the left, or they are diatomic molecules, shown below on the right. When a molecule is diatomic, it is made of two atoms that are the same.



Atoms or molecules of nonmetal gases have low attraction to each other. This means they have high potential energy and high kinetic energy. In turn, this means that these gases boil at very low temperatures. It is easy for these gas particles to escape attractions to their neighboring particles. Due to the large amount of space between particles, these gases do not conduct electricity or thermal energy. The gas particles cannot easily transfer charge or energy to other gas particles.

Scientific Vocabulary
conduct
(verb) to serve as a medium through which something can flow

Nonmetal Solids The nonmetal solids are individual atoms of the same type that are connected. They form an extended structure. The attraction between the atoms is low. This makes the substance brittle and dull. Nonmetal solids, like nonmetal gases, are poor conductors of electricity or thermal energy, because they have a low attraction between atoms. These substances have low potential and kinetic energy as compared to gases. Most nonmetal solids have low melting points compared with solid metals.

Scientific Vocabulary
conductor
(noun) a material that allows heat, light, sound, or electric charge to flow from one thing to another

Metals Almost all metals are solid at room temperature. This is because metal atoms are attracted to one another and form extended structures. Many metals are shiny. Most are malleable. That means the closeness of the atoms allows them to slide past each other instead of breaking when the substance is bent or hammered. For example, you can bend a metal paperclip without breaking it.

The closeness of the atoms also means that electric charges and thermal energy can easily pass from one atom to the next. Metals have low potential and kinetic energy. That means a greater amount of thermal energy must be added to change the solid to a liquid. This is why metals have very high melting and boiling points.

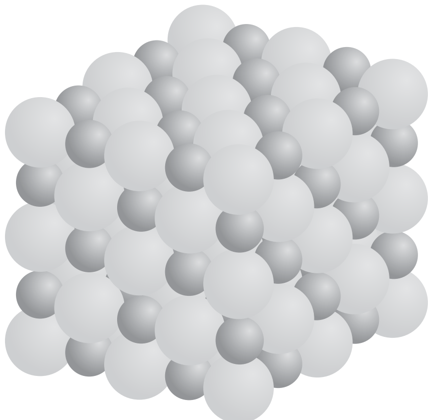
How do compounds differ?

You have read that the properties of elements differ. What happens when elements combine? Compounds make up most of the matter around you, including living and nonliving things. How do the properties of compounds differ from the properties of elements and from one another?

Scientific Vocabulary

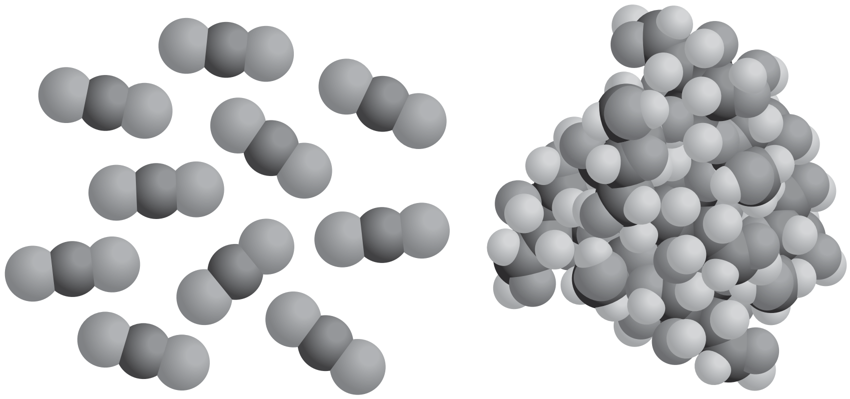
compound
(noun) matter that is made up of two or more different kinds of atoms joined together by chemical bonds

Types of Compounds Atoms can form complex molecules. Some molecules contain a few atoms and some have thousands of atoms. Individual atoms of different types can repeat to form extended structures. The sodium chloride shown below is an example of a compound that can form an extended structure. Sodium chloride is also known as table salt. This type of structure usually forms between atoms of a metal and a nonmetal of opposite charges. This is true for table salt. Sodium is a metal. Chlorine is a nonmetal.



Molecules Recall that some elements are molecules. They are made up of two of the same type of atom. Some compounds are also molecules. Compound molecules are made up of different types of atoms. Some molecules are not attracted to one another. Carbon dioxide, shown below on the left, is an example of this type of molecule.

Other compound molecules are attracted to each other. These molecules come together to form extended structures. The sugar shown below on the right is one example of this type of molecule. These different structures give compounds different properties that can be observed.



Properties of Ionic and Covalent Compounds The properties of compounds are related to their atomic structures. Just like elements, compounds can be classified into groups based on their structures and their properties.

Ionic Compounds Ionic compounds are formed from atoms that have opposite charges. The atoms have a strong force of attraction to each other, due to their charges. Because of this, ionic compounds form extended structures as solids. These structures can form crystals. The strong attractive forces give ionic compounds their properties. Ionic compounds have high melting and boiling points. Ionic compounds are brittle because when they are hit with a force, the atoms separate from each other. Many ionic compounds will dissolve when placed in water. Water with an ionic compound dissolved in it is a good conductor of electricity.

Extended Structures Extended structures made of the same atoms are elements. Extended structures made of two or more different atoms are compounds.

Scientific Vocabulary

crystal
(noun) a solid, with an orderly, repeating pattern

Scientific Vocabulary

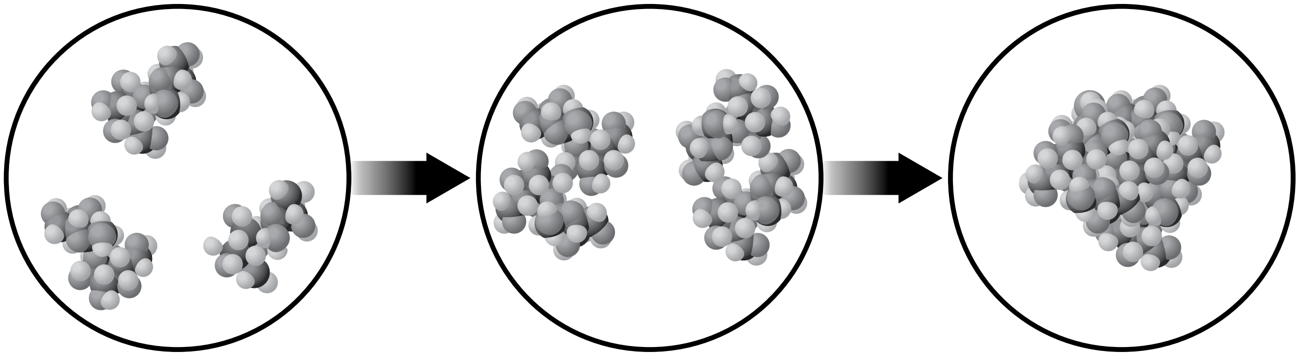
brittle
(adjective) easily broken or cracked

Scientific Vocabulary

dissolve
(verb) to blend two or more substances together to make a solution

Properties of Covalent Compounds Covalent compounds form molecules. Recall that a molecule is a group of atoms that are held together by bonds and act as a unit. Covalent compounds usually have low melting and boiling points. They are usually gases or liquids at room temperature. They are poor conductors of electricity and thermal energy.

Polar Covalent Compounds Atoms of the elements carbon, hydrogen, and oxygen have strong attraction to one another. They form many different molecules. One molecule they form is sucrose, also known as table sugar. The chemical formula for sugar is $C_{12}H_{22}O_{11}$. Every sugar molecule has these atoms in the same pattern, as shown below. A molecule of sugar is attracted to other molecules of sugar. The groups of molecules make a crystal structure. These molecules attract each other strongly. They have high melting and boiling points. These molecules dissolve in water.



Nonpolar Covalent Compounds Another type of compound is a nonpolar covalent compound. Nonpolar covalent compounds, such as carbon dioxide, are not attracted to like molecules. They have very low melting and boiling points. Most are a gas at room temperature, but some can be solids or liquids. These molecular substances are dull and melt or evaporate at low temperatures. They do not dissolve in water. Nonpolar covalent compounds also do not conduct electricity.

Academic Vocabulary
simplify
(verb) to make easier to understand

To Dissolve or Not to Dissolve A nonpolar covalent compound will not easily dissolve in a polar compound. It will dissolve in other nonpolar compounds. This idea is simplified to the phrase “like dissolves like.” This means that polar covalent compounds can dissolve other polar compounds. Similarly, nonpolar compounds can dissolve in other nonpolar compounds. Sugar and water are both polar compounds. Water easily dissolves sugar. Oils are nonpolar compounds. Oil does not dissolve in water. The atomic structure of these substances explains why sugar will dissolve in water but oil will not.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Matter: Properties and Changes

Properties of Matter

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	The particles in a solid object do not move.	
	Your weight depends on your location.	

Read to Learn

How can a substance's properties be measured?

Matter has many different properties. For example, a helmet you wear while biking is hard and shiny. The water in a stream might be cool and clear. Learning about physical properties and chemical properties will help you to identify many types of matter and their uses.

Physical properties *are any characteristics of matter that you can observe without changing the identity of the substances that make it up.* Examples of physical properties are state of matter, shape, mass, volume, density, solubility, and temperature.

Mass Some physical properties, such as mass and weight, depend on the size of the sample. **Mass** *is the amount of matter in an object.*

Mass v. Weight Weight is the gravitational pull on an object. Weight depends on the location of an object. Mass does not. The mass of an object is the same on Earth as it is on the Moon. An object's weight, however, is greater on Earth than it is on the Moon because Earth's gravity is stronger than the Moon's gravity.

Key Concept

- Why do athletes bite their medals?

Mark the Text

Use an Outline As you read, make an outline to summarize the information in the lesson. Use the main headings in the lesson as the main headings in the outline. Complete the outline with the information under each heading.

Academic Vocabulary

observe
(verb) to watch and notice something

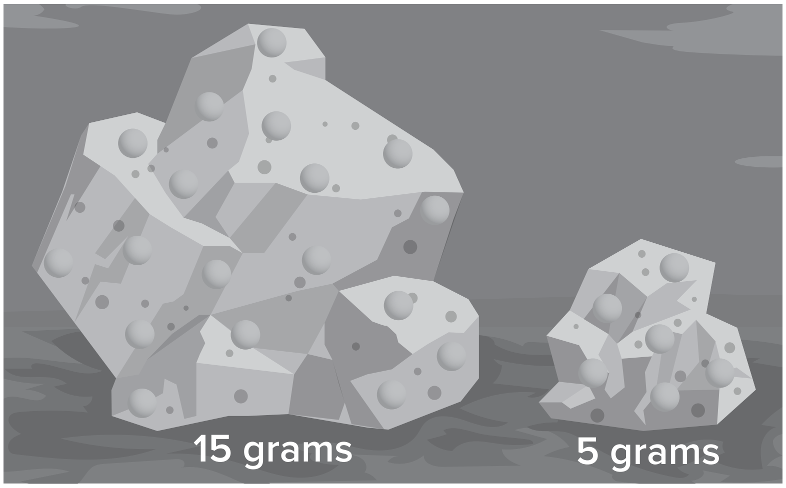
Scientific Vocabulary

property
(noun) a quality or feature of something

Scientific Vocabulary

gravitational pull
(noun) the attraction caused by gravity

Modeling Mass Mass can be modeled by representing the particles in a substance. The more particles in a substance, the greater the mass of the substance, as shown in the figure below.



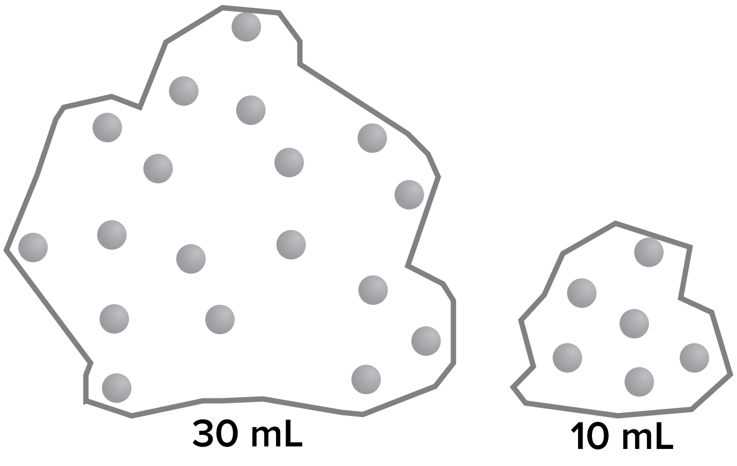
Volume Like mass and weight, the volume of an object is a physical property. **Volume** *is the amount of space a substance takes up*. It depends on the size of the sample. You can measure the volume of a liquid by pouring it into a measuring cup or a graduated cylinder. You can measure the volume of a solid in two ways. If a solid has a regular geometric shape, multiply its length, width and height together. You can find the volume of a solid with an irregular shape by using the displacement method. A graduated cylinder is filled part way with water. The volume of water is noted. The solid is then placed in the cylinder. The volume of the solid is the difference between the water level before and after placing the solid in the water. The common unit for liquid water is the milliliter (mL).

Scientific Vocabulary
graduated cylinder
(noun) a tube that has lines on the side and is used to measure the volume of liquids

Scientific Vocabulary
irregular
(adjective) not even or smooth

Scientific Vocabulary
displacement
(noun) the amount of water moved by an object when it is placed in water

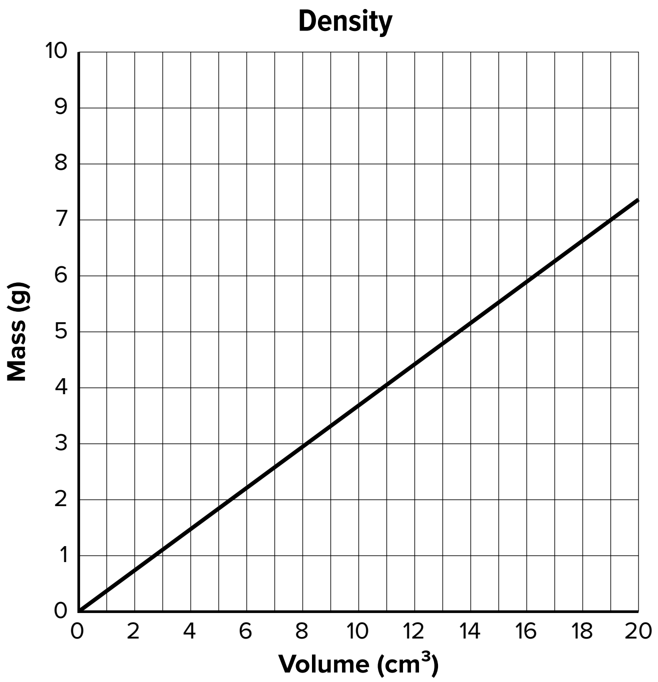
Modeling Volume An observable volume can be represented by the shape of the substance. The larger the shape, the more volume the substance has, as shown in the figure below.



How can a substance's mass and volume be used to identify a substance?

Mass and volume are related. This relationship can be expressed by another physical property.

Density This physical property of matter is called density. **Density** *is the mass of a substance divided by the volume of the substance*. It does not depend on the size or amount of the sample. Look at the slope of the graph in the figure below. As the mass increases, the volume increases by an equivalent amount. The density of a substance never changes.



Density and States of Matter Solids are the densest state of matter because the particles are very close together. In liquids, particles are farther apart. Liquids are less dense than solids, but are much denser than gases. Gases have very low densities because the particles are far apart and move freely.

Calculating Density Understanding the relationship between mass and volume will help you calculate density.

Density Equation

$$\text{Density}\left(\frac{\text{g}}{\text{mL}}\right) = \frac{\text{mass (g)}}{\text{volume (mL)}}$$

$$D = \frac{m}{V}$$

A sample of a substance, regardless of its size, will always have the same density.

Academic Vocabulary
calculate
(verb) to use numbers to find out something

How can a substance be identified based on how it changes?

Matter can change physically and chemically. Some changes in matter change the identity of the substance.

Chemical Properties Substances undergo chemical reactions when they change into other substances. *A* **chemical property** *is a characteristic of matter that can be observed as it changes to a different type of matter.*

Flammability Some substances, such as wood and paper, are flammable. **Flammability** *is the ability of a type of matter to burn easily*. Flammability is a chemical property.

Oxidation You have probably seen objects, such as old cars, that have begun to rust. Rust is a substance that forms when iron reacts with oxygen and water in the air. The ability to rust is a chemical property of iron or metals that contain iron. Rusting is a type of oxidation. **Oxidation** *is the reaction of a substance with an oxidizing agent, changing it into a new substance.*

Reaction to Acid Many substances react with acid. **Reactivity** *occurs when a substance reacts with another substance, changing it into a new substance.*

How can a substance's properties be used to identify a substance?

Academic Vocabulary
identify
(verb) to recognize and name a thing or person

Look at the table of substances and their physical properties. You can identify the unknown substance by comparing its physical properties to the physical properties of the known substances.

Substance	Color	Mass g	Melting Point °C	Density g/cm^3
Table salt	white	14.5	801	2.17
Sugar	white	11.5	148	1.53
Baking soda	white	16.0	50	2.16
Unknown	white	16.0	801	2.17

All the substances are white. So, you cannot identify the unknown substance by its color. You cannot identify it by its mass. Mass is a property that changes with the amount of the sample. However, melting point and density do not depend on the size or amount of the sample. The unknown substance has the same melting point and density as table salt, so it must be table salt.

Identifying a Substance Using Properties

Both physical properties and chemical properties are used for identifying and sorting (classifying) materials. You probably often sort materials by their properties without realizing it. Objects are usually sorted based on the physical and chemical properties they have in common.

Conductivity, melting and boiling points, and solubility are some physical properties that can be useful for sorting matter and identifying substances.

Conductivity Some materials conduct electricity. Conductivity is the ability to conduct electricity or thermal energy.

Melting and Boiling Point Each material has a melting point and a boiling point. Melting point and boiling point do not depend on the size or the amount of the material. The melting point is the temperature at which a solid changes to a liquid. The boiling point is the temperature at which a liquid changes to a gas. Melting point and boiling point are physical properties.

Solubility You can observe another physical property of matter when a solid, such as sugar, dissolves in water. *To dissolve* means "to mix evenly." Solubility (sahl yuh BIH luh tee) is the ability of one material to dissolve in another material.

Word Origin
solubility
From Latin *solubilis*, means "capable of being dissolved"

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Matter: Properties and Changes

Property Changes in Chemical Reactions

Key Concept

- How do atoms rearrange to form new substances in a chemical reaction?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	If a substance bubbles, you know a chemical reaction is occurring.	
	During a chemical reaction, some atoms are destroyed and some new atoms are made.	

Mark the Text

Underline Main Ideas As you read, underline the main ideas under each heading. After you finish reading, review the main ideas you have underlined.

Read to Learn

What can happen when substances interact?

Some changes in matter change the identity of the substance. *A* **chemical change** *is a change in matter in which the substances that make up that matter change into substances with different chemical and physical properties.*

Signs of a Chemical Change How do you know when a chemical change occurs? What signs show you that new types of matter have formed? Signs of chemical changes include the formation of bubbles or a change in odor, color, or energy. For example, the odor of fruit changes when it rots. Leaves change color in autumn. Energy changes when fireworks explode. These signs do not always mean a chemical change has occurred. When you heat water on a stove, bubbles form as the water boils. In this case, bubbles show that the water is changing state, which is a physical change. Bubbles that form when you add an antacid tablet to water is evidence that a chemical change might have occurred. However, the only proof of chemical change is the formation of a new substance.

Scientific Vocabulary

odor
(noun) a particular smell

Academic Vocabulary

proof
(noun) something which shows that something else is true

What happens to the mass of substances during a chemical change?

Mass is conserved during chemical changes. The masses of two substances that can chemically react can be measured and added. After the two substances react to form new substances, the total mass after the reaction can be measured. The total mass before and the total mass after the reaction are the same.

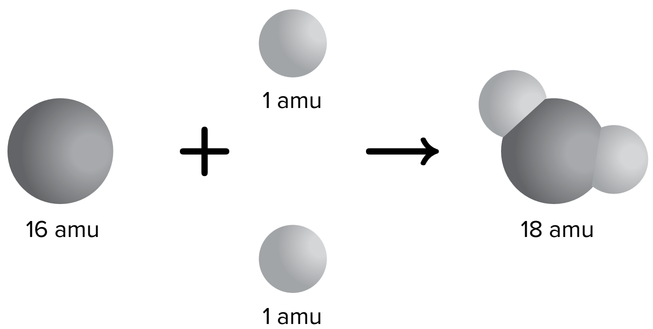
The **law of conservation of mass** *states that the total mass before a chemical reaction is the same as the total mass after the chemical reaction.* This is always true because particles are only rearranged. They cannot be created or destroyed, so the total mass cannot increase or decrease.

What happens to the atoms during a chemical change?

Particles in matter move constantly. As the particles move, they collide with each other.

Bonds Break and Bonds Form If the particles collide with enough force, the bonded atoms that make up the particles can break apart. These atoms then rearrange and bond with other atoms. *A* **chemical reaction** *occurs when atoms of one or more substances rearrange to form one or more new substances.* Chemical changes often are called chemical reactions. **Reactants** *are the starting substances in a chemical reaction.* **Products** *are the substances that are produced by the chemical reaction.*

Atomic Mass Each atom in a reaction has a characteristic mass indicated by an atomic mass unit (amu). When atoms are rearranged during a reaction, the sum of the masses of the new products will be the same as the sum of the masses of the reactants. The figure on the next page shows that when oxygen and hydrogen atoms react to form water, the new product has the same mass as the sum of the masses of the reactants.



Science Use v. Common Use

bond
Science Use a force that holds atoms together

Common Use a close personal relationship between two people

Word Origin

product
from Latin *producere,* means "bring forth"

Scientific Vocabulary

sum
(noun) the result of adding two or more numbers together

Atomic Arrangement Mass is conserved in a reaction because atoms are conserved. During a chemical reaction, bonds break and new bonds form. However, a reaction does not destroy atoms, and it does not form new atoms. All atoms at the start of a chemical reaction are present at the end of the reaction. Suppose you attach a balloon with baking soda inside to a flask of vinegar. You place the flask on a scale and record the mass. Then you mix the two substances. They react, and the balloon fills with gas. You find that the products after the reaction have the same mass as the reactants. Mass is conserved. The atoms also are conserved.

Science Use v. Common Use

substance

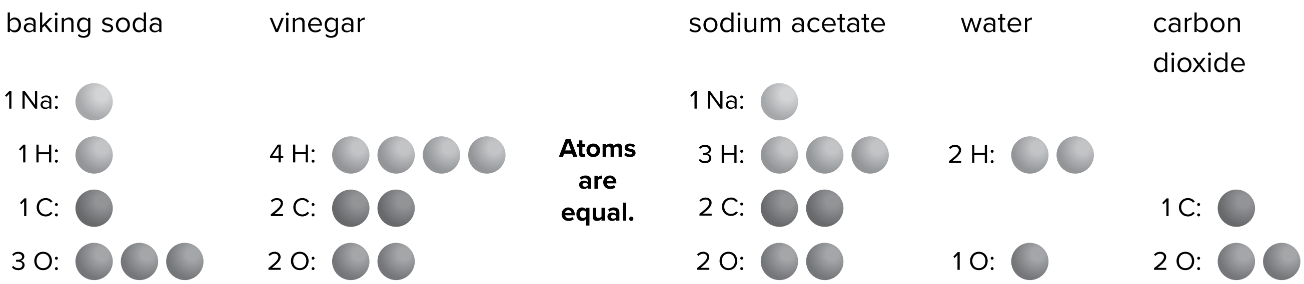
Science Use matter that has a particular chemical makeup

Common Use the quality of being meaningful, useful, or important

Let's look at the chemical formulas for the reaction of baking soda and vinegar. The scientific name for baking soda is sodium bicarbonate. Its chemical formula is $NaHCO_3$. Look at the left side of the image below. There is one sodium (Na) atom, one hydrogen (H) atom, one carbon (C) atom, and three oxygen (O) atoms.

Vinegar's chemical formula is CH_3COOH. There are two carbon (C) atoms, four hydrogen (H) atoms, and two oxygen (O) atoms.

The products of the reaction are sodium acetate (CH_3COONa), water (H_2O), and carbon dioxide (CO_2). You can count the number of atoms for the products. The number of each type of atom is the same on the left side and the right side.



How can a chemical reaction be represented?

In a science laboratory, chemical reactions are usually described in the form of a chemical equation. A chemical equation is a description of a reaction using element symbols and chemical formulas. Element symbols represent elements. Chemical formulas represent compounds.

Academic Vocabulary

represent
(verb) to be a sign or symbol of something

Scientific Vocabulary

compound
(noun) matter that is made up of two or more different kinds of atoms joined together by chemical bonds

Chemical Equations A chemical equation is a useful way to express what happens during a chemical reaction. A chemical equation shows the chemical formula of each substance in the reaction. Let's look at the reaction between baking soda and vinegar again. The formulas to the left of the arrow represent the reactants. Reactants are the substances present before the reaction takes place. The formulas to the right of the arrow represent the products. Products are the new substances present after the reaction.

Reactants				Product				
baking soda	+	**vinegar**	→	**sodium acetate**	+	**water**	+	**carbon dioxide**
$NaHCO_3$		$HC_2H_3O_2$		$NaC_2H_3O_2$		H_2O		CO_2

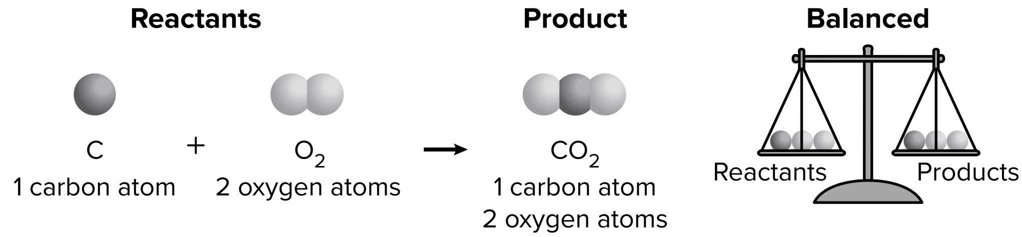
In a chemical equation, the plus sign separates two reactants or products. The arrow indicates that a reaction has taken place. In a chemical equation, the arrow is read as "yields." A reaction between the reactants to the left of the arrow yields, or produces, the new products on the right side of the arrow.

Recall that during physical and chemical changes, mass is conserved. This means that the total mass before and after a change must be equal. Therefore, in a chemical equation, the number of atoms of each element before a reaction must equal the number of atoms of each element after the reaction. This is called a balanced chemical equation, and it illustrates the conservation of mass.

Scientific Vocabulary

equation
(noun) a statement where two groups of numbers, letters, or symbols are equal

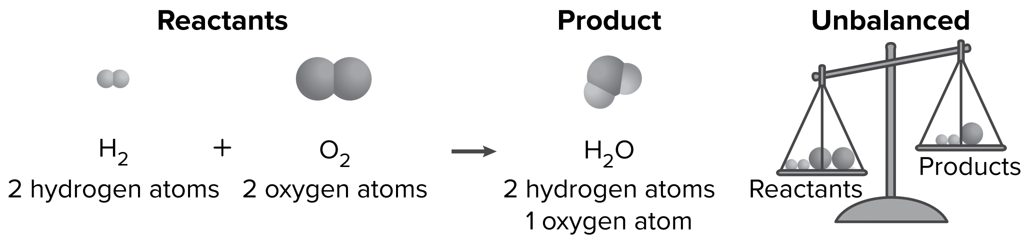
The figure below shows the formation of carbon dioxide from carbon and oxygen. There is one carbon atom and two oxygen atoms on the reactants side of the equation. The product, carbon dioxide, also has one carbon atom and two oxygen atoms.



When balancing an equation, you cannot change the chemical formula of any reactants or products. Changing a formula changes the identity of the substance. Instead, you can place coefficients in front of formulas. *A* **coefficient** *is a number placed in front of an element symbol or chemical formula in an equation.* The coefficient acts as a multiplier. For example, the equation in the figure below is not balanced.

Scientific Vocabulary

balanced
(adjective) equal amounts of something



An H_2O molecule has two H atoms and one O atom. However, there are two O atoms on the reactants side of the equation. Placing the coefficient 2 before H_2O ($2H_2O$) means that you double the number of H atoms and O atoms present. The coefficent 2 must also be placed in front of H_2 on the reactant side of the equation.

2 × 2 H atoms = 4 H atoms

2 × 1 O atom = 2 O atoms.

Note that $2H_2O$ is still water. However, it describes two water particles instead of one.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Matter: Properties and Changes

Energy Changes in Chemical Reactions

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Reactions that release energy require energy to get started.	
	Energy can be created during a chemical reaction.	

Key Concept

- Why do some reactions give off thermal energy and some absorb thermal energy?

Read to Learn

Where does the energy in a chemical reaction come from?

When an injury occurs, someone might place a medical instant cold or hot pack on the injury. How do these packs become hot or cold so quickly? Each pack has a different chemicals inside. When the chemicals are mixed in the hot and cold packs, a temperature change happens. For the temperature of the packs to change, the energy of the system has to change. This energy has to either come from the chemical bonds holding the atoms together or the surrounding environment.

Energy Transfers All matter is constantly moving. The more energy particles have, the more they move and collide with one another. When they collide with each other with the right amount of force, the bonds between the atoms break. The breaking of chemical bonds requires energy. When individual atoms collide and form bonds, energy is released. The atoms release this energy to the environment as light or heat. **Chemical potential energy** *is the energy released when atoms form bonds.* The chemical potential energy is dependent on the arrangement and strength of the bonds.

Mark the Text

Create a Quiz Write a quiz question for each paragraph. Answer the question with information from the paragraph. Then work with a partner to quiz each other.

Scientific Vocabulary

dependent
(adjective) determined by something else

How does energy input and output compare between chemical reactions?

If all chemical reactions both absorb energy and release energy, then how can you explain the temperature changes in the hot and cold packs? The transfer of energy can be tracked as energy flows through a system. When the hot pack became hot, it was because energy was released by the chemical reaction to the surroundings. The cold pack became cold because it absorbed energy from the surroundings.

Energy in Chemical Reactions Not all bonds release and absorb the same amount of energy. Some atoms release a high amount of energy when they form compounds. For instance, the chemical reactions that occurs in a firework release a large amount of energy in the form of thermal energy, light, and sound. Other compounds require a lot of energy to break apart. The elements and compounds involved in the chemical reaction determine if an overall change in energy is noticeable. Scientists connected the evidence of temperature change to the explanation of thermal energy transfers.

Energy Absorbed On a very warm day, have you ever heard someone say that the sidewalk was hot enough to fry an egg? To fry, the egg must absorb energy. *Chemical reactions where more energy is required to break the bonds of the reactants than is released when products form are* **endothermic reactions**. For an endothermic reaction to continue, energy must be constantly added.

reactants + thermal energy → products

The overall reaction absorbs energy. This is why thermal energy appears on the side with the reactants in the chemical equation above.

Energy Released Some chemical reactions release energy as opposed to absorbing it. *In an* **exothermic reaction** *more energy is released when the products form than is required to break the bonds in the reactants.*

reactants → products + thermal energy

The overall reaction releases energy. This is why thermal energy appears on the side with the products in the chemical equation above. The bonds of the reactants contain more energy than the bonds of the products.

Academic Vocabulary

as opposed to
(phrase) rather than; instead of

Word Origin

exothermic
from Greek *exo-*, means "outside"; *therm*, means "heat"

Life Science Connection Energy changes in chemical reactions do not just create changes in temperature. They also provide the energy that we use every day. All living organisms harness chemical reactions to supply their cells with energy. Plants and some unicellular organisms use the Sun's energy for photosynthesis. During photosynthesis, plant cells use the energy from sunlight to split water into hydrogen atoms and oxygen atoms. The cells then release the gaseous oxygen atoms into the atmosphere. A second set of reactions involves energy, hydrogen, and carbon dioxide from the air. The energy absorbed by the cells breaks the bonds between the hydrogen molecules and the carbon dioxide molecules. The sugar glucose, a molecule with 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms ($C_6H_{12}O_6$) is formed. The plant can then store the glucose for later use.

When the plant is eaten by animals, the animals obtain the glucose molecules from the plant cells. When the chemical bonds of glucose are broken, by either a plant or an animal, energy is released. This process is called cellular respiration. The chemical bonds of glucose molecules break, which releases energy cells can then use. The photosynthesis/cellular respiration combination is a process in which plants absorb radiant energy from the Sun and transfer it into the chemical bonds of the molecule glucose. When other organisms eat the plant, the glucose bonds break and energy is released.

Concentration What happens to a plant if any one of the reactants needed for photosynthesis is reduced? Can the reaction happen in the same way? No, if the amount of carbon dioxide, water, or light is reduced, the plant will not function normally. The plant needs to have enough concentration of all the reactants to function properly. This is also true of other reactions, like the hot and cold packs. The correct concentration of reactants will lead to the most products.

Think of a crowded hallway. Because the concentration of people is higher in the crowded hallway than in an empty hallway, people probably collide more often. Similarly, increasing the concentration of one or more reactants increases collisions between particles. More collisions result in a faster reaction rate. When particles are closer together, more collisions occur.

Scientific Vocabulary
organism
(noun) a living thing, such as an animal or plant

Scientific Vocabulary
harness
(verb) to use something for a particular purpose

Scientific Vocabulary
gaseous
(adjective) having the form of gas

Academic Vocabulary

overall
(adjective) considered as a whole; in general

Conserving Energy As you have seen, when atoms collide with each other, they transfer energy and chemical reactions occur. Some reactions absorb more energy than they give off, and others release more energy than they absorb. Energy is constantly transferring between the surroundings and chemical bonds. Yet the total amount of overall energy remains the same. *The* **law of conservation of energy** *states that even though energy is always transferring, energy is not created and energy is not destroyed.* Energy is constantly being reused. In a hot pack, energy moves to the environment as it is released by the chemical bonds of the reactants. In a cold pack, energy is absorbed. So, the energy moves from the environment into the chemical bonds of the products.

Life Science Connection The laws of conservation of energy and matter apply to both the physical and living environments. Plants store glucose molecules in their tissues. When plants are eaten by animals, energy and matter transfer to the consumer. One way energy can return to the environment is in the form of thermal energy given off by organisms. Another way is when plants and animals die, the energy and matter contained in their tissues is recycled by decomposers. Food webs model how matter and energy are transferred through ecosystems.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Dynamic Earth

Moving Continents

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	India has always been north of the equator.	
	All the continents once formed one supercontinent.	

Key Concept

- What evidence supports the continental drift hypothesis?

Read to Learn

Why do some continents have matching shapes?

Nearly 100 years ago, a scientist named Alfred Wegener (VAY guh nuhr) began an investigation. He wanted to know if Earth's continents had always been in the same place, or if they had moved. Wegener proposed that *all the continents were once part of a supercontinent called* **Pangaea** (pan JEE uh). Over time, Pangaea broke apart, and the continents slowly drifted to their present locations. Wegener proposed the hypothesis of continental drift. *The* **continental drift** *hypothesis suggested that continents are in constant motion on the surface of Earth.*

Wegener looked at the coastlines of continents that are now separated by oceans. He saw similarities in the shapes of the continents, including the continental shelves. For instance, Africa and South America seemed to fit together like the pieces of a puzzle.

Wegener knew that he needed evidence to support his hypothesis of continental drift. The most obvious evidence was the puzzle-like nature of the continents. But other scientists were doubtful of his hypothesis. Wegener needed more evidence.

Mark the Text

Identify the Main Ideas
Highlight two or three phrases in each paragraph that summarize the information presented. After you have finished the lesson, review the highlighted text.

Scientific Vocabulary

drift
(verb) to slowly and gradually move

Scientific Vocabulary

continental shelf
(noun) areas of continent that are under shallow water

Word Origin

Pangaea
from Greek *pan-*, means "all"; and Greek *gaia*, means "earth"

How do rocks provide evidence that continents move?

Some of the evidence used by Wegener to support his idea of continental drift came from rock formations on the continents in the Southern Hemisphere.

Evidence from Rock Formations Many rock formations and mountain ranges on Australia, South America, Africa, India and Antarctica all seemed to have formed in the same way at the same time. Today geologists know that there were large-scale volcanic eruptions on the western coast of Africa and on the eastern coast of South America hundreds of millions of years ago. Geologists have studied rocks from these eruptions. They determined that the volcanic rocks from both continents were identical in chemistry and age.

Scientific Vocabulary
chemistry
(noun) the structure of substances and the way that they combine or change with each other

More evidence came from the rocks that make up two mountain chains in Europe and North America. The Caledonian mountain range is in northern Europe, and the Appalachian Mountains are in eastern North America.

Rocks in these two mountain chains are similar in age and structure. Both are also composed of the same rock types. If you could place North America and Europe next to each other, these mountain chains would meet. They would form one long, continuous mountain belt.

Academic Vocabulary
compose
(verb) to form or make up

Evidence from Glacial Features Another clue used by Wegener to support continental drift came from glaciers. When Wegener pieced Pangaea together, he proposed that South America, Africa, India, and Australia were located closer to the South Pole 290 million years ago. He suggested that a large ice sheet covered much of these continents. When the ice sheet melted as Pangaea spread apart, it left rock and sediment behind. Wegener studied the similarities of these sediments.

Scientific Vocabulary
ice sheet
(noun) a glacier that spreads out over land in all directions

Wegener also studied glacial grooves. Glacial grooves are deep scratches in rocks made as ice sheets move across the land. Wegener found glacial grooves on many different continents. By studying these grooves, he was able to determine the direction that the ice sheet moved across the joined continents.

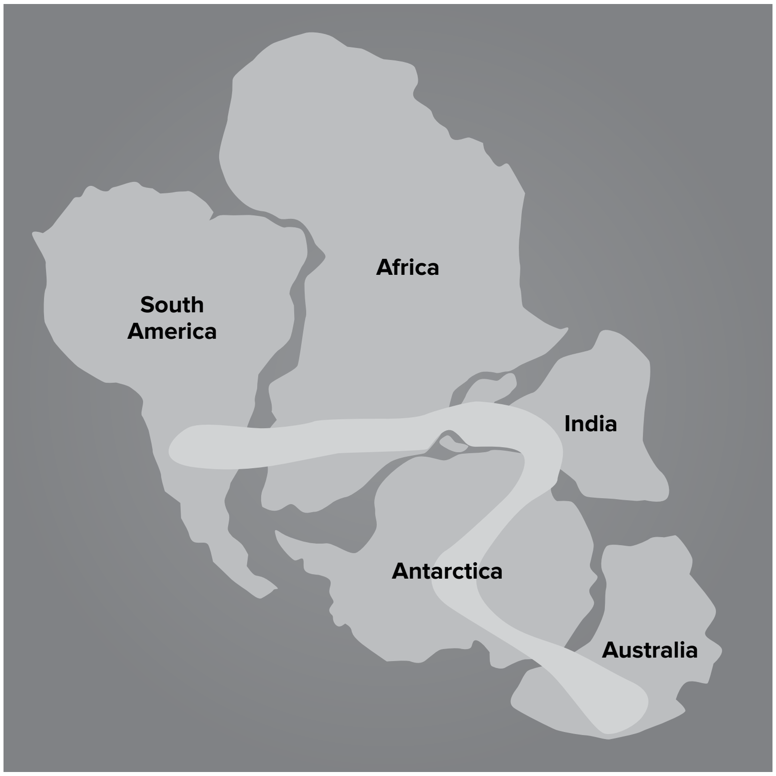
Evidence from Coal Deposits Coal beds are in Antarctica, a polar climate today. Yet coal formed from fossilized plants that lived long ago in warm, wet climates. This meant that Antarctica must have been warmer and wetter when these plants were alive. Wegener used this evidence to conclude that Antarctica must have been much closer to the equator sometime in the geologic past.

How do fossils provide evidence that continents move?

There are many animals and plants that live only on one continent. For example, lions live in Africa but not in South America. Because oceans separate the continents, animals cannot travel from one continent to another by natural means. However, fossils of similar organisms have been discovered on several continents that are now separated by oceans.

Evidence from Fossils Fossils of a plant called *Glossopteris* (glahs AHP tur us) have been discovered in rocks from South America, Africa, India, Antarctica, and Australia. Today these continents are far apart and separated by oceans. The plant's seeds, which were large and heavy, could not have traveled across the oceans.

The figure below shows how some of the continents were joined as part of Pangaea 250 million years ago. The lighter area on the map shows where *Glossopteris* fossils have been found. Notice that the plant once grew in parts of five continents—South America, Africa, India, Antarctica, and Australia. Because these plants grew in a swampy environment, this region, including Antarctica, was different from how it is today. Most of Antarctica is covered in ice sheets. No swampy environments are found there now.



Academic Vocabulary

separate
(verb) to stop being together

Scientific Vocabulary

fossil
(noun) the naturally preserved remains, imprints, or traces of organisms that lived long ago

Academic Vocabulary

skeptical
(adjective) to be doubtful about something

Scientific Vocabulary

mantle
(noun) the middle layer of Earth, situated between the crust above and the core below

What was missing?

Wegener supported his continental drift hypothesis until his death in 1930. Wegener's ideas were not widely accepted until nearly 40 years later. Why were scientists skeptical of Wegener's hypothesis?

Continental drift is a slow process. Wegener could not measure how fast the continents moved. Wegener also could not explain what forces caused the continents to move. The mantle under the continents and seafloor was made of solid rock. How could continents push their way through solid rock? Wegener needed more scientific evidence to prove his hypothesis.

The evidence for drifting continents was hidden on the seafloor. During Wegener's lifetime, scientists did not have the tools to determine what happens beneath the oceans. Wegener also could not have known what the seafloor looked like. The evidence needed to prove continental drift was not discovered until long after Wegener's death.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Dynamic Earth

Development of a Theory

Before You Read

What do you think? Read the three statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	The seafloor is flat.	
	Volcanic activity occurs only on land.	
	Continents drift across a molten mantle.	

Key Concept

- What evidence supports the theory of plate tectonics?

Read to Learn

What can scientists "see" at the bottom of the sea?

Scientists began exploring the seafloor in greater detail during the late 1940s. They used a device called an echo sounder to measure the depths of the ocean floor. An echo sounder produces sound waves that travel from a ship to the seafloor. The waves echo, or bounce, off the seafloor and back to the ship. The echo sounder records the time it takes the echo to return. When the ocean is deeper, the time it takes for the sound waves to bounce back is longer. Scientists calculated ocean depths and used these data to create topographic maps of the seafloor.

Ocean Floor Topography These new topographic maps showed large mountain ranges that stretched for many miles along the seafloor. *The mountain ranges in the middle of the oceans are called* **mid-ocean ridges.** Mid-ocean ridges are much longer than any mountain range on land.

The maps also revealed that underwater mountain chains had counterparts called ocean trenches. **Ocean trenches** *are deep, underwater troughs on the seafloor*. The Mariana Trench in the Pacific Ocean is the deepest landform on Earth. It is so deep it could fit Mount Everest with six Empire State buildings stacked on top!

Study Coach

Two-Column Notes As you read, organize your notes in two columns. In the left column, write the main idea of each paragraph. In the right column, write details that support each main idea. Review your notes to help you remember the details of the lesson.

Academic Vocabulary

calculate
(verb) to use numbers to find out something (cost, time)

Scientific Vocabulary

topographic
(adjective) relating to the shape of the land

What pattern can be found on the seafloor?

Using rock samples from the ocean floor, scientists were able to determine the age of the seafloor and create isochron maps. An isochron is an imaginary line on a map that shows points that have the same age—that is, they formed at the same time.

Word Origin
isochron
from Greek *isos-*, means "equal"; and Greek *khronos* means "time"

These isochron maps of the ocean floor revealed an interesting pattern. The ages form a series of stripes across the seafloor parallel to the mid-ocean ridges. Each stripe represents the age of that strip of crust, and match from one side of a ridge to the other. Relatively young ocean-floor crust is near mid-ocean ridges. Older ocean crust is found along ocean trenches. The seafloor ages as you move further away from a mid-ocean ridge, on either side of the ridge.

Scientific Vocabulary
parallel
(adjective) two things that are the same distance apart along their whole length

So how do continents drift?

Why would the seafloor age as you move further away from mid-ocean ridges? In the 1960s, scientists proposed a new process that helped explain ocean-floor features, ages, and continental drift. This process is called seafloor spreading. **Seafloor spreading** *is the process by which new oceanic crust continuously forms along mid-ocean ridges and is destroyed at ocean trenches.*

The Conveyor Belt When the seafloor spreads, the rock below the seafloor becomes molten. *Molten rock below Earth's surface is called* **magma.** The magma is less dense than the surrounding mantle. The magma rises through cracks in the crust along the mid-ocean ridge. *When magma reaches Earth's surface, it is called* **lava.** As the lava cools and crystallizes on the seafloor, it forms new oceanic crust. Two halves of the oceanic crust spread apart slowly, and move apart like a conveyor belt.

Scientific Vocabulary
crystallize
(verb) to change from a liquid into a solid with an orderly, repeating pattern

As the seafloor continues to spread apart, new crust that is forming pushes the older crust away from the mid-ocean ridge and eventually sinks at ocean trenches. This explains why the closer the crust is to a mid-ocean ridge, the younger the oceanic crust is. Scientists concluded that as the seafloor spreads, the continents must move along with it. Seafloor spreading is the mechanism that explains Wegener's hypothesis of continental drift. Continents do not move through the solid mantle or the seafloor. Instead, continents move as the seafloor spreads along a mid-ocean ridge.

Academic Vocabulary
explain
(verb) to give information about something

Academic Vocabulary
mechanism
(noun) the processes or system responsible for a natural phenomenon

What is the theory of plate tectonics?

By the late 1960s, the concepts of continental drift and seafloor spreading led to a more complete theory called plate tectonics. The theory of **plate tectonics** states that *Earth's surface is made of rigid slabs of rock, or plates, that move with respect to each other*, or in relation to each other. This new theory suggested that Earth's surface is divided into large pieces of rock. These pieces are called plates. Each plate moves slowly over Earth's hot and semiplastic mantle.

Scientific Vocabulary

rigid
(adjective) not able to bend or move easily

Tectonic Plates Earth's outermost layers are cold and rigid compared to the layers within Earth's interior. The cold and rigid outermost rock layer is called the lithosphere. The crust and the solid, uppermost mantle form the lithosphere.

Word Origin

lithosphere
from Greek *lithos-,* means "stone"; and Greek spharia, means *"sphere"*

The lithosphere varies in thickness. It is thin below mid-ocean ridges. It is thick below continents. Earth's tectonic plates are large pieces of lithosphere. These plates fit together like the pieces of a giant jigsaw puzzle.

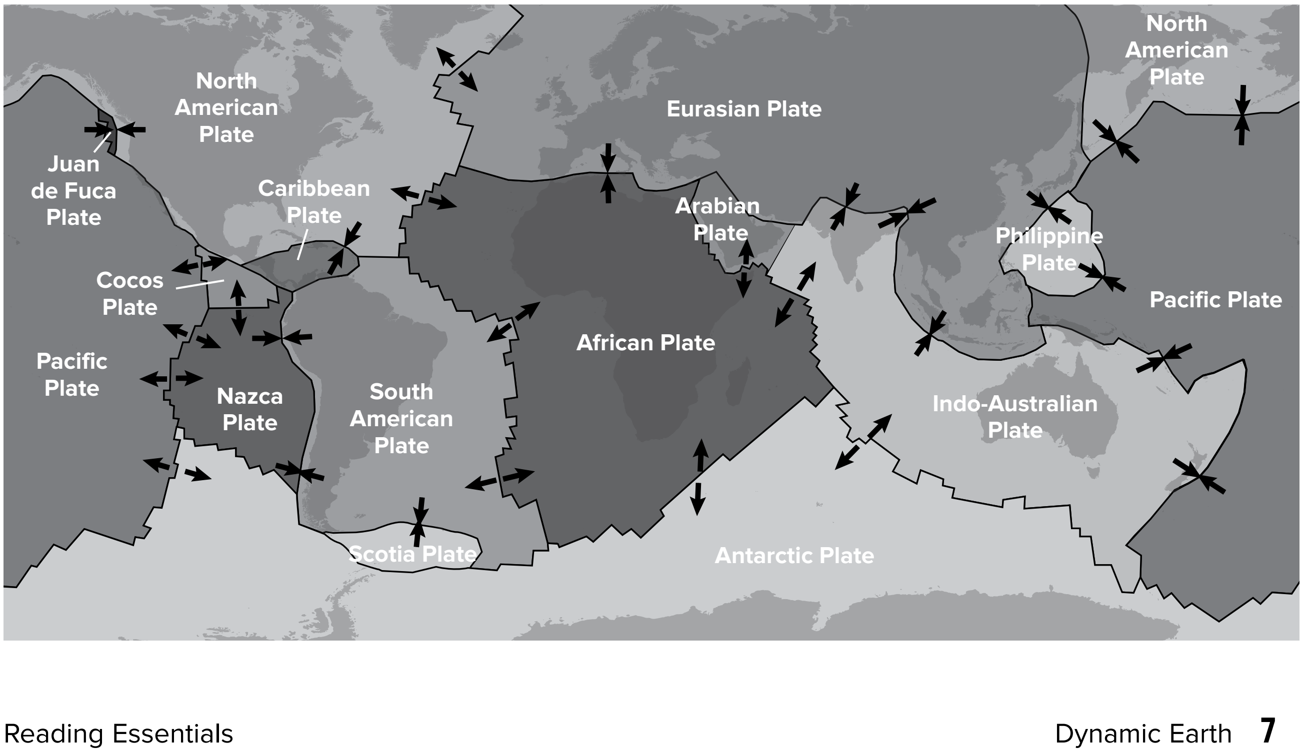
Directly below the lithosphere is a very hot part of the mantle. This layer of Earth is called the asthenosphere (as THEN uh sfihr). Even though it is solid, the asthenosphere behaves like a plastic material because it is so hot. The asthenosphere flows below Earth's plates and enables the plates to move.

Science Use v. Common Use

plastic
Science Use capable of being molded or changing shape without breaking

Common Use any of numerous organic, synthetic, or processed materials made into objects

Look at the map below. It shows Earth's major plates and their boundaries. Notice how some boundaries are in the middle of the oceans. Many of these boundaries are located at mid-ocean ridges. The Pacific Plate is the largest plate. The Juan de Fuca is one of the smallest plates.



Over billions of year, continents have moved great distances, collided, and spread apart. Tectonic plates move slowly, only 1–9 cm per year. But these massive plates have so much force they can build tall mountains, form deep valleys, and rip Earth's surface apart. Because tectonic plates move very slowly, most changes to Earth's surface take a long time. But some changes, like earthquakes and volcanic eruptions, occur very quickly and violently. You will learn about these changes in the following lesson.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Dynamic Earth

Shaping Earth's Surface

Before You Read

What do you think? Read the five statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Mountain ranges can form when continents collide.	
	Volcanoes can erupt anywhere on Earth.	
	Volcanic eruptions are rare.	
	Earth's crust is broken into rigid slabs of rock that move, causing earthquakes and volcanic eruptions.	
	All earthquakes occur at plate boundaries.	

Key Concept

- How does the movement of tectonic plates form mountains and volcanoes, and cause earthquakes?

Read to Learn

What happens where Earth's plates meet?

You have learned that the distribution of continents on Earth's surface is caused by the slow and large-scale motion of Earth's tectonic plates over billions of years. The movement of Earth's plates is also responsible for many other large-scale features on Earth. The features and geologic events that occur depend on the movement of the plates where they meet.

How do scientists describe the movement of a tectonic plate? They describe a plate's relative motion—how it moves in relation to another plate. For example, the North American Plate is moving away from the Eurasian Plate, but it is also moving toward the Pacific Plate. As plates move relative to each other, they form different types of boundaries. The type of boundary depends on the relative motion of the plates.

Study Coach

Make Flash Cards Think of a quiz question for each paragraph. Write the question on one side of a flash card. Write the answer on the other side. Work with a partner to quiz each other using the flash cards.

Word Origin

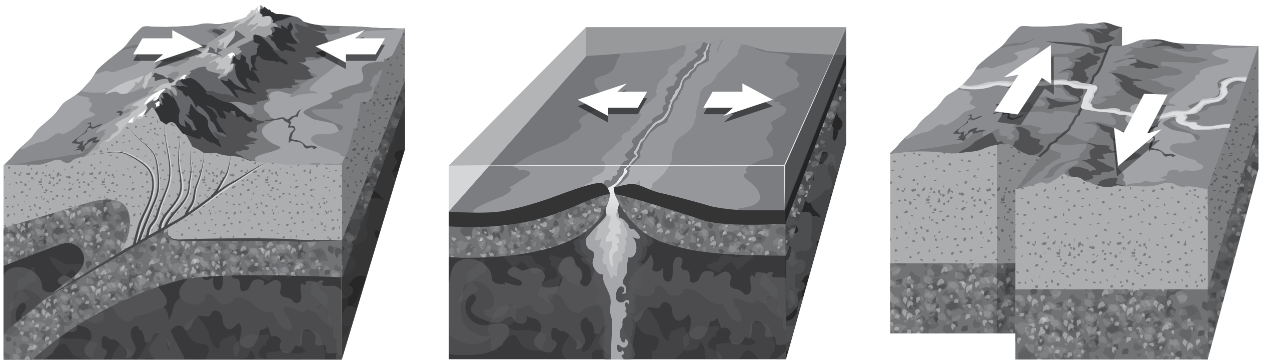
tectonic
from Greek *tekton,* means "builder"

Scientific Vocabulary

plate boundary
(noun) zone along the edges of tectonic plates

Plate Boundaries Imagine two books side by side and that each book is a tectonic plate. The place where the edges of the books meet represents a plate boundary. How many ways can you move the books along this boundary? You can pull them away from each other. You can push them together. You can slide them past each other. Earth's tectonic plates move in much the same way as you can move these books.

A plate boundary may be convergent, divergent, or transform. The figure below shows each type.



Convergent boundary **Divergent boundary** **Transform boundary**

Academic Vocabulary

collide
(verb) to come together with direct impact

Word Origin

subduction
from Latin *subductus,* means "to lead under, removal"

Word Origin

transform
from Latin *trans,* means "across"; and *formare,* means "to form"

A **convergent boundary** *forms where two plates collide.* When a dense oceanic plate and a less-dense continental plate collide, *the denser plate sinks under the edge of the less-dense plate in a process called* **subduction.** This process can also occur when two oceanic plates collide. An older and denser oceanic plate will subduct beneath a younger, less-dense oceanic plate. When two continental plates collide, neither plate is subducted.

A **divergent boundary** *forms where two tectonic plates separate. Divergent* means "moving apart." Mid-ocean ridges are located along divergent boundaries. Divergent boundaries can also exist in the middle of a continent. At these boundaries, continents pull apart and a rift valley forms. The East African Rift is one example of a continental rift.

A **transform boundary** *forms where two tectonic plates slide past each other.* The famous San Andreas Fault in California is an example of a transform boundary.

How do large mountain ranges form on land?

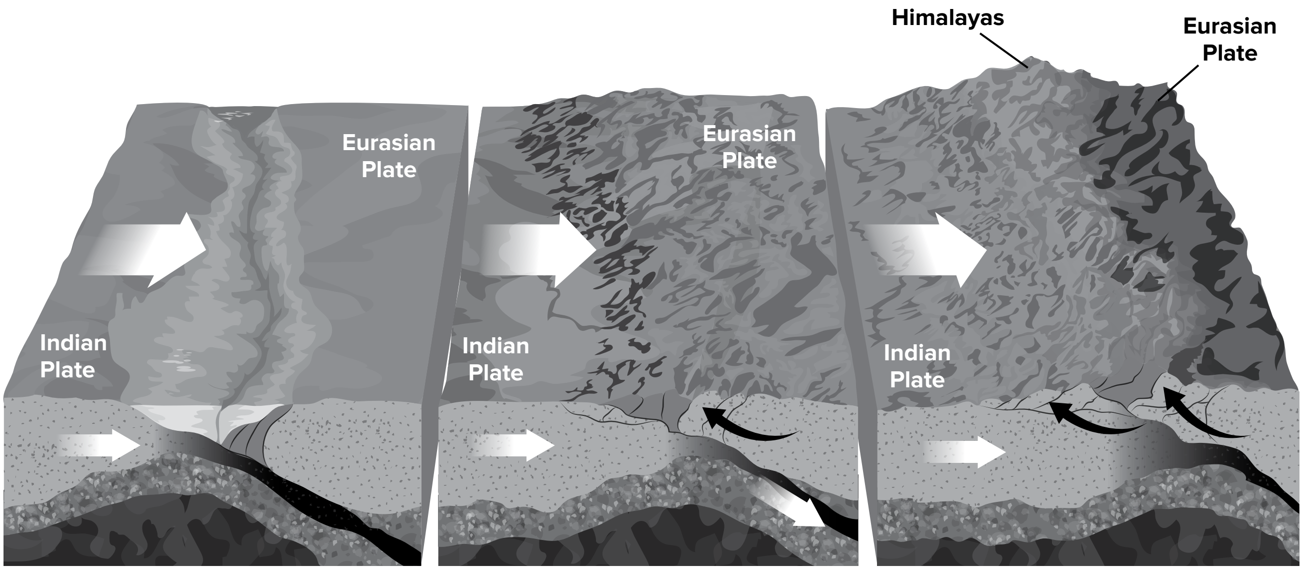
The direction of motion of Earth's plates creates a variety of features at the boundaries between the plates. Majestic mountain ranges are one feature produced by the slow and large-scale motion of Earth's plates. Mountain ranges form slowly, and they change slowly.

Fold Mountains When two continental plates collide at a convergent boundary, large mountain ranges form. The tectonic plates are under extreme pressure and fold or crumple upward, forming fold mountains. The arrangement of the folds in fold mountains is not accidental. You can show this with a piece of paper. Gently push the ends of a sheet of paper toward one another to form a fold. The fold is a long ridge that is perpendicular to the direction in which you pushed. Fold mountains are similar. The folds are perpendicular to the direction of the compressional—or squeezing—forces that created them. Like your paper, when folds run up and down in a mountain, the compression must have come from the sides.

Academic Vocabulary
accidental
(adjective) occurring unexpectedly or by chance

Scientific Vocabulary
perpendicular
(adjective) forming a 90-degree angle

Fold mountains form slowly and in stages over millions of years. The Himalayas, for example, formed as the Indian Plate converged with the Eurasian Plate, as shown below. The Himalayas are the largest and highest mountain range in the world, and they are still growing!



The Andes are also an example of fold mountains. As the denser Nazca Plate collides with the South America Plate, it is forced under the South American Plate. This causes the leading edge of the South American Plate to fold upward. The Andes are the longest mountain range on Earth.

Scientific Vocabulary

tension
(noun) stress that pulls something apart

Fault-Block Mountains Not all of Earth's mountains are fold mountains. Where plates move apart, tension—or pulling—stresses stretch Earth's crust. Sometimes tension stresses within a continent form mountains. How? As tension pulls crust apart, faults form. *A* ***fault*** *is a break in Earth's crust along which movement occurs.* At the faults, some blocks of crust fall and others rise. Fault-block mountains are parallel ridges that form where blocks of crust move up or down along faults.

The parallel ridges of fault-block mountains run perpendicular to the direction of stress. For example, the Basin and Range Province in Nevada, Utah, California, Arizona, and northwestern Mexico consists of dozens of parallel fault-block mountains that are oriented north to south. The tension that created the mountains pulled in the east-west directions.

Word Origin

Appalachian
from the Apalachee abalahci, means "other side of the river"

Scientific Vocabulary

elevation
(noun) height above sea level

Weathering and Erosion Mountains do not last forever. The processes of weathering and erosion gradually wear them down over time. The Appalachian Mountains are an old mountain range that stretches along most of the eastern United States. They are not as high or as rugged as the Rocky Mountains in the west because they are much older. Weathering has rounded the peaks and lowered the elevations. You'll learn more about how weathering and erosion gradually change Earth's surface in the next lesson.

How do volcanic landscapes form?

Some of Earth's mountains are volcanic mountains. Perhaps you have heard of some famous volcanoes such as Mount St. Helens, Kilauea, or Mount Pinatubo. *A* ***volcano*** *is a vent in Earth's crust through which molten rock flows.* Volcanoes can be as small as a car. They also can be more than 10 km in height.

Volcanic eruptions constantly shape Earth's surface. Sometimes lava flows from volcanoes slowly cover the region surrounding the volcano. At other times, volcanoes can erupt explosively. They can form large mountains, create new crust, and leave a path of destruction behind. Scientists have learned that the movement of Earth's tectonic plates causes volcanoes to form and to erupt.

Scientific Vocabulary

convergent
(adjective) coming from different directions and meeting at the same point

Volcanoes on Earth Volcanoes can form along convergent boundaries. Recall that when two plates collide, the denser plate sinks, or subducts, into the hot mantle. The thermal energy below the surface and fluids driven off the subducting plate melt the mantle and form magma. Magma is less dense than the mantle and rises through cracks in the crust. This forms a volcano.

Some volcanoes form in the ocean where oceanic plates converge and one plate subducts. These volcanoes emerge as islands. *A curved line of volcanoes that forms parallel to a plate boundary is called a* **volcanic arc.** Most of the active volcanoes in the United States are part of the Aleutian volcanic arc in Alaska. They formed as a result of the Pacific Plate subducting under the North American Plate.

Volcanic arcs can also form on land where an oceanic plate subducts under a continental plate. Volcanoes in the Cascades, for example, are a result of the Juan de Fuca plate subducting under the North American Plate. Volcanoes in the Andes are also a result of an oceanic plate subducting under a continental plate.

Lava also erupts along divergent boundaries. More than 60 percent of all volcanic activity on Earth occurs at divergent boundaries along mid-ocean ridges. As the seafloor slowly spreads apart along mid-ocean ridges, lava erupts into the rift formed by the separating plates. As the lava cools and hardens, it forms new oceanic crust.

Scientific Vocabulary
rift
(noun) a long, narrow fissure or opening in rock

How do earthquakes affect Earth's surface?

The large-scale motion of Earth's tectonic plates creates more than mountains and volcanoes. Earthquakes result from the buildup and rapid release of stress along active plate boundaries. *An* **earthquake** *is the rupture and sudden movement of rocks along a break or a crack in Earth's crust.*

Scientific Vocabulary
stress
(noun) the force acting on a surface

When the Ground Shakes Imagine bending a stick until it breaks. When the stick snaps, it vibrates, releasing energy. Earthquakes release energy in a similar way, and can change Earth's surface quickly and dramatically. We see the results of earthquakes in faults, landslides, and tsunamis.

Faults associated with earthquakes can be visible at Earth's surface. Natural and human-made features that cross the fault, such as streams and railroads, are shifted by earthquakes. Some faults, such as the San Andreas Fault in California, can be more than 1,000 km long. The San Andreas Fault is not a single fault. Many smaller faults exist in the area around the San Andreas Fault. *An area of many fractured pieces of crust along a large fault is called a* **fault zone.**

Science Use v. Common Use
fault
Science Use a fracture in the crust of a planet

Common Use responsibility for wrongdoing or failure

Academic Vocabulary
trigger
(verb) to cause to start or happen

Scientific Vocabulary
catastrophic
(adjective) sudden and great damage

Academic Vocabulary
displace
(verb) to move physically out of position

Earthquakes can also trigger landslides, quickly changing Earth's surface. *A* **landslide** *is the rapid downhill movement of soil, loose rocks, and boulders.* The vibrations of an earthquake can cause large amounts of Earth materials to separate from a slope. Gravity quickly causes materials to come crashing downhill.

Underwater earthquakes can cause catastrophic tsunamis. *A* **tsunami** *is a wave that forms when an ocean disturbance suddenly moves a large volume water.* As blocks of crust move up along a fault, the water above is displaced and forms a gigantic wave. Tsunamis can quickly destroy coastlines.

Besides plate motion, what else creates major features on Earth?

Not all major features on Earth's surface are caused by plate motion. For example, craters are not formed by the movement of tectonic plates. Instead, they form when a meteoroid from space strikes Earth's surface. These impacts leave *giant, circular depressions in the ground called* **impact craters.** There are more than 170 impact craters on Earth.

Like volcanic eruptions and earthquakes, meteoroid impacts are catastrophic changes that create surface features over a very short period of time. And just like mountains and other landforms on Earth, impact craters are subject to further changes over time. For example, the Barringer Crater in Arizona is estimated to have lost between 15–20 meters in height due to erosion and weathering processes on Earth.

Academic Vocabulary
interaction
(verb) the act of things coming together and having an effect on each other

Other distinct landforms on Earth that are not formed by plate interaction are canyons. These are formed as rivers erode the land over which they flow. You will learn more about these features and the processes that create and shape them in the next lesson.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Dynamic Earth

Changing Earth's Surface

Before You Read

What do you think? Read the five statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Humans are the main cause of weathering.	
	Plants can break rocks into smaller pieces.	
	Wind, water, ice, and gravity continually shape Earth's surface.	
	Different sizes of sediment tend to mix when being moved along by water.	
	A glacier leaves behind very smooth land as it moves through an area.	

Key Concept

- How do weathering, erosion, and deposition change Earth's surface?

Read to Learn

What processes change Earth's surface over time?

Everything around you changes over time. Brightly painted walls slowly fade. Shiny cars become rusty. Things made of wood dry out and change color. These changes are some examples of weathering. *The physical and chemical processes that change objects on Earth's surface over time are called* **weathering.**

Weathering also changes Earth's surface. Earth's surface in the past was different from what it is today and what it will be in the future. Weathering processes break, wear, abrade, and chemically alter rocks and rock surfaces.

Weathering Two types of weathering can occur: physical weathering and chemical weathering. Physical weathering breaks rocks into small pieces without changing the composition or chemical make-up of the rock. When granite is broken up by physical weathering, the smaller pieces that result are still granite.

Study Coach

Identify Main Ideas Work with a partner. Read a paragraph to yourselves. Then discuss what you learned in the paragraph. Continue until you and your partner understand the main ideas of this lesson.

Scientific Vocabulary

abrade
(verb) to wear away or scrape by rubbing against

Life Science Connection Animals can physically weather rocks. Animals that live in soil make holes in the soil. Water enters the holes and causes weathering. Animals also help break down rocks as they dig through loose rock.

Plants can also help weather rocks. Imagine a plant growing into the crack in a rock. As the plant grows, its stem and roots get longer and wider. The growing plant pushes on the sides of the crack. Over time, the rock breaks.

Physical Science Connection Chemical weathering changes the materials that are part of a rock into new materials. A chemically weathered piece of granite is no longer granite.

Scientific Vocabulary
dissolve
(verb) to blend two or more substances together to make a solution

Water is important in chemical weathering because most substances dissolve in water. When a rock dissolves, its minerals break up into smaller parts in solution. The minerals that make up most rocks dissolve very slowly in water. Even after several years a mineral might not show any signs of dissolving.

Scientific Vocabulary
solution
(noun) a mixture formed when a solid, liquid, or gas is mixed with a liquid

Scientific Vocabulary
seep
(verb) to flow slowly through small openings

Acids cause chemical weathering to occur at a faster rate than rain or water does. When carbon dioxide in the air mixes with rainwater, a weak acid forms. Some of this rainwater becomes groundwater. As acidic groundwater seeps through rocks and soil, it can pass through layers of limestones. Acidic water dissolves and washes away the limestone, forming a cave. The formation of a cave can take tens of thousands to millions of years.

Erosion and Deposition You have read what happens to rocks when they are exposed to agents of physical and chemical weathering. But what happens to the material that is weathered? Much of it is transported to another place. **Erosion** *is the moving of weathered material from one location to another.* Agents of erosion include water, wind, glaciers, and gravity. Muddy water in a river is evidence of erosion. The river is muddy because of the sediment it carries.

Word Origin
deposition
from French *deposer,* means "put down"

Weathering and erosion are destructive processes that shape Earth's surface. After material has been weathered and eroded, a constructive process takes place. **Deposition** *is the laying down or settling of eroded material.* As water and wind slow down, they have less energy and can hold less sediment. Some of the sediment they carry is then laid down, or deposited.

Together, the processes of weathering, erosion, and deposition constantly change the surface of Earth. These processes occur at different spatial scales and time scales. For example, weathering occurs at scales ranging from microsopic to large, and over time periods ranging from seconds to millions or billions of years.

Academic Vocabulary
spatial
(adjective) relating to space, or the extent of the area under study

How does water change Earth's surface?

Moving water can cause great changes both on and below Earth's surface. The shape of the landforms created by water erosion and deposition depends on the speed of water movement and the depositional environment.

Water Erosion and Deposition Have you ever gone swimming in an ocean? If so, then you know that moving water can have great energy. Moving water causes erosion along streams and rivers, at beaches, and underground.

Flowing water deposits sediment as the water slows. A loss of speed reduces the amount of energy that the water has to carry sediment.

Scientific Vocabulary
sediment
(noun) rock material that has been broken down

Stream Erosion and Deposition Streams are active systems that erode land and transport sediment. Erosion by a stream depends on the stream's energy. Streams in mountainous areas usually have the greatest energy. Water flows rapidly downhill where the mountain slopes are steep. The rushing water often carves steep, V-shaped valleys. Waterfalls and river rapids are common in steep mountain streams.

Scientific Vocabulary
slope
(noun) ground that forms an incline

Academic Vocabulary
steep
(adjective) going up or down very quickly

Water in mountain streams slows as it reaches gentler slopes near the base of mountains. The shape and speed of these streams are different from those of mountain streams. Here they flow more slowly through gently sloping valleys. Slower-moving water erodes the sides of the stream channel more than it erodes the bottom of the channel. Curves called meanders develop in the channel. A meander is a broad, C-shaped curve in a stream. Meanders can make a stream into a large, snake-shaped feature in the land.

A stream moves even slower when it reaches flat land. Over time, meanders change shape. More erosion occurs on the outside of bends, where the water flows faster. More deposition occurs on the inside of bends, where the water flows slower. Over time, this increases the size of the meander.

Deposition by a stream takes place anywhere along its path where the water's speed decreases. Slower-moving water deposits sediment on the inside curves of meanders. A stream also deposits sediment when it reaches flat land or a body of water, such as a lake or an ocean. A delta is a large deposit of sediment that forms where a stream enters a large body of water.

Coastal Erosion and Deposition Like streams, coastlines are always changing. Waves and currents along a shore cause erosion of loose sand, gravel, and rock. A longshore current is a current that flows parallel to the shoreline. Longshore currents transport sediment from place to place, continually changing the size and shape of the beaches.

Much of the sand on most ocean beaches was originally deposited by rivers. Longshore currents moved the sand along ocean coasts. The sand was eventually deposited where the currents were slower and had less energy. Sandy beaches often form at those locations.

Groundwater Erosion and Deposition Water that flows underground can also erode rock. Recall that when carbon dioxide in the air mixes with rainwater, a weak acid forms. The acidic water seeps into the ground and dissolves and washes away layers of limestone, forming a cave.

Scientific Vocabulary
acid
(noun) substance with a pH between 0 and 7

Deposition forms many structures within caves. Caves contain landforms that dripping groundwater form as it deposits minerals. Over time, the deposits develop into stalactites and stalagmites. Stalactites hang from the ceiling. Stalagmites build up on the cave's floor.

Word Origin
stalactite
from Greek *stalaktos,* means "dripping"

Word Origin
stalagmite
from Greek *stalagma,* means "a drop"

How does wind change Earth's surface?

The gentle winds that blow leaves around in autumn are not likely to cause much land erosion and deposition. However, strong or long-lasting winds can greatly change the land.

Wind Erosion and Deposition As wind blows, it carries sediment. This sediment cuts and polishes exposed rock. Abrasion is the grinding away of rock or other surfaces as particles carried by wind, water, or ice scrape against them. Sediment that has been eroded by wind has distinct polished, etched, and pitted surfaces.

Wind erosion can form distinct types of landforms. Arches as well as scoured and sandblasted surfaces form as sediment carried in blowing wind cuts and abrades the rock layers. Continuous abrasion over millions of years results in their formation.

Two common types of windblown deposits are dunes and loess (LUHS). A dune is a pile of windblown sand. Dunes form when wind loses energy and drops the sand it is carrying. The shapes of dunes are mostly controlled by whether wind blows consistently in one direction, or is more variable in direction. Some dunes can be many kilometers long. Grain by grain, sand dunes migrate in the direction the wind blows. Entire fields of dunes can move over land as wind blows the sand.

Loess is a crumbly, windblown deposit of silt and clay. One type of loess forms from rock that was ground up by glaciers. As the glaciers melted, the silt and clay flowed out in the melt water. When the wind picked up this small, fine-grained sediment and dropped it, thick layers of loess formed.

Sediment Transport and Wind Wind is capable of moving sand and finer sediment, as well as pieces of plants and other materials lying on the surface. A microscopic grain of sand can be moved easily and over long distances in a fairly short period of time. However, the movement of larger sediment pieces would take a longer amount of time and require more force.

How does ice change Earth's surface?

A **glacier** *is a large mass of ice that forms on land and moves slowly across Earth's surface.* Glaciers also cause erosion and deposition. Glaciers form on land in areas where the amount of snowfall is greater than the amount of snowmelt. Glaciers don't look like they move. However, they might move several centimeters or more a day.

The two main types of glaciers are alpine glaciers and continental glaciers, also called ice sheets. Alpine glaciers form in mountains and flow downhill. Continental glaciers cover large areas of land. They move outward from central locations. Ice sheets as large as continents covered many parts of Earth during past ice ages. Today, continental ice sheets exist only on Antarctica and Greenland.

Academic Vocabulary

variable
(adjective) subject to change

Word Origin

loess
(noun) from Swiss German *Lösch,* means "loose"

Science Use v. Common Use
till
Science Use rock and sediment deposited by a glacier

Common Use to work by plowing, sowing, and raising crops

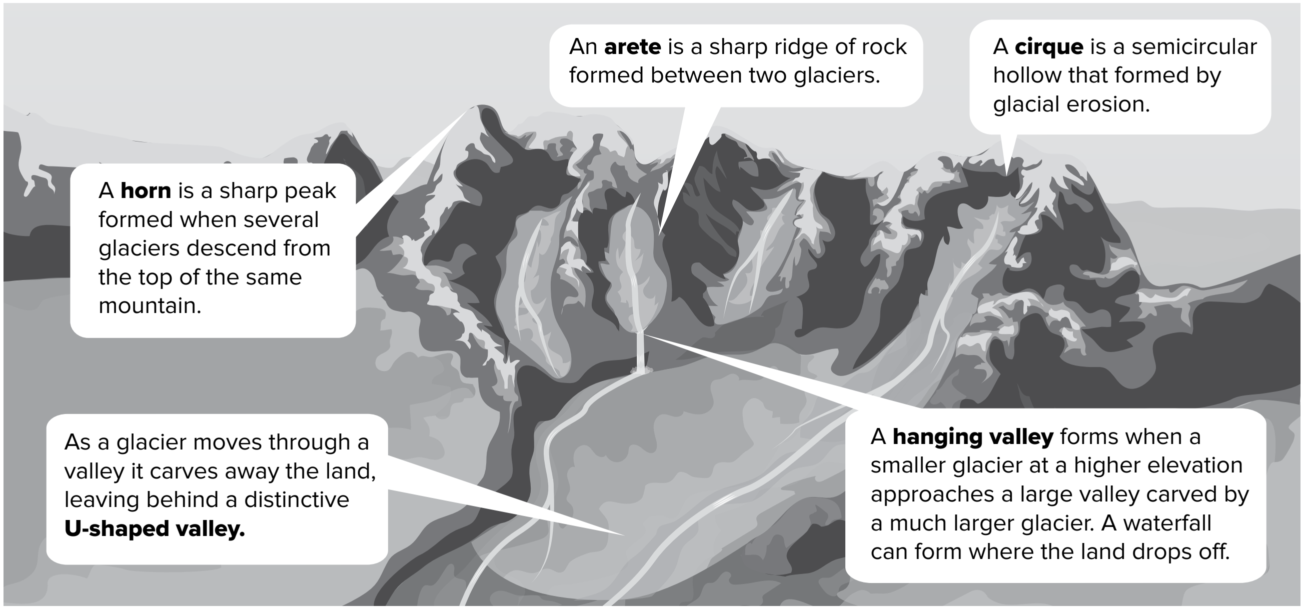
Word Origin
moraine
from French *morena,* means "mound of earth"

Erosion by Ice Glaciers erode Earth's surface as they slide over it. They carve the land as they move. Rocks and grit frozen in glaciers create grooves and scratches on the rock beneath the ice. While both types of glaciers produce recognizable features, erosion by alpine glaciers produces features that are more distinct and familiar. The figure below illustrates some of these features.

Glacial Debris Glaciers slowly melt as they move down from high altitudes or when the climate warms. Sediment that was once frozen in the ice is deposited. Till is a mixture of various sizes of sediment deposited by a glacier. Deposits of till are poorly sorted. They contain particles that range in size from large boulders to silt. Till collects along the sides and fronts of glaciers. A moraine is a mound or ridge of unsorted sediment deposited by a glacier. Outwash is layered sediment deposited by streams of water that flow from a melting glacier. Outwash consists mostly of well-sorted sand and gravel.

Glacial Features A glacial horn is a sharp peak formed when several glaciers descend from the top of the same mountain. An arete is a sharp ridge formed between two glaciers. A cirque is a bowl-shaped depression formed by glacial erosion.

A hanging valley forms when a smaller glacier at a higher elevation joins with a large glacial valley at a lower elevation. Waterfalls can form where the land drops off. A U-shaped valley forms as a glacier moves through an area and carves away the land.



Continental glaciers also leave behind features caused by erosion. The most notable are large flat exposures of rocks with surfaces that seem to have been scoured flat by a giant piece of sandpaper. Sometimes these surfaces have scratches that show the direction the ice was moving at the time.

Academic Vocabulary

scour
(verb) to clear, dig, or remove

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Dynamic Earth

The Cycling of Earth's Materials

Key Concept
- What is the rock cycle?

Mark the Text

Building Vocabulary Skim the lesson before you read it. Circle any words that you do not know. As you read, underline the words that help you understand the meaning of the words you circled. Review the circled words and their definitions after you finish reading the lesson.

Academic Vocabulary

fragment
(noun) a broken piece of something

Scientific Vocabulary

inorganic
(adjective) not containing any living thing

Before You Read

What do you think? Read the five statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Once a rock forms as part of a mountain, it does not change.	
	Some rocks, when exposed on Earth's surface, undergo weathering and erosion.	
	All sedimentary rocks on Earth formed from the remains of organisms that lived in oceans.	
	With the right pressure and temperature conditions, minerals in a rock can change shape without breaking or melting.	
	Metamorphic rocks have layers that form as minerals melt and then recrystallize.	

Read to Learn

Rocks and Minerals

Rocks are everywhere. Mountains, valleys, and the seafloor are made of rocks. Parts of your home are likely made of rock. Floors, countertops, and some tabletops are made of rock.

Rocks and Minerals *A* **rock** *is a natural, solid mixture of minerals, smaller rock fragments, organic matter, or glass.* Geologists call the fragments that make up a rock grains. Most rocks are composed of minerals. **Minerals** *are naturally occurring, inorganic solids that have crystal structures and definite chemical compositions.*

Rocks and minerals form as a result of natural processes that occur on and below Earth's surface. Geologists classify rocks, or place them into groups, according to how they form. The three major groups of rocks are igneous, sedimentary, and metamorphic.

How do igneous rocks form?

Igneous rocks are the most abundant rocks on Earth. Most of them form deep below Earth's surface, but some of them form on Earth's surface. Igneous rocks might form in different places, but they all form in a similar way.

Igneous Rock Formation When molten rock on or below Earth's surface cools, it begins to crystallize. *The process of* **crystallization** *occurs when particles dissolved in a liquid or a melt solidify and form crystals.* As molten rock cools and crystallizes, it becomes igneous rock.

Scientific Vocabulary
molten
(adjective) liquefied by heat; melted

Scientific Vocabulary
melt
(noun) molten rock

Where do igneous rocks form?

Melted rock material is present both on and below Earth's surface. Recall that molten rock that erupts onto Earth's surface is called lava. Molten rock is called magma when it is inside Earth. Igneous rocks are classified based on whether they form on Earth's surface or below.

Word Origin
lava
from Latin *lavare,* means "to wash"

Extrusive Igneous Rocks *When lava cools and crystallized on Earth's surface, the igneous rock that forms is called* **extrusive rock.** Lava cools quickly when it comes in contact with the cooler air or water. Rapid cooling keeps large crystals from growing. Geologists describe the texture of igneous rocks with small crystals as fine-grained.

Sometimes lava cools too quickly to form crystals. When this occurs, the resulting extrusive rock is called volcanic glass. Obsidian is an example of volcanic glass. It has a shiny, glasslike surface with no internal crystalline structure.

Intrusive Igneous Rocks Not all magma makes it to Earth's surface. Large amounts of magma cool and crystallize beneath Earth's surface. *Igneous rock that forms as magma cools underground is called* **intrusive rock.**

Word Origin
intrusive
from Latin *intrudere,* means "to push in"

Magma cools slowly underground. No cool air comes in contact with the magma. As a result, the process of cooling and crystallization takes much longer, and large crystals form. The crystals are arranged randomly in intrusive rocks. These large crystals lock together like pieces of a jigsaw puzzle. The random arrangement and large size of the crystals are features of intrusive igneous rocks.

What happens to rocks at Earth's surface?

When rocks, such as igneous rocks, are exposed on Earth's surface, they can break down into sediment and be transported to new environments. Recall that sediment is rock material that forms where rocks are broken down into smaller pieces or dissolved in water as rocks erode.

How do rocks weather into sediment? Water and air can change the physical or chemical properties of rock. This change can cause rock to break apart, to dissolve, or to form new minerals. When water travels through rock, some of the elements in the rock can dissolve and be transported to new locations. Mineral and rock fragments can also be eroded by water, glacial ice, gravity, or wind.

Science Use v. Common Use

deposit

Science Use to lay down or allow to fall through a natural processes

Common Use to put money in a bank

Scientific Vocabulary

delta

(noun) a landform created where sediment carried by a river is deposited when the river enters slower-moving water

What happens to eroded sediment?

Sediment is eventually deposited, or laid down. Usually, the sediment ends up in a body of water such as a lake or ocean. Locations where sediment is deposited are called depositional environments. These locations are on land, along coasts, or in oceans. They include swamps, deltas, beaches, and the ocean floor.

Deposition Environments where sediment is transported and deposited quickly are high-energy environments. High energy environments include fast-moving rivers, ocean shores with large waves, and deserts with strong winds. Large grains of sediment tend to be deposited in high-energy environments.

Smaller grains of sediment are often transported and deposited in low-energy environments. Deep lakes, swamps, and areas of slow-moving air or water are low-energy environments. Silt and clay are deposited in low-energy environments such as swamps.

Sediment deposited in water often forms layers called beds. Beds often form as layers of sediment are deposited at the bottoms of rivers, lakes, and oceans. Over time, these layers can be preserved in sedimentary rocks.

How do sedimentary rocks form from layers of sediment?

Lithification *is the process through which sediment turns into rock.* Imagine sediment deposits becoming thicker over time. Younger sediment layers bury older sediment layers. Eventually, the old and young layers of sediment can be buried by even younger sediment layers. *The weight from the layers of sediment forces out fluids and decreases the space between grains during a process called* **compaction.**

Cementing Rock Together Compaction is often followed by a process called cementation. **Cementation** *is the process by which minerals dissolved in surrounding water crystallize between grains of sediment.* Mineral cement holds the grains together. Common minerals that cement sediment together include quartz, calcite, and clay.

What are the different types of sedimentary rocks?

Sedimentary rocks are classified based on how they form. Sedimentary rocks form when sediments, rock fragments, or organic materials are deposited, compacted, and then cemented together. They also form when minerals dissolved in water form crystals as the water evaporates. Some ocean organisms remove minerals from the water as they form their shells or skeletons. These hard parts can form sedimentary rock.

Clastic Sedimentary Rocks Clastic (KLAH stik) rocks are sedimentary rocks that are made up of broken pieces of minerals and rock fragments. The broken pieces and fragments are called clasts. Clasts occur in a variety of sizes. Sandstone, which has a gritty texture, is a common clastic sedimentary rock. Clastic rocks are identified by clast size and shape. Some sedimentary rock is made up of rounded clasts. The large sediment pieces of these rocks were polished and rounded as they bounced along the bottom of a river channel. Breccia is a sedimentary rock that has angular fragments. Its sharp edges have not been worn away. The forces that created the angular fragments were not as strong or long-lived as the forces that created polished and rounded clasts.

Academic Vocabulary

cement
(verb) to unify or make firm as if by cement

Academic Vocabulary

classify
(verb) to place into groups based on ways that they are alike

Scientific Vocabulary

organic
(adjective) related to or from living things

Word Origin

clastic
from Greek *klastos,* means "broken"

Scientific Vocabulary

texture
(noun) a rock's grain size and the way the grains fit together

Sediment size alone cannot be used to determine the environment where a clastic rock formed. Sediment pieces deposited by a glacier can be as large as a house or as small as individual grains of sugar. The ice of a glacier can move both large and small clasts. Geologists also study the shape of clasts to help determine where the rock formed. A fast-flowing river can move large, rounded pieces of sediment. Small, gritty pieces of sediment are usually deposited in calm environments, such as on the seafloor or a lake bottom.

Chemical Sedimentary Rocks As river water flows through cracks in rock, it can dissolve minerals in the rock. Rivers eventually carry these dissolved minerals to the oceans. Dissolved minerals entering the ocean add to the saltiness of seawater. Water can become saturated with dissolved minerals. When this occurs, particles can crystallize out of water to form minerals. Chemical rocks form when minerals crystallize directly from water. Some common chemical rocks are rock salt, rock gypsum, and limestone.

Chemical sedimentary rocks often have interlocking crystalline textures, similar to the textures of many igneous rocks. One difference between them is that intrusive igneous rocks are composed of a variety of minerals and appear multicolored. Chemical sedimentary rocks are composed of one dominant mineral and are uniform in color. For example, granite is make of quartz, feldspar, and mica. But rock salt is composed only of the mineral halite.

Scientific Vocabulary
dominant
(adjective) most common

Biochemical Sedimentary Rocks Biochemical rock is a sedimentary rock that was formed by organisms or contains the remains of organisms. Limestone is the most common biochemical sedimentary rock. Marine organisms make their hard parts from dissolved minerals in the ocean. When these organisms die, their hard parts settle to the seafloor as sediment. This sediment is compacted and cemented to form limestone. Sometimes, the remains of these organisms are preserved as fossils in the sedimentary rock.

Scientific Vocabulary
property
(noun) a quality or feature of something

Geologists use chemical properties to identify varieties of limestone. Limestone that contains fossils is called fossiliferous (FAH suh LIH fuh rus) limestone. Limestone is classified as a type of carbonate rock because it contains the elements carbon and oxygen. Carbonate rocks will fizz in the presence of hydrochloric acid.

Natural Hazards

Earthquake Risks

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	All earthquakes occur at plate boundaries.	
	Earthquakes can be predicted.	

Key Concept

- Why are some areas more likely to experience an earthquake than others?

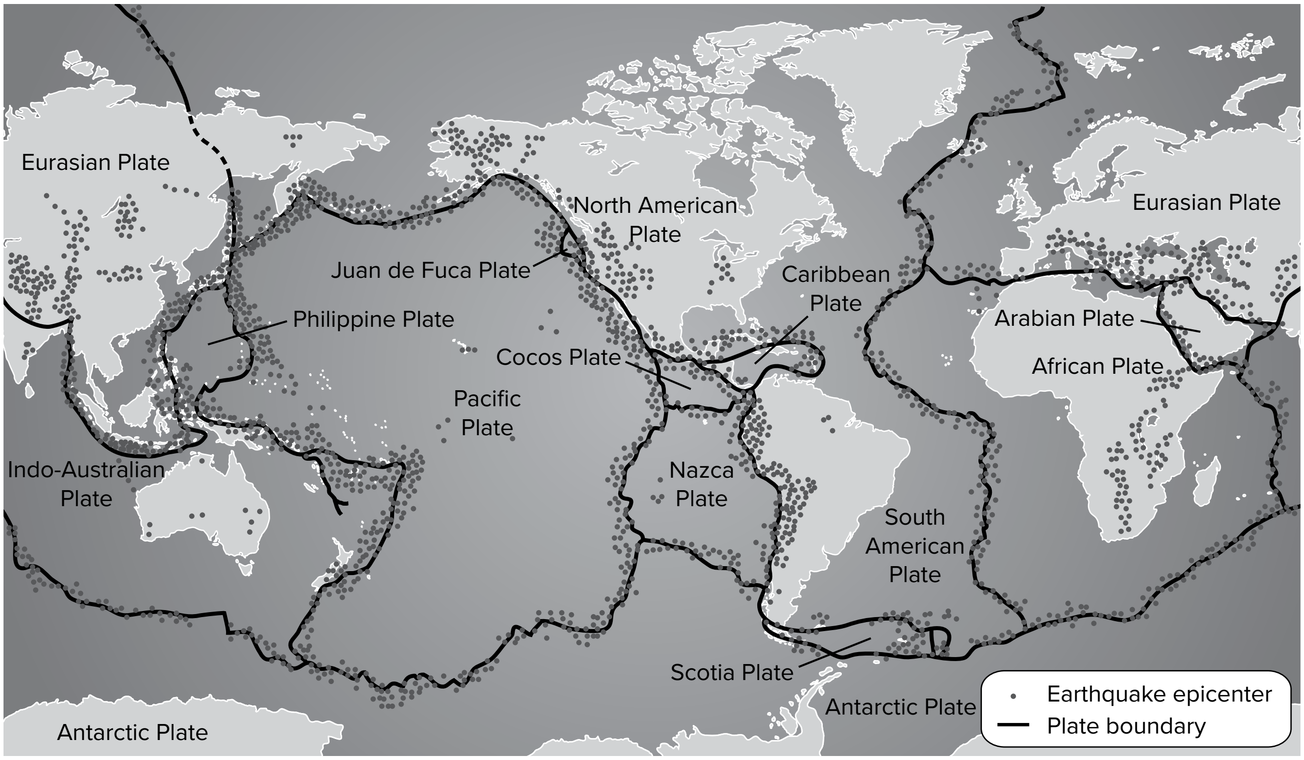
Read to Learn

Where do earthquakes occur?

The map below shows where earthquakes occur on Earth. Few earthquakes occur in the middle of a continent. Most earthquakes occur in the oceans and along the edges of continents where tectonic plates meet.

Mark the Text

Identify the Main Ideas Write a phrase beside each paragraph that summarizes the main point of the paragraph. Use the phrases to review the lesson.



Earthquakes and Plate Boundaries Notice the pattern in the map between earthquakes and plate boundaries. Earthquakes result from the buildup and release of stress along plate boundaries. Imagine bending a stick until it breaks. When the stick snaps, it vibrates, releasing energy. Earthquakes release energy in a similar way. Earthquakes are the vibrations in the ground that result from movement along breaks in Earth's crust. These breaks are called faults. A fault is a break in Earth's crust along which movement occurs.

Scientific Vocabulary
force
(noun) a push or a pull

Scientific Vocabulary
tectonic plates
(noun phrase) the large sheets of rock that form the surface of the Earth

Academic Vocabulary
vertical
(adjective) going straight up and down

Academic Vocabulary
horizontal
(adjective) flat and level

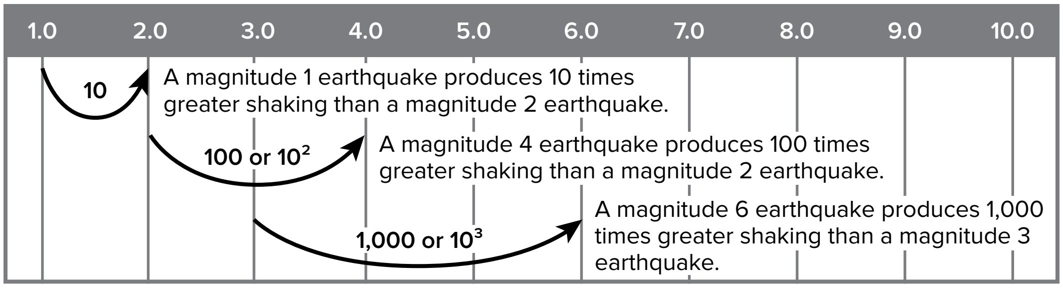
Why do rocks move along a fault? The forces that move tectonic plates also push and pull rocks along a fault. If these forces become large enough, the blocks of rock on either side of the fault can move past each other. The rocks might move vertically (up or down) or horizontally (sideways). The size of an earthquake depends on the amount of force applied to the fault. The greater the force applied to a fault, the greater the chance of a large and destructive earthquake occurring. Earthquakes can occur anywhere between Earth's surface and depths of greater than 600 km.

How are earthquakes measured?

Earthquakes range from barely noticeable vibrations to devastating waves of energy. Magnitude describes the amount of energy released by an earthquake. Scientists have developed several methods for measuring an earthquake.

Earthquake Magnitude *The* **Richter magnitude scale** *is a numerical rating system that measures the energy, or magnitude, of the largest seismic waves produced by an earthquake.* This scale is based on the height, or amplitude, of earthquake waves. The waves are measured using a tool called a seismograph.

The Richter scale uses the amount of ground motion at a given distance from an earthquake to determine magnitude. Each increase of one unit on the Richter scale represents 10 times the amount of ground motion. For example, a magnitude 8 earthquake produces 10 times greater shaking than a magnitude 7 earthquake does and 100 times greater shaking than a magnitude 6 earthquake does (10 × 10).



The differences in the amounts of energy released by earthquakes are even greater than the differences between the amplitude of their waves. For each increase of one unit on the scale, an earthquake releases 32 times more seismic energy. For example, a magnitude 6 earthquake releases approximately 1,024 times more energy than a magnitude 4 earthquake does (32 × 32).

Scientific Vocabulary
seismic
(adjective) relating to or caused by earthquakes

Moment Magnitude Scale When an earthquake is first reported, the Richter magnitude scale is usually applied first. After further study, the moment magnitude of the earthquake can be determined. *The* **moment magnitude scale** *is a rating scale that measures the energy released by an earthquake, taking into account the size of the fault that breaks, the motion that occurs along the fault, and the strength of the rocks that break during an earthquake.* Both scales measure the magnitude of an earthquake, and can produce similar readings. However, the moment magnitude scale uses newer technologies to produce a more accurate measurement of an earthquake.

Modified Mercalli Scale Another way to measure and describe an earthquake is to examine the amount of damage that results from the shaking. Shaking is directly related to the intensity, or strength, of an earthquake. *The* **Modified Mercalli scale** *measures the intensity of an earthquake based on descriptions of its effects on people and structures.* The scale ranges from I, an earthquake that people do not feel, to XII, an earthquake that destroys everything. The higher the number is, the greater the effects.

Earthquake Damage The amount of damage from an earthquake depends on the strength of the earthquake, the nature of surface materials, the design of structures, and the distance to the epicenter. The epicenter is the point on Earth's surface directly above where the energy from an earthquake is first released. Often, the area closest to the epicenter will suffer the most damage.

Scientific Vocabulary
factor
(noun) one thing that influences or causes a situation

Word Origin
frequency
from Latin *frequentia,* means "crowded"

Scientific Vocabulary
sway
(verb) to move back and forth

Scientific Vocabulary
debris
(adjective) the pieces that are left after something is destroyed

What factors affect the amount of damaged caused by an earthquake?

Earthquakes are relatively common along plate boundaries. An earthquake of magnitude 5 can devastate one area along a boundary, yet cause little harm to another area. Many factors determine how much damage an earthquake causes. These factors are called earthquake hazards. Scientists can help prevent some damage and loss of life by identifying an area's earthquake hazards.

Structural Failure A nearby guitar string tuned to the same frequency will begin to vibrate by itself in response to the sound waves traveling through the air. This is resonance. Seismic waves can generate the same kind of resonance in structures "tuned" to the same frequency as the seismic waves. This can result in structural failure. Structures can fail in different ways. They can fail when supporting walls are weak, or when the height of a building causes the building to violently sway. The table below describes two ways structures can fail.

Structural Damage	
Pancaking	Pancaking happens when the supporting walls of the ground floor of a building fail. This causes the upper floors to fall and collapse as they hit lower floors. The resulting debris resembles a stack of pancakes, so the process is called pancaking.
Building Height	Structural failure can result because of the height of a building. All structures have natural frequencies of vibration. Tall buildings sway with a natural period that depends on their heights and other factors. The higher the building, the longer its natural period of vibration is. Seismic waves with the same period as that of a tall building can cause the building to sway violently and collapse during an earthquake.

Land and Soil Failure In addition to factors related to a building's structure, an area's geology can contribute to structural failure. The shaking of an earthquake produces more damage in areas covered by loose sediment than it does in places built on solid bedrock.

Wet soil can be strong most of the time, but the shaking from an earthquake can cause it to act more like a liquid in a phenomenon called **liquefaction.** The liquid-like ground is not strong enough to support heavy buildings. So part of a building can sink into the ground, causing the building to collapse. Liquefaction is responsible for most damage to buildings after an earthquake occurs. In sloping areas, earthquakes can trigger massive landslides. *A* **landslide** *is the rapid downhill movement of soil, loose rocks, and boulders.*

Tsunami You have learned about the hazards associated with earthquakes that occur on land. But what happens when earthquakes occur on the ocean floor? *A* **tsunami** *is a large ocean wave generated by vertical motion of the seafloor during an earthquake.* A tsunami can be caused by an underwater earthquake. Far from shore, a tsunami has a short wave height, often less than 30 cm high. However, the wavelength can be hundreds of kilometers long. As a tsunami nears shore, it slows down and grows higher. Many tsunamis grow only a few meters high as they move onto shore. But some can rise as high as 30 m. The water from a tsunami is driven by powerful energy from an earthquake. As a result, tsunamis can cause major damage.

What determines if an area is at high risk for earthquakes?

Earthquakes can be devastating to places and people. For this reason, scientists work hard to determine when and where earthquakes will likely occur. An area's earthquake risk is based in part on how often it experiences an earthquake. Areas that experience the most earthquakes are at greater risk.

In the United States, the highest risk of earthquakes occurs near tectonic plate boundaries of the western states. The transform plate boundary in California and the convergent plate boundaries in Oregon, Washington, and Alaska have the highest earthquake risks. However, not all earthquakes occur near plate boundaries. Some parts of the central and eastern United States have high earthquake risk because of past activity. Their risk is based on their geologic history. Areas that experience earthquakes in the past will likely experience earthquakes again.

Academic Vocabulary

devastating
(adjective) causing great damage or harm

Science Use v. Common Use

transform
Science Use horizontal relative motion

Common Use to change

How can scientists predict when an earthquake will happen?

The probability that you will be affected by an earthquake depends on where you live and whether that area experiences tectonic activity. Scientists can tell you how likely it is that your area will experience an earthquake, but they cannot tell you exactly when the earthquake will occur.

Predicting Earthquakes Earthquakes cannot be predicted reliably. But scientists can determine where earthquakes are most likely to occur in the United States. This helps cities plan for future earthquake events. Cities can take action to reduce damage and loss of life. Areas at high risk for earthquakes help drive the need for earthquake safe technologies.

Scientific Vocabulary

probability
(noun) how likely something is to happen

Reducing the Impacts of Earthquakes Scientists evaluate risk in several ways. They study the probability that an earthquake will occur in an area. They study past earthquake activity, the geology around a fault, the population density, and the building design in an area. Engineers use these risk assessments to design buildings that can withstand the shaking during an earthquake. City and state government officials use risk assessments to help plan and prepare for future earthquakes. Given the damage earthquakes can cause, it is important for scientists to learn as much as possible about earthquakes to try and reduce their impact on society.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Natural Hazards

Volcano Risks

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Volcanic eruptions are rare.	
	Volcanoes can erupt anywhere on Earth.	

Key Concept

- What warning signs do volcanoes give off before an eruption?

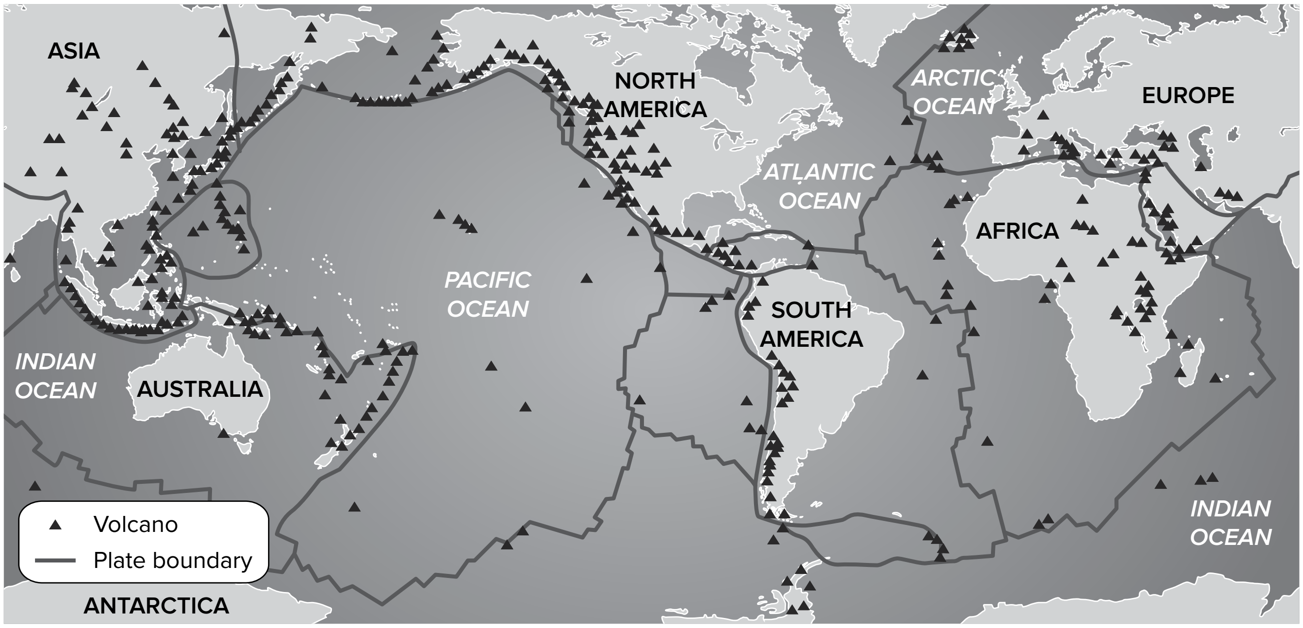
Read to Learn

Where do volcanoes occur?

A volcano is a vent in Earth's crust through which molten rock flows. In any given year, volcanoes will erupt in about 60 different places on Earth. The motion of Earth's tectonic plates causes the formation of volcanoes and volcanic eruptions. Volcanoes form at convergent boundaries and divergent boundaries, and away from plate boundaries at hot spots. The map below shows where volcanoes occur on Earth.

Study Coach

Make Flash Cards Think of a quiz question for each paragraph. Write the question on one side of a flash card. Write the answer on the other side. Work with a partner to quiz each other using the flash cards.

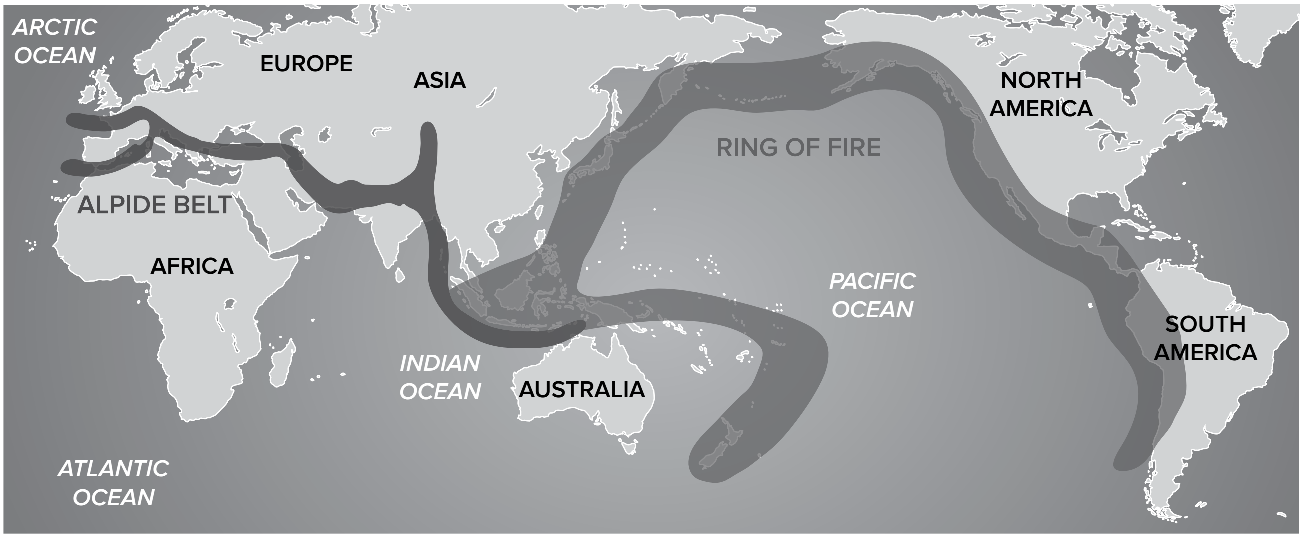


Major Volcano Belts Volcanoes associated with plate boundaries form two major belts. One belt surrounds the Pacific Ocean. It is called the Ring of Fire because volcanoes form a ring around most of the ocean. This area experiences a lot of earthquake and volcanic activity. The Ring of Fire stretches along the western coasts of North and South America, across the Aleutian Islands, and down the eastern coast of Asia. It is associated with convergent plate boundaries.

Scientific Vocabulary
convergent
(adjective) coming from different directions and meeting at the same point

Scientific Vocabulary
margin
(noun) boundary area

The Alpide belt, or Alpine-Himalayan belt, includes many mountain ranges. These ranges extend along the southern margin of Eurasia. They stretch from Java to Sumatra through the Himalayas, to the Mediterranean, and out into the Atlantic. The Alpide belt is smaller than the Pacific Ring of Fire. It includes two well-known volcanoes in Italy—Mount Etna and Mount Vesuvius. The Alpide Belt runs along the boundaries between the Eurasian, African, and Arabian plates. The tectonic plates here are also converging. The map below shows the two major volcano belts.



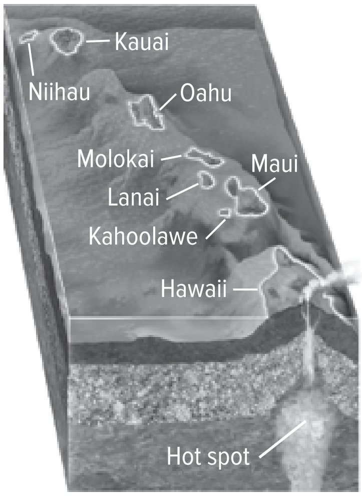
Hot Spots Not all volcanoes form on or near plate boundaries. Volcanoes that are not associated with plate boundaries are called hot spots. Geologists hypothesize that hot spots form above a rising current of hot mantle materials, called a plume. Plumes do not move. Instead, a volcano forms as a tectonic plate moves over the plume. As the moving plate carries a volcano away from the hot spot, the volcano becomes dormant, or inactive. As the plate continues to move, a chain of volcanoes forms. The oldest volcano will be the farthest away from the hot spot. The youngest volcano will be directly above the hot spot.

Scientific Vocabulary
hypothesize
(verb) to suggest a possible explanation that has not yet been proved to be true

The Hawaiian Islands are in the middle of the Pacific Plate, far from its edges. They sit on top of a hot spot under the Pacific Plate. Hot rock at these areas is forced toward the crust where it melts partially to form hot spot volcanoes. The Pacific Plate is moving over a stationary hot spot. Kauai, the oldest Hawaiian island, was once located where the Big Island, Hawaii, is situated today. As the plate moved, Kauai moved away from the hot spot and became a dormant volcano. As the Pacific Plate continued to move, the other Hawaiian Islands were formed. The Hawaiian Islands, shown in the diagram below, formed over a period of about 5 million years.

Scientific Vocabulary

dormant
(adjective) not active, but capable of becoming active



What factors affect the amount of damage caused by a volcano?

On average, about 60 different volcanoes erupt each year. Many factors determine the severity of damage produced by a volcano. These factors are called volcanic hazards. A violent volcanic eruption can have far-reaching impacts. Its hazards can affect all Earth systems. Volcanic ash can block sunlight and disrupt air travel. Lava flows can cover large areas of land. Volcanic gases can harm living things. Mudflows and pyroclastic flows can destroy villages and kill thousands of people. The table on the next page describes different types of volcanic hazards.

Scientific Vocabulary

eruption
(noun) an explosion, usually of volcanic rock

Science Use v. Common Use

concentrate

Science Use to increase the amount of a substance in a space

Common Use to fix one's efforts or attention on one thing

Volcanic Hazards	
Mudflows	The thermal energy produced during an eruption can melt snow and ice on a volcano's summit. This meltwater can then mix with mud and ash on the mountain to form mudflows. Mudflows, also called lahars, can sweep down the mountainside and bury everything below.
Lava Flows	The slow movement of lava is called a lava flow. Lava flows are usually associated with nonviolent eruptions. They move slowly, so they are rarely deadly. But lava flows can cause damage. Lava melts everything in its path as it flows. When the lava hardens, it can leave behind thick, black layers of rock. Farmland is lost, and homes cannot be rebuilt on the land.
Volcanic Ash	Explosive eruptions can spew volcanic ash high into the air. Volcanic ash is a mixture of tiny particles of rock and glass. Ash can cause airplane engines to stop in mid-flight. Ash in the air can cause breathing problems. Large quantities of ash can affect climate by blocking sunlight and cooling Earth's atmosphere.
Volcanic Gases	Magma contains dissolved gases such as small amounts of carbon dioxide and sulfur dioxide. Sulfur dioxide can irritate the skin and eyes, and carbon dioxide can be deadly. Carbon dioxide from an eruption can settle in low-lying areas and become highly concentrated. A concentration of 3 percent can cause headaches and dizziness. Concentrations of 15 percent can cause death.
Landslides	Landslides are the rapid downhill movement of soil, loose rocks, and boulders. During an eruption, the volcano shakes and rocks are weakened. Large landslides of rocks, from small particles to boulders, are common volcanic hazards.
Pyroclastic Flows	Explosive volcanoes can produce pyroclastic (pi roh KLAS tihk) flows—avalanches of hot gas, ash, and rock. These flows can travel at speeds of more than 100 km/h and reach temperatures above 1,000°C. A pyroclastic flow from Mount St. Helens killed 58 people.

What areas have the highest risk for volcanic hazards?

The United States has about 169 volcanoes that are classified as potentially active. These volcanoes all have the potential to erupt someday, and cause damage and loss of life. Where are these volcanoes located?

Most volcanoes in the United States are part of the Ring of Fire. Alaska, Hawaii, Washington, Oregon, and northern California all have active volcanoes. Mount Redoubt in Alaska is an active volcano. Mount St. Helens in Washington is also an active volcano. It exploded with a violent eruption in 1980.

Volcanic Risk Some places have a high risk of volcano hazards. In other places, the risk is low. Scientists evaluate the shape, eruptive style, and history of a volcano to determine its risk to an area. Other factors that determine risk include proximity to the volcano, valleys, wind direction, and the volcano's own unique features. The United States Geological Survey (USGS) estimates that about 80,000 people are at risk if Mount Rainier in Washington erupts again. They based this estimate on the number of people who currently live in areas impacted by earlier eruptions.

Academic Vocabulary
evaluate
(verb) to judge how good, useful, or successful something is

Can volcanic eruptions be predicted?

Recall that scientists cannot predict earthquakes, but what about volcanoes? They are caused by plate tectonics, too. Are they also difficult to predict? One factor that scientists consider when predicting a volcano is the past eruptive history of the volcano. Has it been inactive for hundreds of years or has it erupted fairly often over time? The risk of future eruptions is higher for volcanoes that erupt more often.

Academic Vocabulary
predict
(verb) to say that something will happen, before it happens

Predicting Volcanoes Volcanic eruptions can be predicted, but the exact moment of the eruption cannot be predicted. Most volcanoes give off warning signs before they erupt. This can help scientists issue advance warnings so people can evacuate the area.

The USGS operates volcano observatories. Because many people live near volcanoes, the USGS has developed a hazard assessment program that predicts where and when an eruption will occur. To predict a volcanic eruption, scientists monitor factors such as gas emissions, earthquake activity, and lava samples. The table on the next page explains how volcanoes are monitored.

Monitoring Volcanoes	
Gas	Scientists collect samples of gases released from volcano vents. They analyze these samples in the lab. Increases in certain gases can indicate an eruption may soon occur.
Deformation	Scientists use technology to monitor the ground around volcanoes and the volcano itself. Magma rises toward Earth's surface before an eruption. Pressure from the rising magma can cause to ground to tilt, sink, or bulge.
Ground Vibration	Earthquake activity beneath a volcano is a sign that an eruption may soon occur. Scientists place earthquake sensors near volcanoes.
Remote Sensing	Remote sensing involves using airplanes and satellites to gather data from above Earth. Scientists use remote sensing to determine how much heat a volcano is giving off and to make 3-D maps of the area. These data can be used to predict where lava might flow and how hot it will be.
Lava Collection	Flowing lava can be as hot as 1,170°C! To measure lava temperature or to collect a sample, scientists must wear protective gear and watch where they step. Samples are collected with heat-resistant materials. The samples are immediately cooled to prevent contamination. Samples of lava help scientists learn about the properties of magma before it erupts, and to compare samples from other active volcanoes to identify patterns.

Scientific Vocabulary

data
(noun) information and facts

Scientific Vocabulary

contaminate
(verb) to make something dirty or harmful by putting something bad in it

Reducing Volcanic Hazards Active volcanoes in the United States are regularly monitored for signs of activity. They are ranked on a scale that ranges from normal (non-erupting) to warning (major eruption predicted). Scientists cannot stop volcanic eruptions, but they can work with communities to reduce the negative effects of an eruption.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Natural Hazards

Severe Weather Risks

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	All severe weather is predictable.	
	The conditions that form a hurricane are the same as the conditions that form a tornado.	

Key Concept

- Why does the risk and type of severe weather vary from place to place?

Read to Learn

What is severe weather?

Some weather and climate events can cause major damage, injuries, and death. These events, such as floods, droughts, hurricanes, and tornadoes, are called severe weather.

The Cost of Severe Weather Severe weather causes billions of dollars in damage every year. Population growth and development make weather disasters even more costly. Two or three major weather disasters per year in the United States can cause more than a billion dollars in damage and threaten many lives. Scientists study the locations, magnitudes, and frequencies of severe weather events to predict, prepare for, and reduce their effects.

Study Coach

Summarize What You Read After you read each paragraph, write a sentence or two in your own words describing what you read. Use your sentences to review the lesson.

Scientific Vocabulary
magnitude
(noun) the size or importance of something

What locations in the United States are at the highest risk for hurricanes?

A **hurricane** *is an intense tropical storm with winds exceeding 119 km/h.* A hurricane can produce strong winds, heavy downpours, lightning, and even tornadoes.

Hurricane Formation Hurricanes usually start as thunderstorms near the west coast of northern Africa. Warm ocean water provides energy for thunderstorms to become tropical storms. Moist air adds water vapor to the growing storms. The storms move west across the Atlantic Ocean and then north along the eastern U.S. coast or into the Caribbean Sea or the Gulf of Mexico.

Word Origin
hurricane
(noun) from Spanish *huracan*, means "tempest"

Academic Vocabulary
monitor
(verb) to watch a situation to see how it changes

Academic Vocabulary
data
(noun) information and facts

Scientific Vocabulary
computer model
(noun phrase) a system or process created on a computer to assist in calculations and predictions

Scientists monitor hurricanes with satellites, ships, and ocean buoys. Sometimes crews fly airplanes into hurricanes to collect data. Radar is used when a storm is close to land. Data about the storm are put into computer models to help scientists predict the storm's path and how strong it will become.

What types of damage do hurricanes cause?

The extent of a hurricane's damage depends on the strength of the hurricane and the characteristics of the coastal area. Winds destroy trees, topple power lines, and blow roofs off buildings. Scientists use the Saffir–Simpson hurricane scale to measure the strength of hurricanes.

Saffir-Simpson Hurricane Scale The Saffir–Simpson hurricane scale is based on wind strength and damage caused by hurricanes. Each category of hurricane is more devastating. Hurricanes are ranked from a Category 1 (least amount of damage) to a Category 5 (most amount of damage). The table below shows how hurricanes are categorized using the Saffir-Simpson hurricane scale.

Saffir-Simpson Hurricane Scale	
Category 1 Hurricane	Hurricanes in this category have wind speeds of 119-153 km/h. Winds can damage unanchored mobile homes. Some coastal flooding and minor pier damage may occur.
Category 2 Hurricane	Hurricanes in this category have wind speeds of 154-177 km/h. Roofs, doors, and windows may be damaged. Flooding can damage piers, and some trees are blown down.
Category 3 Hurricane	Hurricanes in this category have wind speeds of 178-209 km/h. Large trees may be blown down. Flooding along the coast can destroy small structures.
Category 4 Hurricane	Hurricanes in this category have wind speeds of 210-249 km/h. Roofs can collapse. Coastal areas experience major beach erosion, and flooding occurs far inland.
Category 5 Hurricane	Hurricanes in this category have wind speeds greater than 249 km/h. Catastrophic winds destroy homes and businesses, and damage ecosystems. Major flooding damages roads and other structures along the shore. Large-scale evacuations may be necessary to keep people safe.

Hurricane Damage Hurricanes cause strong winds, heavy rains, and storm surges. A storm surge is a large wave pushed by high winds onto land. A storm surge can be 2–3 m high, and cause widespread flooding. The water can move sand, flood coastal towns and ecosystems, and damage buildings. Beaches and coastal highways can be washed away. Even a building designed to withstand strong winds can be destroyed when water weakens its foundation.

What locations in the United States are at highest risk for tornadoes?

A **tornado** *is a violent, whirling column of air in contact with the ground.* Most tornadoes occur in an area in the central United States. This area has been named Tornado Alley. It extends from Nebraska to Texas.

Tornado Risk Because of its geography, more tornadoes occur in North America than anywhere else on Earth. The southeast borders the warm Gulf of Mexico. The northeast extends into the Arctic. Much of the eastern part of the continent is fairly flat. As a result, warm, moist air moving north can collide with cold air blowing south from Canada. These conditions are ideal for severe thunderstorms and tornadoes, especially in Tornado Alley.

What kind of damage do tornadoes cause?

Dr. Ted Fujita developed a scale to classify tornadoes based on the damage they cause. The scale is called the Enhanced Fujita Damage Intensity scale. Each category of tornado is more damaging.

Tornado Damage On the Enhanced Fujita Damage Intensity Scale, EF–0 tornadoes cause light damage. They can break tree branches and damage billboards. EF–1 though EF–4 tornadoes cause moderate to devastating damage. They can tear roofs from homes, derail trains, and throw vehicles in the air. EF–5 tornadoes cause incredible damage. They can demolish concrete and steel buildings and pull the bark from trees. The table on the next page explains how tornadoes are categorized.

Scientific Vocabulary

scale
(noun) a rule by which something can be measured or judged

Scientific Vocabulary

demolish
(verb) to break into pieces

Enhanced Fujita Damage Intensity Scale		
Category	**Wind Speed**	**Damage**
EF–0	105–137 km/h (65–85 mi/h)	**Light Damage** Chimneys are damaged; tree branches are broken; shallow-rooted trees are toppled.
EF–1	138–177 km/h (86–110 mi/h)	**Moderate Damage** Roof surfaces are peeled off; windows are broken; tree trunks are snapped.
EF–2	178–218 km/h (111–135 mi/h)	**Considerable Damage** Roof structures are damaged; manufactured homes are destroyed.
EF–3	219–266 km/h (136–165 mi/h	**Severe Damage** Roofs and some walls are torn from structures; small buildings are destroyed; most trees in forests are uprooted.
EF–4	267–322 km/h (166–200 mi/h)	**Devastating Damage** Some structures are lifted from their foundations and blown some distance. Cars also are blown some distance. Large debris becomes airborne.
EF–5	>322 km/h (>200 mi/h)	**Incredible Damage** Strong frame houses are lifted from foundations; reinforced concrete structures are damaged. Automobile-sized debris becomes airborne. Trees are completely debarked.

Tornado Safety Tornadoes can be dangerous. To help keep people safe, forecasters issue a tornado watch when conditions are right for tornado formation. When a tornado is spotted, forecasters issue a tornado warning. When a tornado warning is issued for your area, go inside a sturdy building. If possible, go to the basement. If an underground shelter is not available, move to an interior room or a hallway on the lowest floor and get under a sturdy piece of furniture. The National Weather Service stresses that some tornadoes develop too quickly for warnings to be issued. That's why it is best to seek shelter at the first sign of threatening skies.

Where do floods and droughts occur?

Tornadoes and hurricanes are severe weather events. Floods and droughts are some effects of severe weather. *A* **flood** *occurs when a large volume of water overflows its boundaries.* Rivers, lakes, and even oceans can flood. *A* **drought** *is an extended period of well-below-average rainfall.* Droughts damage crops and decrease water supplies. They can lead to wildfires and heat-related illnesses.

Floods Floods can be caused by heavy rains from a single powerful storm. Often, this can lead to flash floods, which are sudden local floods that occur with little warning. Floods can also be caused by steady rains from a mild storm. Floods can occur anywhere a river or stream overflows its banks. They cause the most weather-related deaths in the United States. Billions of dollars worth of property is damaged each year.

Flood Dynamics Rivers and streams are dynamic systems. They change as the amount of water entering the system changes. A flood happens when too much water enters the system. The water cannot be contained within the streambed and it overflows as a flood. Flooding can be caused by natural processes or human-caused events. The table below summarizes some of the factors that cause floods.

Factors that Cause Floods	
Snowmelt	Flooding can occur when warm temperatures or rainfall melt snow and ice in the drainage basin of a river or stream.
Dam Failure	Dams are both natural and human-made features. Poorly built dams have failed, releasing floodwaters downstream.
Local Heavy Precipitation	Some floods are caused by heavy rains over a short period of time, resulting in flash flooding.
Volcanic Eruption	Some volcano peaks are covered with snow for all or part of the year. An eruption can melt the snow and cause flooding and mudflows.
Urbanization	As cities replace farms and forests, more land is paved for streets, buildings, sidewalks, and parking lots. Water can run off the paved areas, leading to flooding.
Regional Precipitation	Regional floods occur when high precipitation falls over a large area for days, weeks, or months. This can happen during a hurricane or monsoon.

Not all of the effects of floods are negative. Wetlands and other ecosystems along streams develop in part from regular flooding. Flooding helps keep these ecosystems healthy.

Droughts Droughts are caused by high-pressure systems that remain over an area for weeks or months. The sinking air stops moisture from rising, and cloud formation cannot occur.

Drought Risk Similar to floods, nearly all places in the United States can experience droughts or dry conditions. Droughts can occur during every month of the year. However, they are more common in summer because many places receive most of their precipitation then. In summer, droughts are often associated with heat waves, or extended periods of above-normal temperatures.

Droughts last longer than floods. They occur when high-pressure systems linger over an area for weeks or months at a time. They last until global weather patterns shift, and the high-pressure system moves on.

Academic Vocabulary

dynamic
(adjective) characterized by constant change

Word Origin

precipitation
from Latin *praecipitationem,* means "act or fact of falling headlong"

Scientific Vocabulary

ecosytem
(noun) all the living and nonliving things in a given area

What hazards are associated with floods and droughts?

We need rain to grow food. We enjoy clear, sunny days. But too much of any type of weather—wet, warm, or dry—can have serious consequences.

Flood Hazards Floods can cause widespread property damage, loss of life, and loss of habitat. In 2017, Hurricane Harvey dropped more than 50 inches of rain in some areas of Texas in a matter of days. This led to record-breaking floods and severe property damage.

Drought Hazards Too much dry weather can cause nearly as much damage as too much rainfall. Drought hazards range from wildfires to soil erosion. Some of the hazards can affect ecosystems for months or years. The table below describes a number of drought hazards.

Academic Vocabulary
lack
(verb) not having any or enough of something

Drought Hazards	
Soil Erosion	During a drought, changing wind patterns can block fronts from reaching an area, preventing rainfall. Less water enters rivers and other ecosystems. If plants die because of lack of water, the top layer of soil can be removed by wind.
Wildfires	Lightning strikes can start wildfires, especially during droughts. Every year, thousands of acres of wilderness and many homes are destroyed by fire. The effects of wildfires continue long after the fire is put out. They include increased risk of floods, soil erosion, landslides, and reduced water quality.
Decrease in Water Supply	The lack of rain during a drought causes the flow of streams and rivers to decrease. Water levels in lakes and reservoirs fall. People have to dig deeper wells to reach groundwater.
Agricultural Impact	Dry conditions can have a devastating effect on livestock and crops. The amount of water available for animals and crop irrigation decreases. Harvests may be small and food prices may rise.

Scientists can determine past patterns of droughts and heavy rainfall using dendrochronology. Dendrochronology is the study of tree rings. Each tree ring represents one year of growth. Live trees add a new growth ring each year. These rings vary in size. The width of the rings can be used to determine the past climate of an area. Wide rings form during wet or warm years, and narrow rings form during cool or dry years.

How do scientists predict severe weather?

Technology ranging from weather balloons to radar is used to help forecast and predict severe weather. Different technology is used to predict different kinds of severe weather.

Predicting Severe Weather Severe weather can be predicted probabilistically. Scientists analyze weather patterns to predict where and when severe weather will occur. Some severe weather forecasts may be given days, hours, or even minutes before the actual event.

For example, hurricanes begin as a low-pressure system that develops over warm ocean waters. A tropical depression forms and begins rotating. If the storm continues to build, it eventually becomes a hurricane. This process could take days to develop.

In contrast, tornadoes form quickly during thunderstorms and hurricanes. During a thunderstorm, air warmed at Earth's surface rises quickly. Sometimes rising air can rotate and form a funnel in the clouds. The spinning funnel grows downward and sometimes reaches Earth's surface. This event can occur in minutes.

Data-collecting technologies are used to help forecast severe weather. These technologies help meteorologists predict when and where a severe weather event might strike.

Reducing the Effects of Severe Weather Tornadoes, hurricanes, floods, and droughts are all dangerous weather events. In many cases, the best way to reduce the effects of severe weather is to get people to safety. People can help by taking safety measures, such as seeking shelter or moving out of the storm's path. Government agencies can help, too, by making sure that people are kept updated on severe weather, and that shelters are ready and evacuation routes are planned ahead of time.

Academic Vocabulary

evacuate
(verb) to leave a dangerous place

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Distribution of Earth's Resources

Natural Resources

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Some of Earth's resources can be replaced faster than they are used.	
	Nonrenewable resources include water and air.	

Key Concept

- How do people use resources from Earth's land, ocean, atmosphere, and biosphere?

Read to Learn

What are natural resources?

The smallest microbe and the largest whale rely on materials and energy from the environment. The same is true for humans. People depend on the environment for food, clothing, and fuels to heat and light their homes. Almost everything you use comes from natural resources. *A* **natural resource** *is something on Earth that living things use to meet their needs.*

Natural Resources Living things on Earth need resources to survive. The term *resource* covers everything we use, including air, soil, timber, and water; fuel resources, such as coal, oil, and gas; and mineral resources, such as sand and gravel.

Study Coach

Building Vocabulary
Work with another student to write a question about each vocabulary term in this lesson. Answer the questions and compare your answers. Reread the test to clarify the meaning of the terms.

How do humans depend on energy resources?

Where does the electricity for electric lights come from? It might come from a power plant that burns coal or natural gas. Or it might come from rooftop solar panels made with silicon, a mineral found in sand.

Think about all the times you use energy in one day. You use it for electricity, transportation, and other needs. That is one reason it is important to know where energy comes from and how much is available for humans to use.

Scientific Vocabulary
depend on
(phrasal verb) to need; be decided by

Scientific Vocabulary
fossil fuels
(noun phrase) fuels such as oil and coal that are formed over millions of years

Energy Resources Energy can come from sunlight, fossil fuels, flowing water, or other sources. The power for lights, computers, appliances, and other electrical devices comes from energy resources. Nearly all manufactured products are made using energy resources. Energy resources provide the fuel you need to get from one place to another, whether it's in a car, bus, plane, or boat. Energy resources keep you warm in cold weather and cool in warm weather.

Physical Science Connection Coal, oil (also called petroleum), and natural gas are fossil fuels. They are important energy resources. They are nonrenewable because they form over millions of years. Ancient plants stored energy from the Sun as chemical energy in their molecules. This chemical energy was passed on to the animals that ate the plants. Over millions of years, the remains of these ancient plants and animals turned into fossil fuels.

How do humans depend on land resources?

People use soil for growing crops. They harvest wood from forests and mine minerals from the land. In each of these cases, people use land as a natural resource to meet their needs.

Land Resources No matter where you live, you and all living organisms use land for living space. Living space includes natural habitats, as well as the land on which buildings and streets are built. People use land to create green spaces, or areas of natural vegetation in urban areas. Cities make up only a small percentage of land use in the United States. Most land is used for agriculture, grasslands, and forests.

Scientific Vocabulary
agriculture
(noun) the science, work, or practice of farming

The wood used to make furniture, paper, cardboard, and other timber products comes from forests that cover the land. Forests covered much of the eastern United States in 1650. By 1920, many of the forests had been cut. Forests have regrown, but the new trees are not as tall. Also, the forests are not as complex as the original forests.

Academic Vocabulary
complex
(adjective) having many different and connected parts

Today, about one-fifth of the land in the United States is used for growing crops, and about one-fourth is used for grazing livestock. Though the amount of land used for agriculture has decreased, crop production has increased in some areas because of advances in farming techniques.

Academic Vocabulary
technique
(noun) a particular way of doing something

Certain minerals are mined from the ground to make products you use every day. These minerals are called ores. **Ores** *are deposits of minerals that are large enough to be mined for a profit.* The average person uses 22,000 kg of mineral resources each year. For example, copper is used in electric wiring and plumbing fixtures, and quartz is used to make glass and ceramics. Car and food manufacturers, farms, and the construction industry use mineral resources. All these resources are mined from Earth.

Word Origin
ore
from Old English *ora*, means "unworked metal"

How do humans depend on air and water resources?

Water is a crucial resource for living things. Like air, we cannot survive without it. In most places in the United States, people are fortunate to have access to clean water and clean air.

Scientific Vocabulary
crucial
(adjective) extremely important

Importance of Air and Water Using some natural resources, such as fossil fuels and minerals, makes life easier. You would miss them if they were gone, but you would still survive. Air and water, on the other hand, are resources that you cannot live without. Most living organisms can survive only a few minutes without air. Your lungs take in oxygen from the air and pass it on to the blood. Oxygen helps your body provide energy for your cells.

Water is needed for many life functions. Water is the main component of blood. Water also helps protect body tissues, helps maintain body temperature, and plays a role in many chemical reactions, such as the digestion of food.

In addition to drinking water, people use freshwater for daily uses such as cooking and cleaning. Water is also used for agriculture, transportation, and recreation. Plants need water to grow. Freshwater is used to irrigate crops. Water is used for mining, manufacturing, and generating power. Rivers, lakes, and oceans are used to transport goods and people from place to place. Fish and seafood are major sources of protein in many places. They come from oceans, lakes, and rivers.

How long will natural resources be around?

Every day you use energy resources when you turn on lights or play a video game. You use water resources when you brush your teeth. You eat plants grown on land. You go places in a bus or car made from minerals and powered by energy resources. You inhale and exhale air every minute of the day. Is there an unlimited supply of natural resources? Or could we someday run out of them?

Scientific Vocabulary

atmosphere
(noun) the mixture of gases that surrounds Earth

Renewable and Nonrenewable Resources Supplies of many natural resources are constantly renewed by natural cycles. The water cycle is an example. When liquid water evaporates, it rises into the atmosphere as water vapor. Water vapor condenses and falls back to the ground as rain or snow. Water is a renewable resource.

Renewable resources *are natural resources that can be replaced by natural processes in a relatively short amount of time.* Renewable resources include water, air, land, and living things.

Renewable resources are replaced by natural processes. Still, they must be used wisely. If people use any resource faster than it is replaced, the resource can eventually run out. A forest cannot be renewed if the trees are cut down faster than they can be replaced.

Do you travel in a vehicle that runs on gasoline? Do you drink soda from aluminum cans or water from plastic bottles? Gasoline, aluminum, and plastic are made from nonrenewable resources.

Nonrenewable resources *are natural resources that are being used up faster than they can be replaced by natural processes.* Nonrenewable resources form slowly, usually over thousands or millions of years. In addition, the environment in which they formed may occur only rarely in Earth's history. If these resources are used faster than they form, they will run out. Nonrenewable resources include fossil fuels and minerals.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Distribution of Earth's Resources

Distribution of Resources

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	All places on Earth have equal amounts of soil.	
	Fossil fuels are being replaced quickly.	

Key Concept

- Why are resources distributed unevenly on Earth?

Read to Learn

Where are minerals found on Earth?

Minerals are the basic building blocks for soil, rocks, and metals. Metal products such as airplanes and zippers come from minerals. The salt you put on your eggs is a mineral. Even the exterior of the Statue of Liberty is coated in a mineral—copper! How do these important resources form and where are they found?

Hydrothermal Deposits Many copper deposits are found near tectonic plate boundaries. Metallic minerals, including copper, gold, silver, lead, iron, and zinc, are associated with plate tectonics. Intense heat from tectonic activity produces hot, mineral-rich fluids that chemically react with rocks. Minerals that crystallize from these fluids are called hydrothermal deposits. Some deposits are found near subduction zones. **Subduction zones** *are areas where one tectonic place sinks beneath another.* Other deposits are part of ancient igneous intrusions. These intrusions formed in Earth's geologic past when landmasses and plate boundaries were different from today.

Minerals are also found along boundaries where plates pull apart. Water moves through cracks in the rocks, carrying dissolved minerals. The water can flow out of a hydrothermal vent, or opening, on the ocean floor. Minerals precipitate out of solution and are deposited around the vent. These minerals form large chimney structures.

Study Coach

Make an Outline
Summarize the information in the lesson by making an outline. Use the main headings in the lesson as the main headings in your outline. Use your outline to review the lesson.

Academic Vocabulary
react
(verb) for a chemical substance to change after coming into contact with another substance

Scientific Vocabulary
hydrothermal
(adjective) relating to hot water

Scientific Vocabulary
precipitate
(verb) to cause a solid to form out of a liquid

Scientific Vocabulary

mineral
(noun) a substance formed naturally in Earth, such as gold

Science Use v. Common Use

element
Science Use a substance that consists of atoms of only one kind
Common Use a part of something

Minerals from Cool Solutions Not all minerals are associated with plate tectonics. Sometimes minerals can crystallize as water evaporates. As water seeps into the ground or flows over Earth's surface, it interacts with minerals in rocks and soil. The water dissolves some of these minerals and picks up elements such as potassium, calcium, iron, and silicon. These elements become dissolved solids. During dry conditions, the water evaporates. The solids crystallize out of the water and form minerals. The mineral halite—common rock salt—forms when water evaporates.

Distribution of Minerals Certain geoscience processes form minerals. These processes do not occur everywhere on Earth. For that reason, minerals are not distributed evenly on Earth. Many minerals that are mined on land actually formed on the ocean floor. The rocks were uplifted from the seafloor to become dry land. For example, the copper mines on the island of Cyprus in the Mediterranean Sea formed by hydrothermal activity millions of years ago.

Most minerals are limited and nonrenewable. They usually take a long time to form—much longer than the length of a human lifetime. Therefore, it's important to conserve mineral resources so some are available for future generations.

History Connection Minerals are still being found today. In 1974, a new mineral was discovered in the Dominican Republic. Called larimar, the mineral is now adding to the country's economy. The turquoise-colored mineral is found in only one place in a fairly remote region. Larimar formed as molten material from volcanoes cooled and crystallized. It is used in jewelry of all kinds.

Which locations have the most soil?

Have you ever grown a garden? If so, you have used one of the most important natural resources on Earth—soil. **Soil** *is the loose, weathered material in which plants grow.* How does this important resource form?

Scientific Vocabulary

bacteria
(noun) very small living things that cannot be seen without a microscope

Soil Formation If you dig down into ground, you would see that soil has a layered structure. At some point in your digging, you would likely hit solid rock. Soil forms directly on top of the rock from which it is made. In most areas it takes 80 to 400 years to form about 1 cm of topsoil. Soil begins forming when weathering breaks down rock. Water, ice, and living things crack and break the rock. Plants, bacteria, and burrowing organisms help break down rocks into small pieces.

Factors Affecting Soil Formation The quality and composition of soil vary from place to place, depending on how the soil formed. Soil formation depends on five factors. These factors include parent material, climate, topography, living things, and time.

Parent Material Parent material is the starting material of soil. It is made of the rock or sediment that weathers and forms soil. Soil can develop from rock that weathered in the same place where the rock first formed. It can also develop from weathered pieces of rock that were carried by wind or water from another location. The particle size and the type of parent material help determine the properties of the soil in an area.

Scientific Vocabulary
sediment
(noun) rock material that has been broken down

Climate Temperature and precipitation help determine an area's climate, or average weather. If the climate is warm and wet, soil can form quickly. But heavy rains carry away nutrients, so the soil is not good for growing plants. Rates of weathering tend to be low in dry climates and cold climates, so soils form slowly in these places. Areas with moderate temperatures and moderate amounts of precipitation tend to have rich soils.

Academic Vocabulary
moderate
(adjective) not too much or little of something; not too hot or cold

Topography Topography is the shape and steepness of the landscape. The topography of an area determines whether water flows over Earth's surface or seeps into the ground. In flat landscapes, most of the water enters the soil. In steep landscapes, most of the water flows downhill. It carries soil with it, leaving some slopes bare of soil. The soil is often deposited at the bottom of the slope. Here, soils tend to be thick.

Living Things The organisms in soil range from tiny bacteria to furry moles. Living things help speed up the process of soil formation. They form passages for water to move through. When they decompose, they add organic matter to the soil.

Time Weathering constantly acts on rock and sediment. Soil formation is a slow, but steady process. Mature soils develop layers as new soil forms on top of older soil. Each layer has different characteristics as organic matter is added or as water carries elements and nutrients downward.

Warm, wet climates produce soil fastest. But heavy rains can wash away nutrients. The thickest, richest soils tend to be found in areas with moderate climates and gentle topography, where soils have been forming for a long time with little erosion.

Why are some regions rich in fossil fuels?

You might turn on a lamp to read, turn on a heater to stay warm, or ride the bus to school. In the United States, the energy to power lamps, heat houses, and run vehicles probably comes from nonrenewable energy resources, such as fossil fuels. Coal, oil, and natural gas are fossil fuels. They are a very concentrated form of chemical energy that easily changes into other forms of energy.

Academic Vocabulary
concentrated
(adjective) to be present in large amounts

Fossil Fuel Formation The fossil fuels used today formed from the remains of prehistoric organisms. The decayed remains of these organisms were buried by layers of sediment and changed chemically by extreme temperatures and pressure. The type of fossil fuel that formed depended on three factors:

- the type of organic matter,
- the temperature and pressure, and
- the length of time the organic matter was buried.

The process that formed oil and natural gas is similar to the process that formed coal. However, oil and natural gas formation involves different types of organisms.

Scientists theorize that oil and natural gas formed from the remains of plankton that lived in oceans. The plankton died and fell to the ocean floor. There, layers of sediment buried their remains. Bacteria decomposed the organic matter, and then pressure and extreme temperatures acted on it. During this process, thick, liquid oil formed first. If the temperature and pressure were great enough, natural gas formed.

Coal formation involved plants. Plants, such as ferns and trees, grew in prehistoric swamps. The first step of coal formation occurred when those plants died. Bacteria, extreme temperatures, and pressure acted on the plant remains over time. Eventually, a brownish material, called peat, formed. Given the right conditions, peat can change into harder and harder types of coal.

Scientific Vocabulary
deposit
(noun) an amount of a substance that exists naturally in a specific area

Geologic Traps Oil and natural gas were formed from the remains of plankton that lived in oceans. Today, deposits of oil and natural gas can be found beneath land as well as oceans. This is because Earth's tectonic plates have shifted greatly over millions of years since the plankton existed. A layer of impermeable rock, called a geologic trap, prevents the oil and gas from escaping to the surface.

Scientific Vocabulary
impermeable
(adjective) not allowing something (like water or gas) to pass through

Location of Fossil Fuels Given the conditions necessary for their formation, fossil fuels are not distributed evenly around the world. The existence of fossil fuels in an area depends on the geologic history of the area. Places rich in coal were swamps hundreds of millions of years ago.

Places rich in oil and natural gas were covered by ancient oceans. If these environmental conditions did not exist in an area, fossil fuels did not form. Oil and natural gas must also be in places with natural geologic traps. Otherwise, they cannot be extracted from the ground.

According to the American Coal Foundation, each person in the United States uses about 3.8 tons of coal each year. That's enough to fill three pickup trucks! This includes coal used to provide heat and electricity, as well as coal used in manufacturing and other industrial processes.

Fossil Fuels and Time Fossil fuels continue to form in the same ways that they did in the past. The amount of time required to form these resources is much longer than a human lifetime. Therefore, these resources are limited to current and near-future generations.

Scientific Vocabulary
swamp
(noun) a wetland occasionally or partially covered with water

Where is abundant groundwater located?

The freshwater beneath Earth's surface is much more plentiful than the freshwater in lakes and streams. Water that lies below ground is called groundwater. It makes up about one-third of Earth's freshwater. Although Earth's crust appears solid, it is composed of soil, sediment, and rock that contain countless small openings, called pore spaces.

Porosity *The amount of pore space in a material is its* **porosity.** The greater the porosity, the more water that can be stored in the material. Well-sorted sediment is all about the same size. Its porosity is greater than that of poorly sorted sediment. In poorly sorted sediment, smaller particles occupy some of the pore spaces and reduce the porosity of the sediment. In the same way, the materials that bind the grains of sedimentary rocks together reduce the rocks' porosity.

Word Origin
pore
from Greek *poros,* means "passage"

Permeability *The measure of water's ability of flow through sediment and rock is called* **permeability.** Permeability depends on pore size and the connections between the pores.

Even if there is a lot of pore space in a rock, the pores must form connected pathways for water to flow easily through rock.

Groundwater Storage People often bring groundwater to Earth's surface by drilling wells. Wells are usually drilled into an aquifer—an area of permeable sediment or rock that holds significant amounts of water.

Groundwater Distribution Groundwater supplies are not distributed evenly across Earth. They are the result of past and current geologic processes, including the water cycle. Recall that water continually cycles between Earth's surface and atmosphere. Processes in the water cycle such as precipitation and infiltration affect groundwater distribution. Features such as mountains influence where precipitation occurs. Warm, moist air flowing up a mountain can cool, condense, and form rain along the windward side of the mountain.

The rock cycle also plays an important role in the distribution of groundwater. The porosity and permeability of materials beneath Earth's surface influence where water collects underground. Sedimentary rock tends to be porous and allows water to flow freely. The best groundwater deposits are in valleys where a large amount of sediment has collected. These valleys often contain porous rocks. Plate motions typically determine the shape of these deposits. The depth of impermeable rock, such as granite, can support or block the formation of groundwater deposits.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Distribution of Earth's Resources

Depletion of Resources

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Demand for energy resources is decreasing.	
	Humans can change the distribution of resources on Earth.	

Key Concept

- How do humans impact resource distribution and availability?

Read to Learn

How does mining affect mineral distribution?

Recall that minerals are not evenly distributed around Earth. The extraction and use of minerals further impacts how much and where minerals are found. How do people extract different minerals?

Mining *is the process by which commercially valuable resources are removed from Earth.* These resources include ores, such as metals; precious stones, such as diamonds; and building stones, such as granite.

Dwindling Deposits As with all natural resources, the demand for minerals continues to increase. The increase is due to population growth, the high use of resources in industrialized countries, and the industrialization of developing countries. Most minerals are nonrenewable, so this increase in resource use is not sustainable. How long will the world's mineral reserves last?

Mineral Supplies For years scientists have warned that important mineral reserves may be depleted because of increased demand. However, depletion has not occurred because total reserves keep increasing.

Mark the Text

Building Vocabulary
As you read, underline the words and phrases that you do not understand. When you finish reading, discuss these words and phrases with another student or your teacher.

Scientific Vocabulary
extract
(verb) to remove or take out of something else

Scientific Vocabulary
deplete
(verb) to greatly reduce the amount of something; use up

The increase is due in part to improved technology that allows scientists to locate new mineral deposits. Also, technological advances in mining have made many low-grade deposits cheaper to extract. This does not mean that present rates of mineral use can go on forever. Even if additional supplies are found, minerals will not be available to future generations if rates of consumption remain high.

Academic Vocabulary
consumption
(noun) the amount of something that is used

How does the extraction of energy resources change their distributions?

Mineral resources are used to make the steel and concrete that help build cities and factories. But energy resources are used to produce the steel and concrete. Energy resources power cities, towns, homes, and factories. About 88% of the energy used by people comes from burning fossil fuels. How are fossil fuels extracted?

Fossil Fuel Extraction Coal can be mined much like a mineral. Deposits of natural gas and oil can be extracted by drilling down into the ground. The deposits are often trapped between layers of impermeable rock. However, mining disturbs habitats and changes the landscape. If proper regulations are not followed, water can be polluted by runoff that contains chemicals from mines.

Scientific Vocabulary
runoff
(noun) rainwater that does not soak into the ground and flows over Earth's surface

Like minerals, fossil fuels are not distributed evenly around Earth. They are also nonrenewable. No one knows for sure when supplies will be gone.

Supply and Demand Coal is more abundant than oil or natural gas. Reserves of coal are projected to last more than 275 years. But natural gas and oil reserves may run out much sooner. Fossil fuels are forming all the time. However, we use them much more quickly than nature replaces them. They will be depleted unless more deposits are found, technology improves, or rates of usage change.

Scientific Vocabulary
reserve
(noun) a supply of something that is stored so it can be used later

How do humans impact groundwater resources?

Groundwater is the primary source of water for more than two billion people worldwide. Nearly half of all Americans depend on groundwater for drinking and other domestic purposes.

Groundwater Depletion Groundwater overdraft is occurring in many areas of the world. **Groundwater overdraft** *happens when groundwater is being withdrawn from aquifers faster than natural recharge can replace it.* Excessive pumping for irrigation and other uses has removed so much water that wells have dried up in many places. Farms, ranches, and even whole towns are being abandoned.

Overpumping wells can also cause water quality issues. The quality, quantity, and reliability of groundwater resources are directly affected by the health of the aquifers. When wells are overdrawn, underlying salt water can rise into the wells and contaminate freshwater aquifers.

Academic Vocabulary

contaminate
(verb) to make something dirty or harmful by putting something bad into it

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Materials Science

Synthetic Technology

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Natural materials can be formed by combining synthetic materials.	
	Synthetic materials are the result of chemical reactions.	

Key Concept

- How to the properties of a material determine what it is used for?

Read to Learn

What are the properties of materials?

A **material** *is the matter from which a substance is or can be made*. Different materials have different properties. You can use the properties of a material to find out how it can be used.

Material Properties Every kind of material can be identified by its physical and chemical properties. Properties can also be used to describe materials. For example, a material might be strong and flexible. It might be soft and absorbent. It might conduct heat or electricity.

The properties of a material can determine its behavior and its uses. A material's properties can also change. They might change depending on how the material is treated or how it is stored.

Study Coach

Record Questions As you read this lesson, write down any questions you have about synthetic materials. Discuss these questions and their answers with another student or your teacher.

What are the differences between natural and synthetic materials?

Some kinds of materials, such as wood and rock, are natural materials. *A* **natural material** *is any physical matter that is obtained or made from plants, animals, or the ground*. Natural materials come from the natural environment, and have been changed very little.

Science Use v. Common Use

material
Science Use matter from which a substance is made

Common Use a piece of fabric

Academic Vocabulary

undergo
(verb) to experience a change

Science Use v. Common Use

organic
Science Use describing a chemical compound that contains carbon and usually contains at least one carbon-hydrogen bond

Common Use grown with natural fertilizers and pesticides; often used to refer to foods, such as fruits, vegetables, and meats

Plastics are an example of a synthetic material. *A* **synthetic material** *is a material that is obtained from a natural material which has undergone a chemical reaction in a laboratory or factory*. Both natural and synthetic materials are found in products you use every day.

Developing Synthetic Materials Materials scientists research and develop new materials. A materials scientist looks for connections between the structure of a material and its properties. That information is used to develop ways to change or improve materials.

Ideas for synthetic materials often come from natural materials. For example, sea cucumbers are an organism that can go from soft and squishy to rigid and tough. Materials scientists are trying to develop a fabric that will copy this behavior by going from flexible to inflexible. Any new synthetic material is a **technology**—*the practical use of scientific knowledge*.

Sources of Synthetic Materials All matter must come from somewhere. Scientists use existing materials to make new synthetic materials. The materials they use must come from natural resources. These materials are obtained from plants, animals, or Earth.

How are synthetic materials formed?

You've read that synthetic materials come from natural resources. The ideas for new synthetic materials come from nature. But how are synthetic materials formed?

New Materials Throughout history, humans have changed natural materials to improve their properties. When changed, the natural materials often undergo chemical reactions. The atoms of the natural material rearrange and form something new, a synthetic material.

From Reactants to Products Synthetic materials are the result of chemical reactions. You might recall that in a chemical reaction, the bonds between the atoms in the reactants are broken. The atoms rearrange and make new bonds to form products.

A polymer is a molecule made up of many small organic molecules bonded together, forming a long chain. A monomer is one of the small organic molecules that makes up the long chain of a polymer. Polymer chains can be very long.

Characteristics of Synthetic Materials There are different types of synthetic materials. They are all made from natural resources that were changed in chemical reactions. They are all made with specific properties to carry out a specific function.

Examples of Synthetic Materials Examples of synthetic materials include synthetic fibers, ceramics, polymers, artificial foods and medicines, and composites. Each of these types of materials has specific properties.

Synthetic fibers are flexible. They can be used to make clothing and other objects. Some examples of synthetic fibers are rayon, polyester, and nylon.

Ceramics are strong but brittle. They are good insulators. Some familiar examples of ceramics are cement, tiles, and bone china.

Polymers are strong and flexible. They can be easily modified to hold different shapes and color. Examples of polymers include polyvinyl chloride, polypropylene, and acrylic. Many common objects are made of synthetic polymers. You might be familiar with some of them. Pipes made of polyvinyl chloride, or PVC, are used in plumbing. Some home siding, rainwear, and garden hoses are also made of polyvinyl chloride. The polymer polytetrafluoroethylene (pah lee teh truh flor oh ETH uh leen) is used for the nonstick coating on cookware. Many types of synthetic ropes are made of polypropylene.

Some food and medicines are synthetic materials. These are made for a specific function or to mimic, or copy, a natural material. Some synthetic foods and medicines include vitamin C, the dye red 40, and hydrogenated oils.

Composites are made up of two or more synthetic materials. They are made to emphasize a specific property, like flexibility or strength. Types of composites include concrete, plywood, and fiberglass.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Scientific Vocabulary
fiber
(noun) a thin, thread-like piece of a material

Scientific Vocabulary
hydrogenated
(adjective) having hydrogen added; it is done to oil to increase how long it will last in foods

Scientific Vocabulary
composite
(noun) something made of several materials

Academic Vocabulary
emphasize
(verb) to give something special importance

Materials Science

Synthetic Materials and Societal Impacts

Key Concept

- What are the impacts of making, using, and disposing of synthetic materials?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Natural resource availability is the same everywhere in the world.	
	Producing synthetic materials can create by-products.	

Read to Learn

Mark the Text

Main Ideas and Details
Highlight the main idea of each paragraph. Highlight two details that support each main idea with a different color. Use your highlighted copy to review what you studied in this lesson.

What limits the production and use of synthetic materials?

Many of the products we use, such as cell phones, are made up of different synthetic materials. Not every country has the same natural resources. Humans depend on Earth's land, ocean, atmosphere, and biosphere for natural resources. Many of the resources are limited. Some are not renewable, meaning they cannot be replaced over human lifetimes.

Natural Resource Availability Natural resources are distributed unevenly around Earth. For example, some countries have a big supply of iron ore, which is used to make steel. Other countries have very little iron ore. Climate can play a role in what resources are available. The climate in Russia is good for growing trees. Timber is one of Russia's resources.

Scientific Vocabulary
climate
(noun) the usual weather conditions in a certain place

Synthetic Material Production The production of synthetic materials varies from region to region. This is due to differences in climate and the natural resource that are available. Economic conditions also determine which synthetic materials are made and used. Sometimes, effort is spent on synthetic products that provide for basic living needs. When the economic conditions are better, more effort can be put into synthetic materials for purposes such as entertainment.

What are the impacts of synthetic materials on individuals and societies?

The need for new synthetic materials can come from society. Technologies are developed based on the needs, wants, or values of a society as a whole. Other technologies are developed based on individual needs or wants. For example, phones developed so people could communicate over long distances. Cell phones are used all around the world. They have many impacts on individuals and society.

Individual and Societal Impacts Synthetic materials can have impacts on individuals and societies, depending on how the material is used. For example, ethanol is a renewable fuel made from plant materials. It has a variety of impacts on individuals and on society. Gasoline mixed with ethanol is less expensive than regular petroleum-based gasoline. Use of ethanol reduces the cost of fuel for individuals.

Ethanol has other impacts at the societal level. When it is used, there is less need for petroleum-based gasoline. When ethanol burns, fewer pollutants are released. It reduces the amount of smog and acid rain created by vehicles.

What are the impacts of synthetic materials on the environment?

The natural resources used to make synthetic materials come from the environment. They are removed from the ground or harvested or farmed from land or water. As demand for a synthetic material increases, the demand for the natural resources used to make the material also increases.

Environmental Connection Sometimes, obtaining the resources needed to make a synthetic material causes large changes the biosphere. For example, draining a wetland can create a lot of land for growing corn, which can be used to make ethanol. But, draining the wetland and planting a single crop damages the habitat of the organisms that lived in the wetland. It could cause the extinction of some species. The long-term functioning and health of any ecosystem is affected by human society.

Academic Vocabulary
individual
(adjective) existing separately from others

Academic Vocabulary
impact
(noun) the effect of one thing on another thing

Academic Vocabulary
fuel
(noun) a material that is burned to produce heat or power

Academic Vocabulary
demand
(noun) the desire people have for a service or product

Scientific Vocabulary
wetland
(noun) aquatic ecosystem that has a thin layer of water covering soil that is wet most of the time

Scientific Vocabulary
extinction
(noun) when a particular species dies out

Scientific Vocabulary

equatorial
(adjective) located at or near the equator

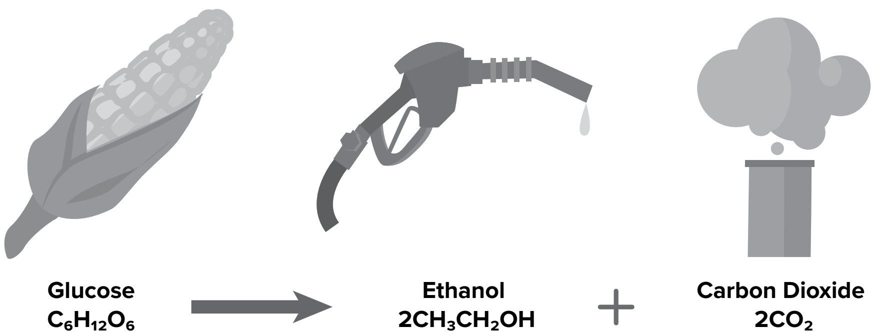
The methods people use to extract, harvest, transport, and consume natural resources also affects natural systems. For example, palm oil is used to make many synthetic materials such as soap, food products, and cleaning agents. The plant that palm oil is harvested from grows best at equatorial regions in the same conditions where rain forests grow. The biodiversity of an area decreases when rain forests are cleared to grow palm trees. As the use of a synthetic material increases, so does the use of the natural materials used to make the synthetic material. This increases the negative impacts to Earth's systems.

Life Science Connection Changes to the biodiversity of an area due to habitat destruction can affect other resources. For example, if a rainforest is cleared to grow crops, the other resources, such as food and medicine, provided by the rainforest are no longer available. Changes to an environment can affect how the biome cleans the water that humans drink. The changes also affect how the biome recycles nutrients. As organisms compete for limited resources, their growth and reproduction is reduced.

Scientific Vocabulary

nutrient
(noun) the parts of food used by living things to grow and survive

By-Products To make ethanol from plant materials, the plant materials have to undergo a chemical reaction. Sometimes when a chemical reaction occurs, a secondary product is also created. *A **by-product** is a secondary product that results from a manufacturing process or chemical reaction*. The chemical reaction that produces ethanol is shown in the figure below. It shows that the reaction also makes carbon dioxide as a by-product.

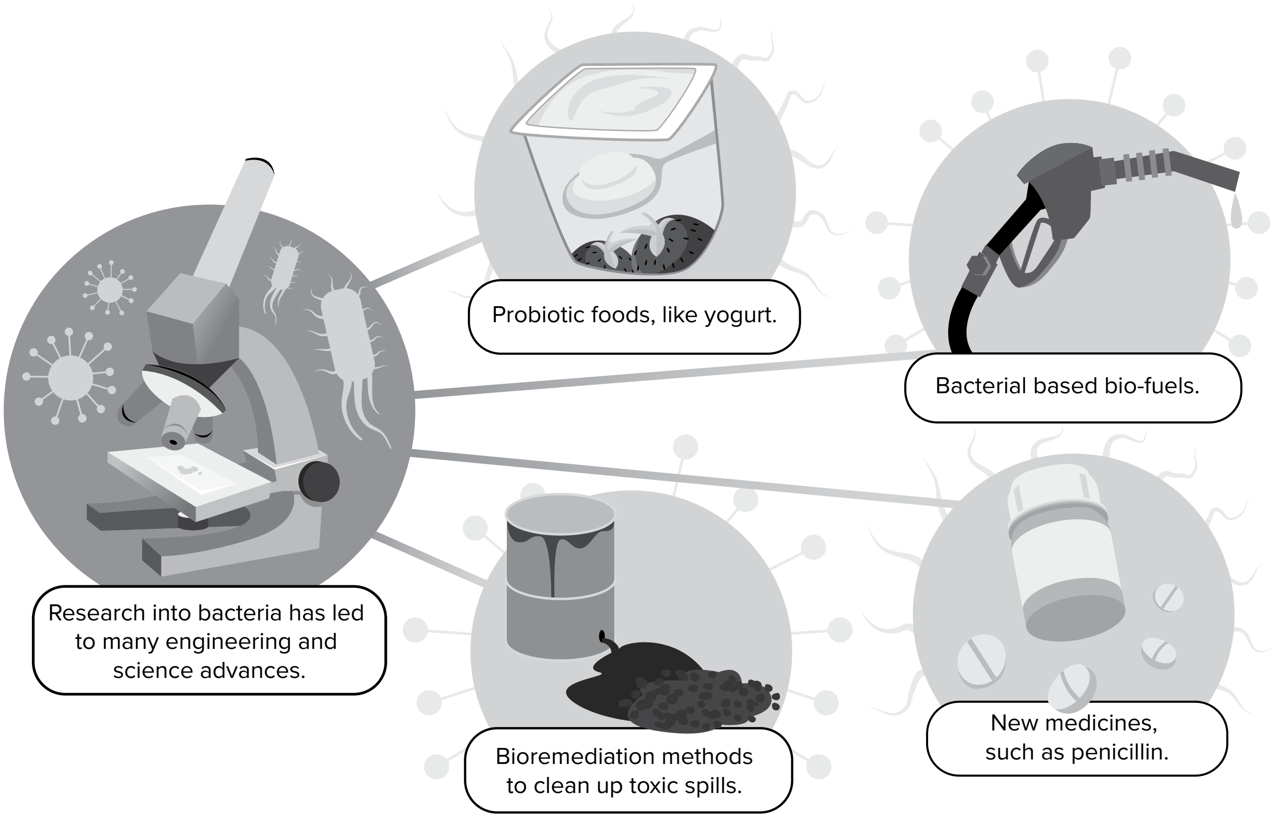


A by-product can be useful, or it can be considered a waste. If a by-product is considered waste, it must be disposed. Disposal of waste by-products can impact society and the environment.

Academic Vocabulary

society
(noun) people living together in a more or less ordered community

Disposing of Synthetic Materials What happens when the synthetic material itself needs to be disposed? For example, more than 125 million cell phones were thrown away in 2010. Gold is one of the natural resources used to make cell phones. That means 10,000 pounds of gold were thrown away with all of those phones. Even though there are ways to recycle or reuse cell phones, many end up in landfills or incinerators. Many other synthetic materials are disposed of in the same ways.



Positive Impacts of Synthetic Materials Some synthetic materials are specifically designed to help reduce human impact on the environment. For example, a new type of fertilizer coated in a synthetic polymer has been developed. The polymer coating controls when and how much of the fertilizer is released. This material could reduce how much fertilizer is used and reduce the amount of fertilizer runoff that goes into the groundwater.

Engineering Connection Engineering advances have led to scientific discoveries. These scientific discoveries have led to the development of whole industries and engineered systems, as shown in the figure above.

Some people might wonder why synthetic materials haven't been developed to reduce every negative impact humans have on the environment. Remember that the development of synthetic materials is limited by current scientific research. This research is driven by societal needs, desires, and values. Materials cannot be created from nothing. That is why humans rely on natural resources to make synthetic materials.

Academic Vocabulary
rely
(verb) to depend on

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Matter and Energy in Ecosystems

Photosynthesis and Cellular Respiration

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Plants do not carry on cellular respiration.	
	Plants make food in their underground roots.	

Key Concept

- How do plants and animals get energy?

Study Coach

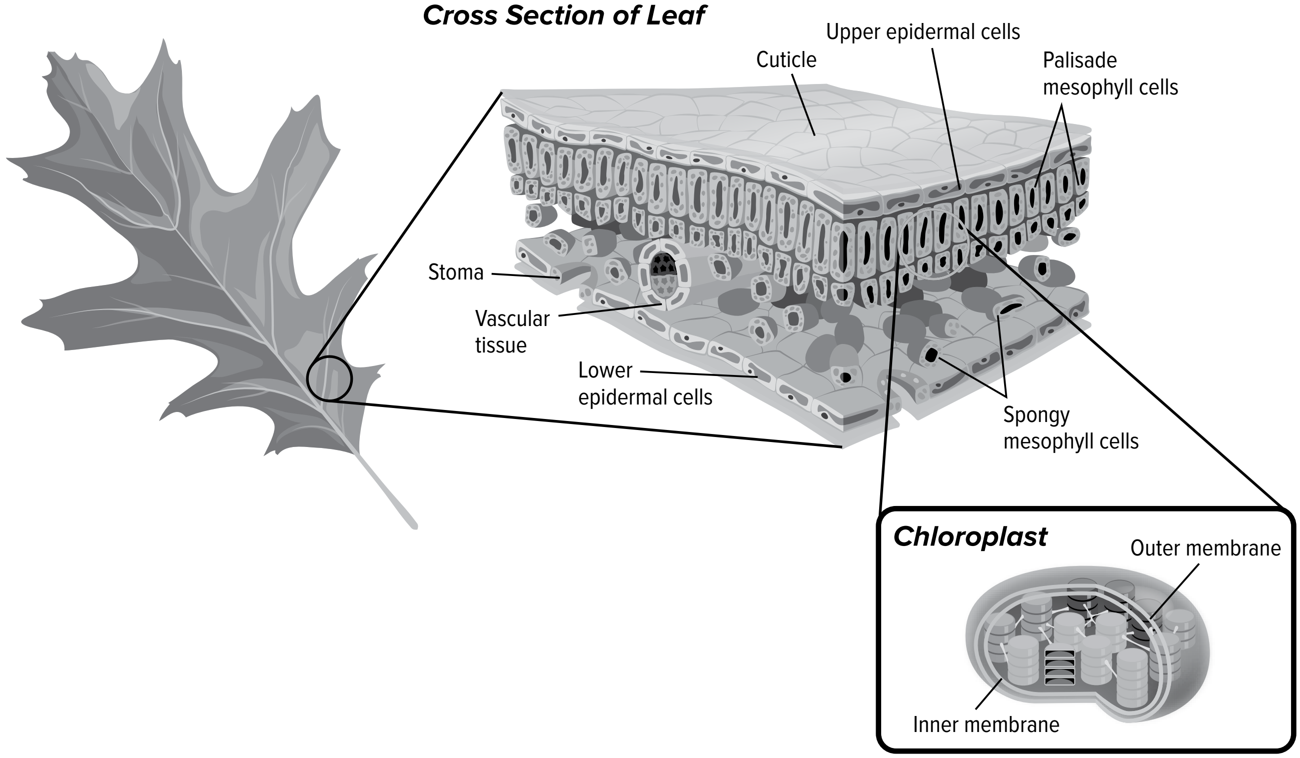
Make an Outline
Summarize the information in the lesson in an outline. Use the main headings in the lesson as the main headings in your outline. Use your outline to review the lesson.

Read to Learn

Why do plants need sunlight?

Plants need food, but they cannot eat food as people do. Plants make their own food. The leaves are the major energy-producing organs of the plant. The figure below shows a cross section of a leaf.

Cross Section of Leaf



Word Origin

photosynthesis
from Greek *photo–*, means "light"; and *synthesis*, means "composition"

Scientific Vocabulary

layer
(noun) one level of a substance or system

Scientific Vocabulary

vapor
(noun) a substance that is in the form of a gas or that has very small particles mixed in the air

Academic Vocabulary

spongy
(adjective) soft and full of holes or water, like a sponge

Photosynthesis Plants make their own food through a process called photosynthesis (foh toh SIHN thuh sus). Some unicellular organisms, such as algae, phytoplankton, and other microorganisms also carry out this process. **Photosynthesis** *is a series of chemical reactions that convert light energy, water, and carbon dioxide into the food-energy molecule glucose, and give off oxygen.* The sugars that are made during photosynthesis can be used by the plant right away or they can be stored for growth or later use.

Leaves have many types of cells. The epidermal (eh puh DUR mul) cells, which are shown in the figure on the previous page, make up the upper and lower layers of the leaf. Epidermal cells are flat and irregularly shaped. The bottom epidermal layer of most leaves has small openings called stomata (STOH muh tuh). Carbon dioxide, water vapor, and oxygen pass through stomata. Epidermal cells can produce a waxy covering called the cuticle.

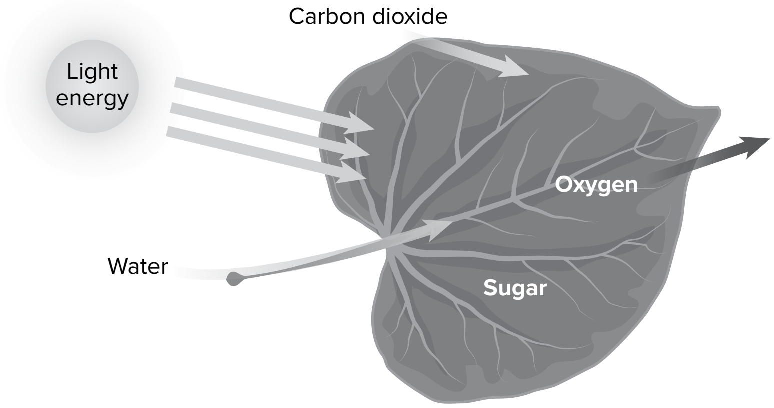
Most photosynthesis occurs in two types of mesophyll (ME zuh fil) cells inside a leaf. Mesophyll cells contain chloroplasts, which are the organelles where photosynthesis occurs. The palisade mesophyll cells are near the top surface of the leaf. They are packed close together. This arrangement exposes the most cells to light. Spongy mesophyll cells are below the palisade mesophyll cells. They have open spaces between them. Gases needed for photosynthesis flow through the spaces between the spongy mesophyll cells.

Capturing Light Energy Photosynthesis is a complex chemical process. It consists of two basic steps: capturing light energy and using that energy to make sugars.

In the first step of photosynthesis, chloroplasts capture the energy in light. Chloroplasts contain plant pigments. Pigments are chemicals that can absorb and reflect light. Chlorophyll is the most common plant pigment, and it is necessary for photosynthesis. Most plants appear green in color because chlorophyll reflects green light. Chlorophyll absorbs the other colors of light. This light energy is used during photosynthesis. After it is trapped and stored, this energy can be transferred to other molecules.

During photosynthesis, water molecules are split apart. The oxygen from the water molecules is released through the stomata into the atmosphere. The hydrogen atoms from the water molecules are used to make sugars called glucose in the second step of photosynthesis.

Making Sugars Sugars are made in the second step of photosynthesis. In chloroplasts, carbon dioxide from the air is converted into sugars by using the energy stored and trapped by chlorophyll. Carbon dioxide combines with hydrogen atoms from the splitting of water molecules and forms sugar molecules. Plants can use this sugar as an energy source. Plants can also store the sugar for later use. Potatoes are examples of plant structures where plants store excess sugar. The figure below summarizes the process of photosynthesis. Arrows are used to show materials and energy entering and leaving the plant. The chemical equation for photosynthesis is also shown in the figure.



Photosynthesis

Carbon dioxide + Water → Sugar + Oxygen

Light energy

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Physical Science Connection Photosynthesis is a chemical reaction. It requires an input of energy. Light is the source of energy. In the chemical reaction for photosynthesis, the reactants carbon dioxide (CO_2) and water (H_2O) use energy from light to form glucose ($C_6H_{12}O_6$) and oxygen (O_2).

Plants and other photosynthetic organisms take in carbon dioxide. They produce oxygen. This makes them a necessary part of any ecosystem. *An* ***ecosystem*** *is all the living and nonliving things in a given area*. Ecosystems come in all sizes. An entire forest can be an ecosystem. A rotting log, a pond, a desert, an ocean, and your neighborhood are all ecosystems.

How does the energy in food molecules become useable?

All living things need energy to survive. Energy is in the chemical bonds of food molecules. How does the energy in food molecules become energy living things can use for life processes?

Academic Vocabulary

complex
(adjective) having many different and connected parts

Scientific Vocabulary

excess
(adjective) too much; more than necessary

Scientific Vocabulary

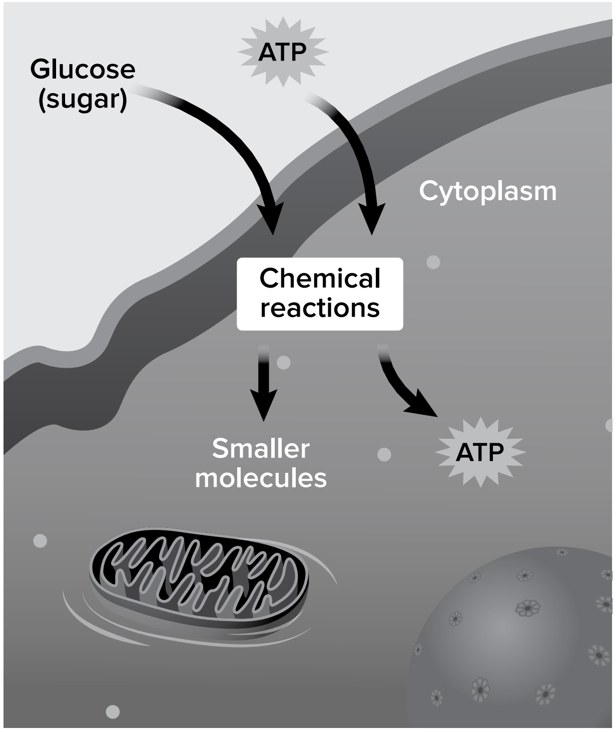
glucose
(noun) a type of sugar that is found in plants and fruits

Academic Vocabulary

necessary
(adjective) so important that you must do it or have it, absolutely needed

Scientific Vocabulary

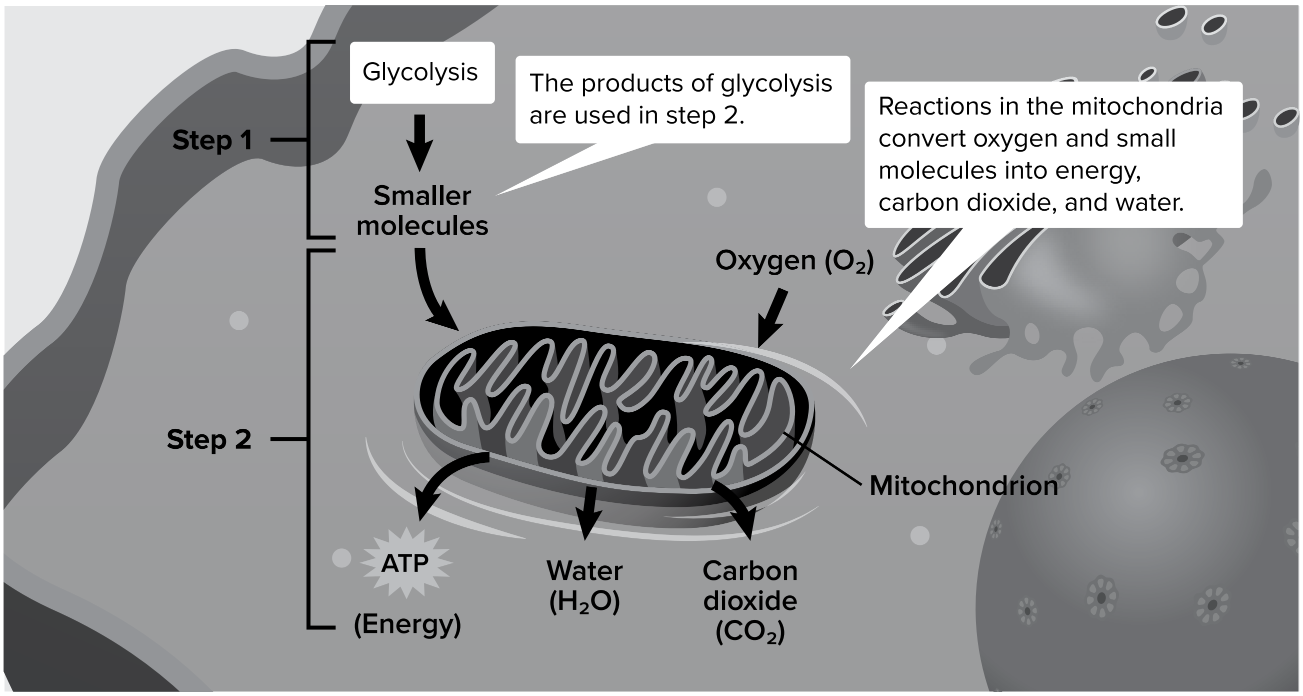
energy
(noun) the ability to cause change



Cellular Respiration The process of cellular respiration occurs in two parts of a cell—the cytoplasm and the mitochondria. **Cellular respiration** *is a series of chemical reactions that convert the energy in food molecules into a usable form of energy called ATP*.

This first step of cellular respiration is called glycolysis, as shown in the figure to the left. It occurs in the cytoplasm of cells. **Glycolysis** *is a process by which glucose, a sugar, is broken down into smaller molecules*. Glycolysis produces some ATP, an energy storage molecule. Glycolysis uses energy from other ATP molecules.

This second step of cellular respiration occurs in the mitochondria of eukaryotic cells. This step requires oxygen. The smaller molecules made during glycolysis are broken down. Large amounts of ATP are produced in this step. Cells use the ATP to power all cellular processes. Water and carbon dioxide are given off as waste products. The figure below shows the second step of cellular respiration.



How are photosynthesis and cellular respiration related?

Animals perform cellular respiration. Plants carry out both photosynthesis and cellular respiration. How do these processes compare?

Comparing Photosynthesis and Cellular Respiration The reactants for photosynthesis are carbon dioxide and water. The products are oxygen and glucose. Most plants and some unicellular organisms, such as algae, carry out photosynthesis. Photosynthesis produces most of the oxygen in Earth's atmosphere.

The reactants for cellular respiration are glucose and oxygen. The products are carbon dioxide and water, and energy is released. Most organisms carry out cellular respiration. Cellular respiration is important because if your body did not break down food, you would not have energy to do anything. Plants produce their own food, but without cellular respiration, they could not use the energy in the food molecules.

Academic Vocabulary

series
(noun) a number of things or events that are arranged or happen one after the other

Scientific Vocabulary

algae
(noun) simple, plantlike organisms that grow in or near water

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Matter and Energy in Ecosystems

Flow of Energy

Key Concept

- How does energy move in an environment?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	The Sun is the source for most energy used by living things on Earth.	
	All living things get their energy from eating other living things.	

Mark the Text

Identify Important Words As you read this lesson, highlight all the words you do not understand. Then underline the part of the text that can help you learn what those words mean.

Scientific Vocabulary

matter
(noun) anything that has mass and takes up space

Read to Learn

How do different organisms get energy?

The main source of energy for most life on Earth is the Sun. Energy flows in one direction through ecosystems. In most cases, energy flow starts with the Sun. Energy moves from one organism to another organism. Many organisms get energy by eating other organisms.

Physical Science Connection Not all of the energy an organism gets is used for life processes. Some is released into the environment as thermal energy. Energy cannot be created or destroyed. Its form can change, though. This idea is called the law of conservation of energy.

Producers *Living things that make their own food are called* **producers**. Most producers use the process of photosynthesis to make food. Some use the process of chemosynthesis (kee moh SIHN thuh sus). In chemosynthesis, producers use the chemical energy in matter to make food.

Consumers Unlike producers, **consumers** *do not produce their own energy-rich food*. They get their energy by consuming, or eating, other organisms. Consumers can be classified by the type of food that they eat.

The groups of consumers include herbivores, carnivores, omnivores, and detritivores. Herbivores eat only producers. A deer eats only plants, so it is an herbivore. Carnivores eat other animals. Lions and wolves are carnivores. Omnivores eat both producers and other consumers. A bird that eats berries and insects is an omnivore.

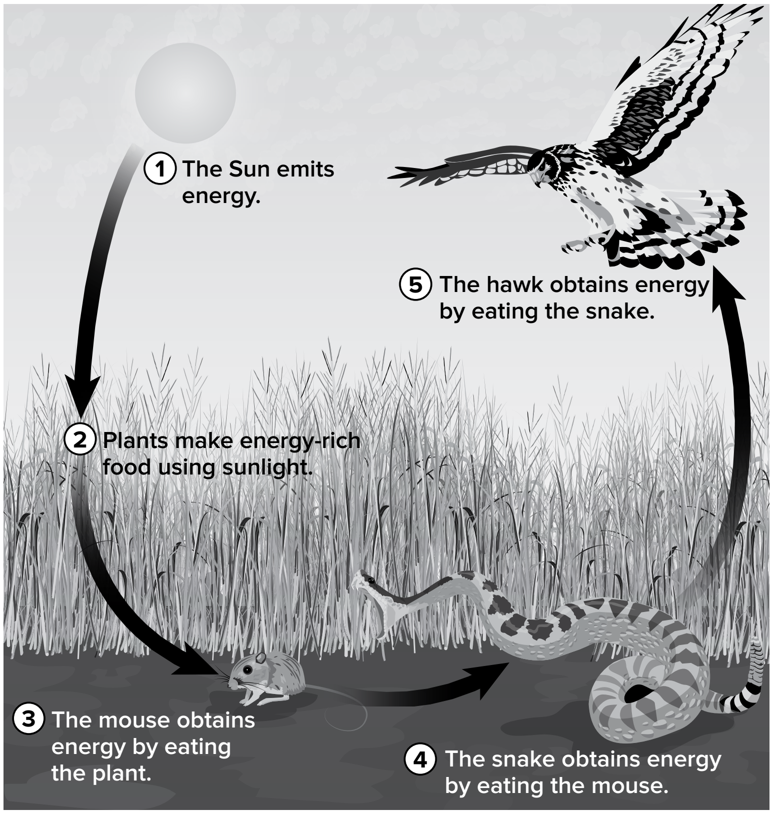
Detritivores Another group of consumers is detritivores (dih TRI tuh vorz). **Detritivores** *get their energy by eating the remains of other organisms.* Detritivores, such as bacteria and mushrooms, feed on dead organisms and help break them down. They are often called decomposers. They produce carbon dioxide that enters the air. Some decayed matter enters the soil. Detritivores help recycle nutrients through ecosystems. They also keep dead organisms from piling up in the environment.

Scientific Vocabulary
bacteria
(noun) very small living things that cannot be seen without a microscope

Scientific Vocabulary
recycle
(verb) to use something again

How does energy move through an environment?

Food energy is transferred from one organism to another through feeding relationships. Feeding relationships in an ecosystem can be shown using models. *A* **food chain** *is a simple model that shows how energy moves from the Sun, to a producer, to one or more consumers through feeding relationships*. In a food chain, arrows show the transfer of energy. For example, the arrow pointing from the Sun to the plants shows that plants get energy from the Sun. The arrow pointing from the snake to the hawk shows that energy moves from the snake to the hawk. The amount of available energy decreases every time it is transferred from one organism to another.

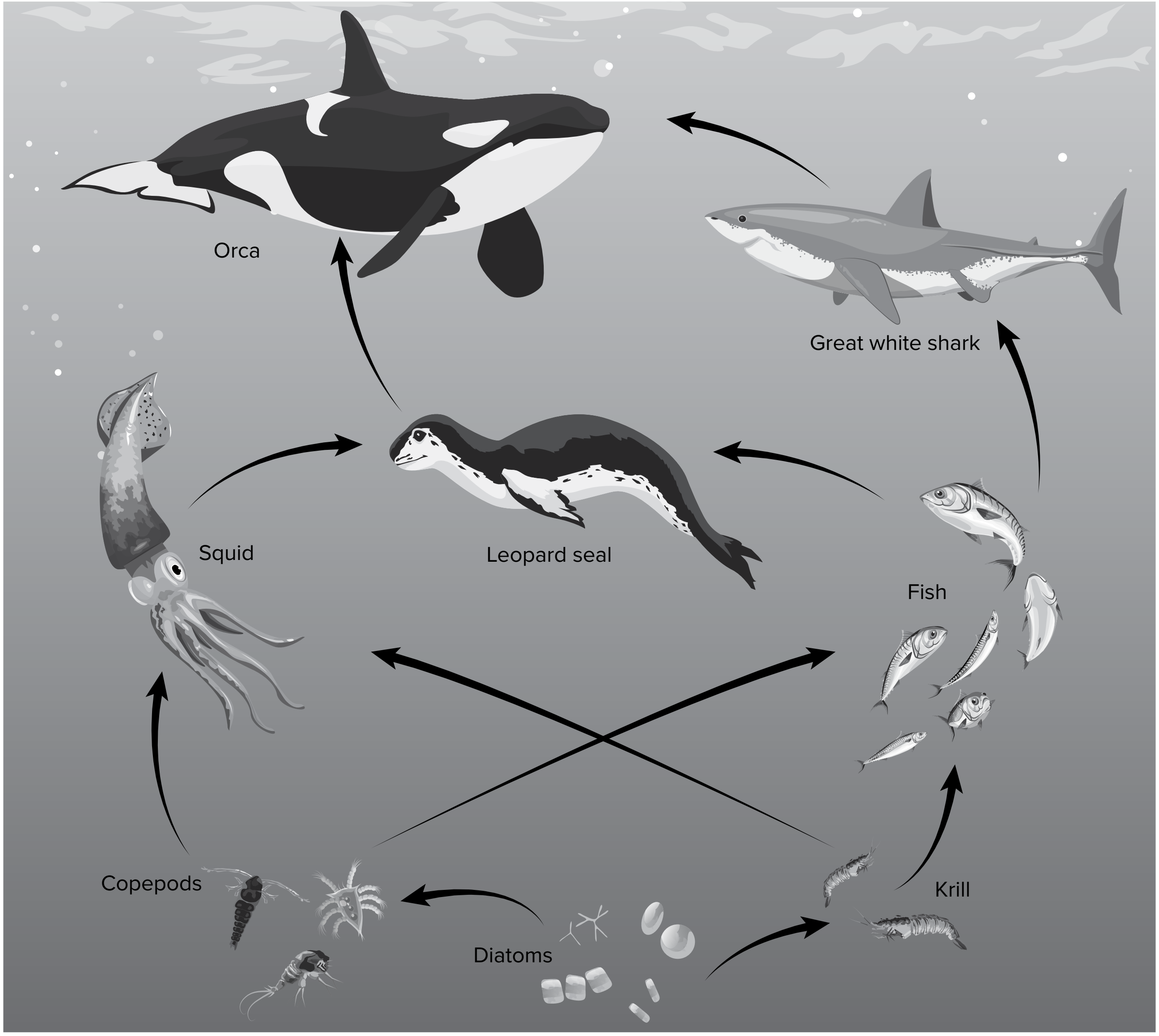


A food chain, like the one shown in the figure, is helpful when studying certain parts of an ecosystem. But, it does not show the whole picture of how energy is transferred in an ecosystem. That's because most living things eat more than one kind of food.

Academic Vocabulary
interconnected
(adjective) having all parts linked or connected

Scientists also use food webs, like the one shown in the figure below, to study the feeding relationships in an ecosystem. *A* **food web** *is a model of energy transfer that shows how food chains in a community are interconnected*. A food web is many overlapping food chains. The food web in the figure shows the complex feeding patterns in an ecosystem. Arrows show how energy flows.

Some organisms in the food web might be part of more than one food chain in that web. For example, diatoms are eaten by both copepods and krill. Krill are eaten by both the fish and the squid. Several food chains overlap in this food web.



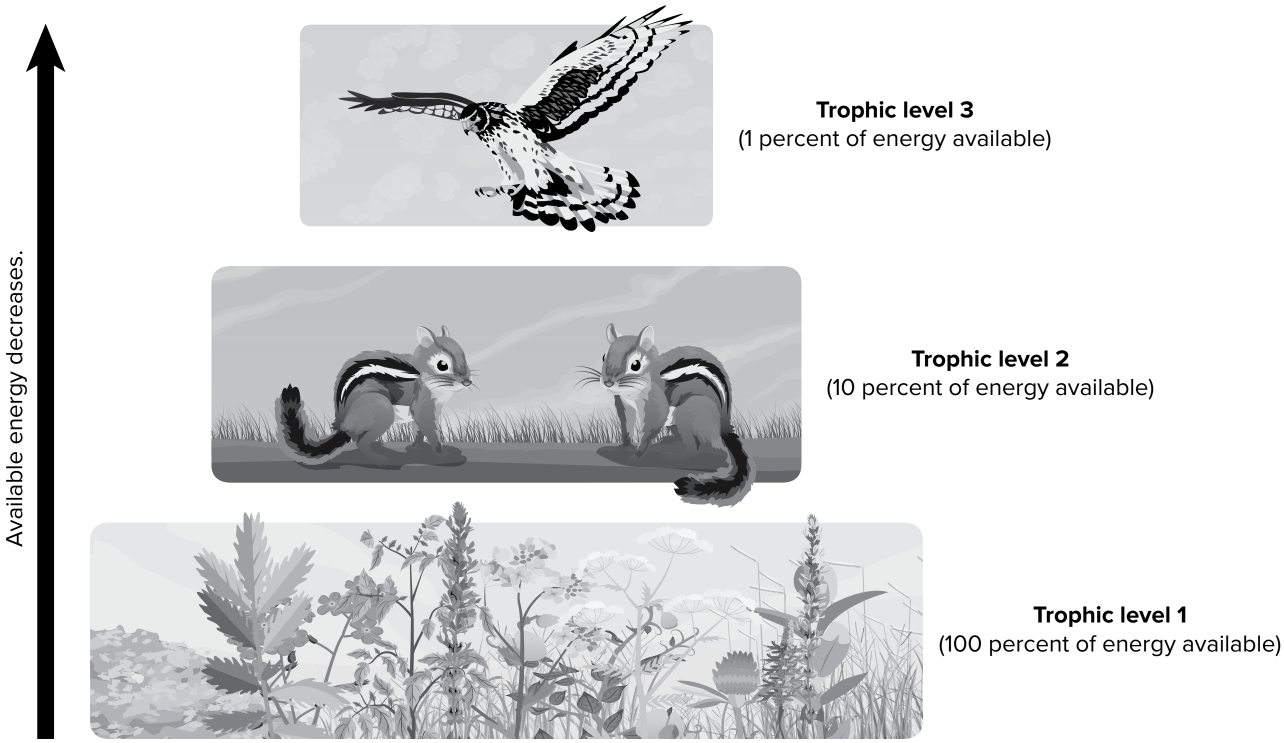
Energy Pyramid Food chains and food webs show how energy moves in an ecosystem. They do not show how the amount of available energy in an ecosystem changes, though. *Scientists use a model called an* ***energy pyramid*** *to show the amount of energy available in each step of a food chain*. The steps of an energy pyramid are called trophic (TROH fihk) levels.

Look at the energy pyramid in the figure below. Producers, such as plants, make up the bottom trophic level. Consumers that eat producers make up the next level. Consumers that eat other consumers make up the highest level.

Notice that as you move to a higher level, there is less energy available for consumers. Only about 10 percent of the energy available at one trophic level transfers on to the next trophic level. Why? As you read earlier, organisms use some of the energy they get from food for life processes. During life processes, some energy is changed to thermal energy. The thermal energy is then transferred to the environment. That energy cannot be passed to the next trophic level in the food chain.

Word Origin

producer
from Latin *producer*, means "lead or bring forth, draw out"



After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Matter and Energy in Ecosystems

Cycling of Matter

Key Concept

- How does matter move through the environment?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Carbon, nitrogen, and other types of matter are used by living things over and over again.	
	Plants and animals can use nitrogen in its natural form.	

Mark the Text

Identify the Main Point As you read, highlight the main point of each paragraph. Then use a second color to highlight a detail or example to help explain the main point.

Read to Learn

How does matter cycle through an environment?

You've read about the flow of energy in ecosystems. Matter also moves through the environment, but instead of flowing through the environment like energy does, matter moves in cycles.

Physical Science Connection As matter moves in cycles, it changes form. But matter is not created or destroyed when the form changes. This idea is called the law of conservation of mass.

Carbon in Nature Carbon takes different forms as it moves through the environment. Tiny ocean organisms called phytoplankton take in carbon dioxide. In some types of phytoplankton, the carbon in carbon dioxide is converted to calcium carbonate. Calcium carbonate is a part of their skeletons. When the phytoplankton die, many sink to the bottom of the ocean. Their skeletons become fossilized. Over time the fossilized skeletons build up and turn into chalk. As the chalk is weathered by rain and waves, it releases carbon into the air in the form of carbon dioxide. The carbon dioxide gas is available for other phytoplankton to take in.

Scientific Vocabulary

skeleton
(noun) the framework of bones in a human or animal's body

Scientific Vocabulary

fossilize
(verb) to turn into a fossil, preserved in rock

The Carbon Cycle All organisms contain carbon. Some organisms, including humans, get carbon from food. Other organisms, such as plants, get carbon from the atmosphere or bodies of water.

Carbon can enter the environment when organisms die and decompose. Decomposition is the breaking down of dead plants and animals. This process returns carbon compounds to the soil and releases carbon dioxide (CO_2) into the atmosphere. Other organisms then use carbon dioxide. Carbon also is found in fossil fuels.

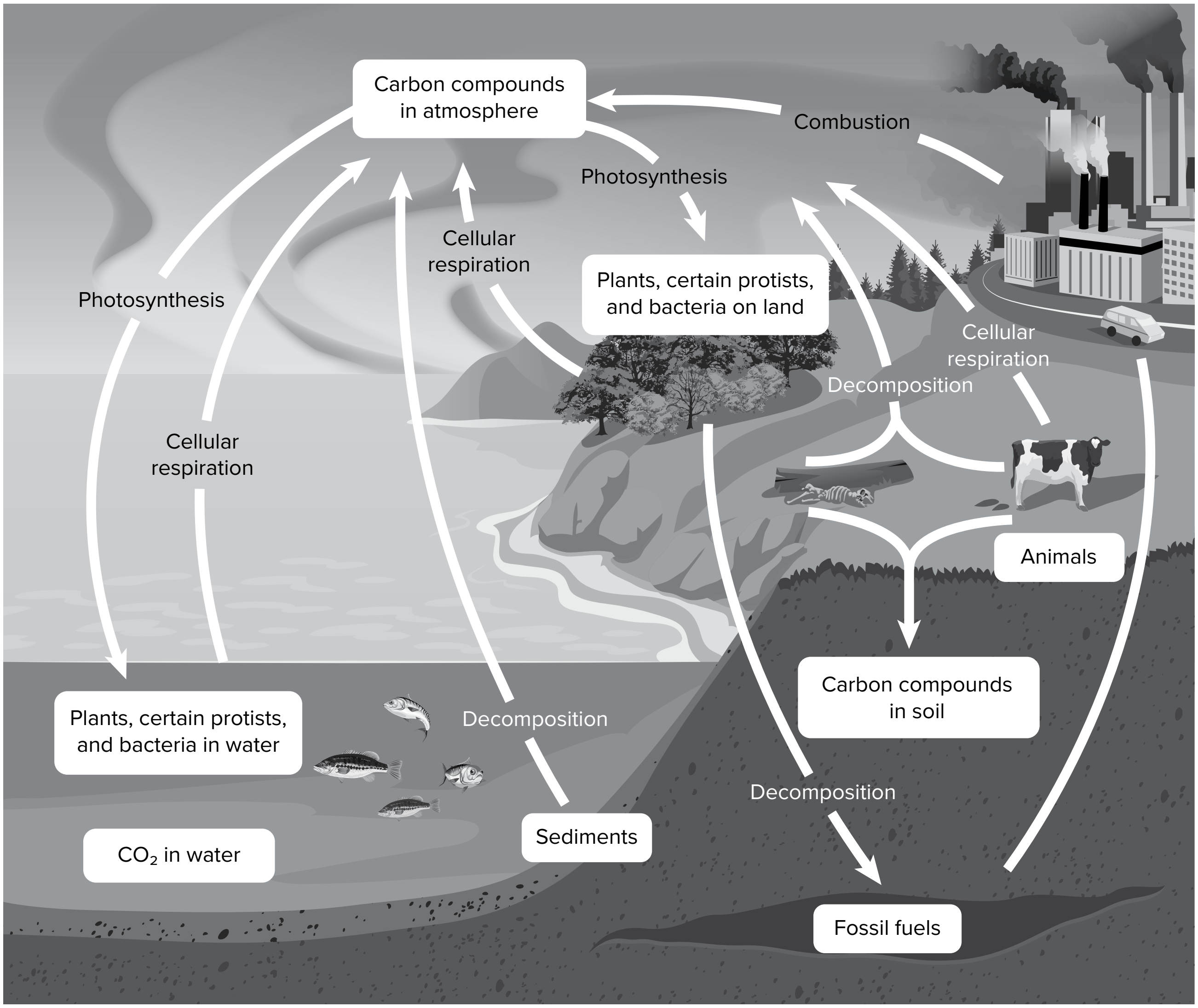
How do living things use the carbon dioxide that is in the air? Plants and other organisms make their own food through photosynthesis. They take in carbon dioxide and water and make sugars. When other organisms eat plants, they get carbon and energy. Carbon dioxide is a by-product of the cellular processes that break down sugars to release energy. Carbon dioxide enters the atmosphere to be used again. The figure below shows how carbon cycles through ecosystems.

Academic Vocabulary

process
(noun) a group of actions that end in a certain result

Scientific Vocabulary

air
(noun) the invisible gases that surround Earth; what we breathe



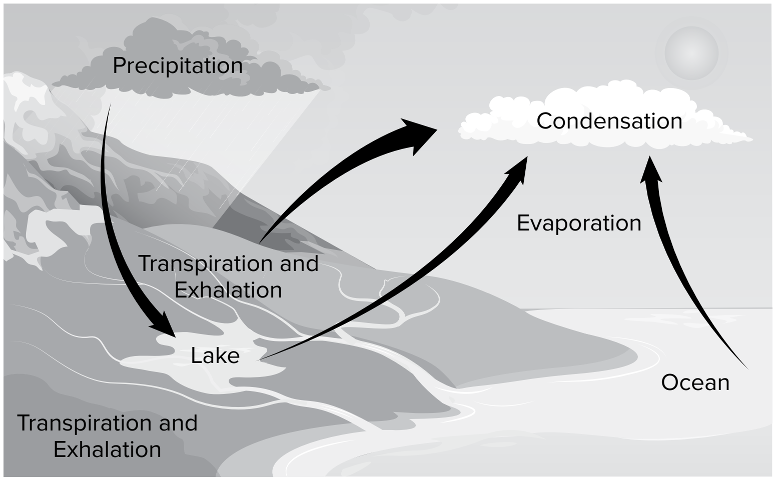
What other important materials cycle through the environment?

Academic Vocabulary
cycle
(noun) a set of events that happen over and over again

Water is another important part of the environment. Water also cycles through ecosystems.

Water covers about 70 percent of Earth's surface. Water surrounds all of Earth's landmasses. Most of Earth's water, about 97%, is in the oceans. Water is in rivers, streams, lakes, and underground. Water is also in the atmosphere, in icy glaciers, and in living things.

The Water Cycle Water is always moving from Earth to the atmosphere and back again. This movement is called the water cycle. The water moves by three main processes: evaporation, condensation, and precipitation. You can see these three processes in the figure below.



Scientific Vocabulary
exhale
(verb) to breathe out

Evaporation (ih va puh RAY shun) *is the process during which liquid water changes into a gas called water vapor*. Water is also released when animals exhale and through transpiration, which occurs when plants give off moisture.

The higher in the atmosphere you are, the cooler the temperature. As water vapor rises in the atmosphere, it cools. This cooling causes condensation. **Condensation** (kahn den SAY shun) *is the process during which water vapor changes into liquid water*.

Scientific Vocabulary
sleet
(noun) frozen or partly frozen rain

Precipitation (prih sih puh TAY shun) *is water that falls from clouds to Earth's surface*. This water enters bodies of water, such as oceans and rivers, or soaks into soil. Forms of precipitation include rain, snow, sleet, and hail.

The Nitrogen Cycle You know that water is necessary for life on Earth. The element nitrogen is also necessary for life. Nitrogen is part of proteins, which all organisms need to stay alive. It also is part of DNA, the molecule that contains genetic information. Like water, nitrogen cycles between Earth and the atmosphere and back again.

Earth's atmosphere is mostly nitrogen. Plants and animals cannot use the form of nitrogen that is in the atmosphere. How do organisms get nitrogen into their bodies? *The process that changes atmospheric nitrogen into nitrogen compounds that are usable by living things is called* **nitrogen fixation** (NI truh jun • fihk SAY shun). Nitrogen from the atmosphere is changed into a different form with the help of nitrogen-fixing bacteria that live in soil and water. These bacteria take in nitrogen from the atmosphere and change it into nitrogen compounds that other organisms can use.

How does nitrogen from living things return to the environment? Decomposers can break down the tissues of dead organisms. They help return the nitrogen in the tissues of those organisms to the environment. You've seen these decomposers at work in a decaying log or a rotten apple. Nitrogen also returns to the environment in the waste products of organisms. Manure is a waste product of organisms. Farmers often spread manure on their fields as a way to provide nitrogen for crops.

The Oxygen Cycle You learned that organisms need water and nitrogen. Almost all organisms also need oxygen for cellular processes that release energy. Oxygen is also a part of carbon dioxide and water, substances that are important to life.

Most of the oxygen in the atmosphere comes from photosynthesis. Earth's early atmosphere probably did not contain oxygen gas. Certain bacteria evolved that made their own food through photosynthesis. Oxygen gas is a by-product of photosynthesis. Over time, other photosynthetic organisms evolved. The amount of oxygen in Earth's atmosphere increased. Photosynthesis is the main source of oxygen in Earth's atmosphere today.

Humans and many other living organisms take in oxygen and release carbon dioxide during cellular processes. There are many other relationships between different types of matter in ecosystems.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Science Use v. Common Use

tissue

Science Use group of similar cells that work together to carry out specific tasks

Common Use a soft, thin paper

Scientific Vocabulary

decay

(verb) to be slowly broken down

Academic Vocabulary

release

(verb) to set free or let go

Dynamic Ecosystems

Resources in Ecosystems

Before You Read

What do you think? ? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	A community includes all organisms of one species that live in the same area.	
	An extinct species has only a few surviving individuals.	

Key Concept

- How do limited resources affect living things?

Read to Learn

What are the levels of organization in an environment?

Step outside and look around. You probably see trees and other plants. You might see animals, such as squirrels and birds. There might be rocks and a body of water in the area. All the natural things you see are part of the biosphere.

The **biosphere** (BI uh sfihr) *is the parts of Earth and the surrounding atmosphere where there is life.* The biosphere includes all the land of the continents and islands. It also includes all of Earth's oceans, lakes, and streams and the ice caps at the North Pole and the South Pole. Parts of the biosphere with large numbers of plants or algae often contain many other organisms. The figure on the next page shows the levels of organization in the biosphere.

Ecosystems The Kalahari Desert in Africa is a part of Earth's biosphere. Several groups of elephants live there in a wildlife refuge. Elephants are large mammals that live in family groups. They move in herds and keep each other safe. Elephants eat vegetation, including leaves, bark, and roots. They can communicate over long distances when they make a low, rumbling sound.

Study Coach

Make Flash Cards Think of a quiz question for each paragraph. Write the question on one side of a flash card. Write the answer on the other side. Work with a partner to quiz each other using the flash cards.

Scientific Vocabulary

atmosphere
(noun) the mixture of gases that surrounds Earth

Scientific Vocabulary

mammal
(noun) a type of animal that feeds milk to its young and usually has hair covering most of its skin

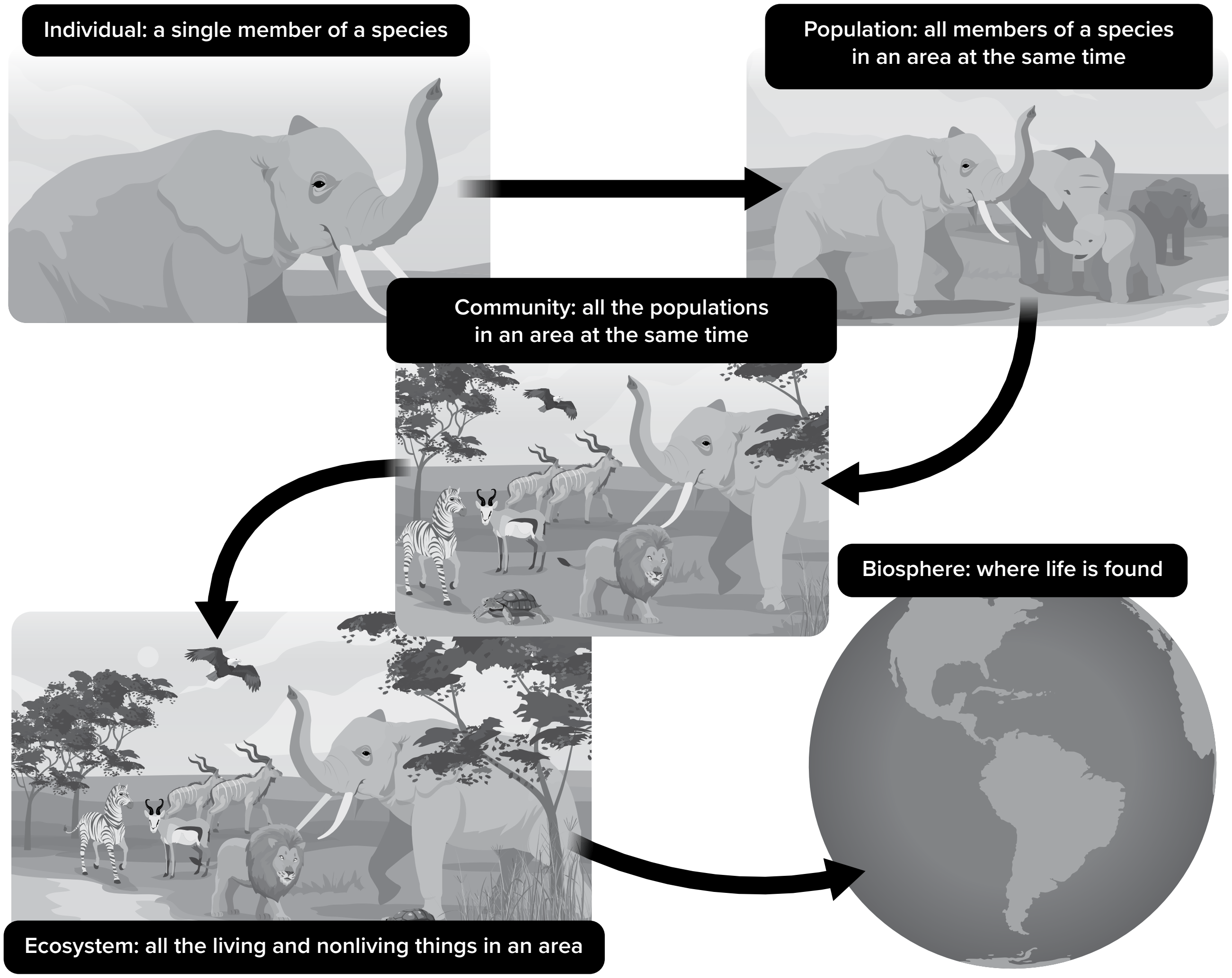
Scientific Vocabulary

desert
(noun) an area of land that gets little rain

Elephants are part of an ecosystem. An ecosystem includes all the living things in an area, such as plants and animals. It also includes all the nonliving things in an area, such as soil, water, and rocks. The Kalahari Desert is one of many ecosystems that makes up Earth's biosphere. The study of all ecosystems on Earth is ecology.

As shown in the figure below, an individual elephant is part of a population. *A* **population** *is all the organisms of the same species that live in the same area at the same time.* Elephants interact with other elephants in order to survive. They reproduce and help each other care for their young. *A* **species** *is a group of organisms that have similar traits and are able to produce fertile offspring.*

Many species besides elephants live in the Kalahari Desert. Zebras, tortoises, and lions all live there. Plants that grow in the desert include shrubs, grasses, small trees, and citron melons. Together, all these plants, animals, and other organisms make up a community. *A* **community** *is all the populations of different species that live together in the same area at the same time.*



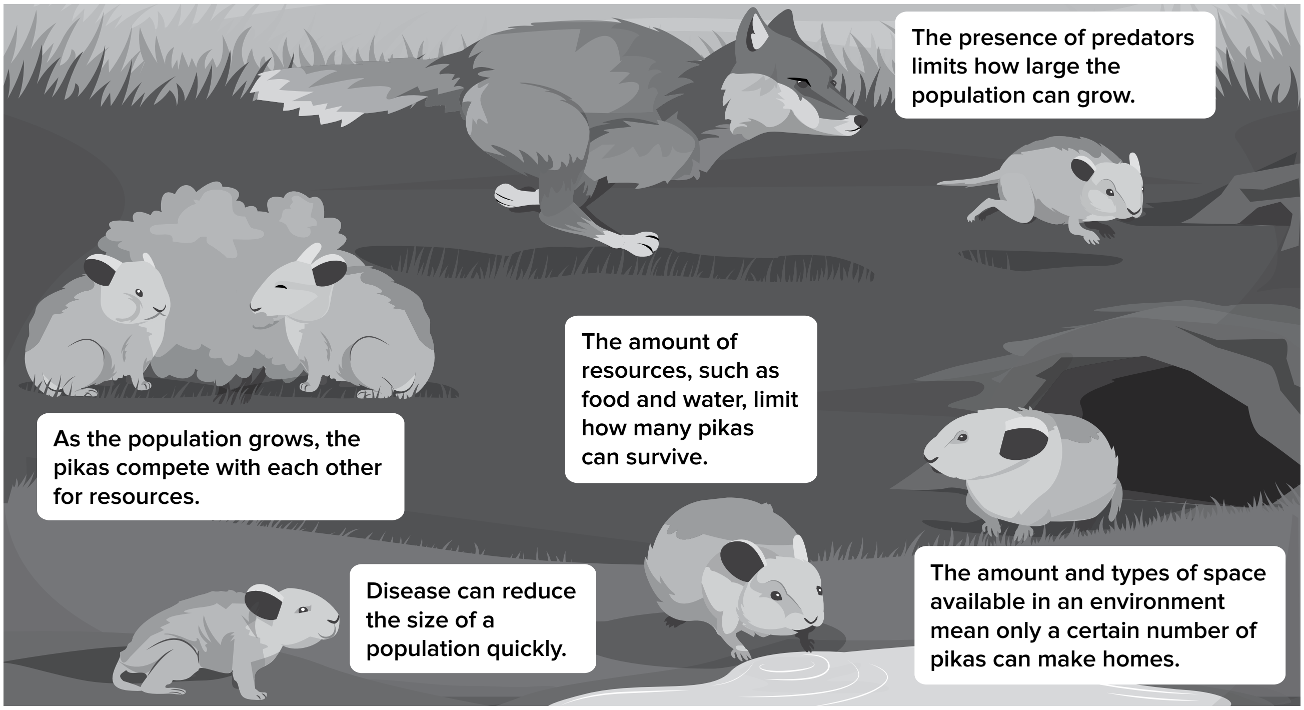
How do resources affect populations?

When there is less food available, a population of elephants gets smaller. Female elephants cannot raise as many young. Some elephants might leave the area to find food elsewhere. If there is plenty of food, the size of a population of elephants grows larger. More elephants survive to adulthood and live longer. Changes in environmental factors can result in changes to a population's size.

Scientific Vocabulary
fertile
(adjective) able to produce children, young animals, etc.

Limiting Factors Environmental factors are possible limiting factors for a population. These factors include available food, water, shelter, sunlight, and temperature. *A* **limiting factor** *is anything that restricts the size of a population.* The figure below shows limiting factors for a population of pikas.

Scientific Vocabulary
temperature
(noun) the measure of the average kinetic energy of the particles in a material



How Limiting Factors Affect Population Temperature is a limiting factor for some organisms. When the temperature drops below freezing, many organisms die. Predators are animals that eat other animals. Predators and diseases can be limiting factors for organisms. Natural disasters, such as fires and floods, also limit the size of populations. Lack of space and lack of sunlight are limiting factors for some organisms. If there is not enough sunlight, green plants cannot perform photosynthesis and make food. If a population does not have enough resources, it might move to a new area. It might even die out.

Scientific Vocabulary
predator
(noun) an organism that survives by hunting another

Word Origin

population
from Latin *populus,* means "people"

Academic Vocabulary

limit
(noun) a point beyond which is it not possible to go

Word Origin

biotic
from Greek *biotikos,* means "fit for life"

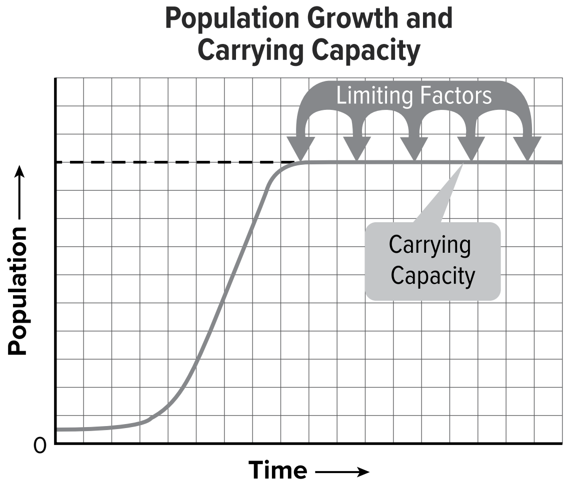
Academic Vocabulary

capacity
(noun) the maximum amount something can hold

How big can populations get?

Imagine that a population of raccoons has plenty of food, water, and den space. The population has no disease. It is not in danger from other animals. The only limit to the size of this population is the number of offspring the raccoons can produce. **Biotic potential** *is the potential growth of a population if it could grow in perfect conditions with no limiting factors.*

No population on Earth ever reaches its biotic potential, because no ecosystem has an unlimited supply of natural resources. Instead, it reaches its carrying capacity. **Carrying capacity** *is the largest number of individuals of one species that an ecosystem can support over time.* As you can see in the figure below, limiting factors restrict the carrying capacity of an ecosystem. Disease, lack of space, lack of food, and predators are some of these factors.



The carrying capacity of an environment does not stay the same. It increases and decreases as the amount of available resources increases and decreases. At times, a population can briefly grow beyond the carrying capacity of an environment.

Sometimes, populations grow so large that they cause problems for other organisms in the community. ***Overpopulation*** *is when a population's size grows so large that it causes damage to the environment.* The population becomes larger than the carrying capacity of its ecosystem. For example, meerkats eat spiders. An overpopulation of meerkats causes a decrease in the size of the spider population in that community. Populations of birds and other animals that eat spiders also decrease when the number of spiders decreases.

Elephants in some African game reserves present another example of overpopulation. Elephant herds searching for food can cause tree damage. They push over trees to feed on treetops. Other animals that use those trees for food and shelter must compete with the elephants. In addition, the loss of trees can damage the soil. This might prevent other trees and plants from growing in that area.

Scientific Vocabulary

reserve
(noun) an area where animals and plants are protected and that has few buildings or homes

Population Size Decrease Population size can increase, but it also can decrease. Lack of resources can cause a population size to decrease. A mouse population might decrease during the winter because less food is available. Some mice will starve. More mice will die than will be born. When food is plentiful, the population usually increases.

Floods, fires, hurricanes, and other natural disturbances also affect population size. They destroy habitats and food sources for organisms.

The spread of disease is another factor that decreases population. For example, in the mid-1900s, a disease destroyed thousands of elm trees in the United States.

In addition, predation reduces population size. Predation is the hunting of animals for food. Cats that live in barns feed on mice and reduce the mouse population.

Extinction Populations can decrease in numbers until they disappear. An extinct species is a species that has died out. No individuals are left. Extinctions can be caused by predation, natural disasters, or damage to the environment.

Word Origin

extinct
from Latin *extinctus*, means "dying out"

For example, about 700 years ago, humans settled in New Zealand. A flightless bird called the giant moa lived there. Humans hunted the moa for food. As the human population increased, the size of the moa population decreased. The species became extinct within 200 years.

Endangered Species Wild mountain gorillas are an endangered species. An endangered species is a species whose population is at risk of extinction. Species that are considered critically endangered face an even higher risk of extinction.

Threatened Species A threatened species is a species that is at risk but is not yet endangered. California sea otters are a threatened species. Worldwide, more than 23,000 species are classified as endangered or threatened.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Dynamic Ecosystems

Interactions Within Ecosystems

Key Concept

- How do living things interact with each other?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	No more than two species can live in the same habitat.	
	In symbiosis, two species cooperate in a way that benefits both species.	

Mark the Text

Identify Main Ideas As you read this lesson, highlight the main ideas. Use the highlighted material to review the lesson.

Scientific Vocabulary

habitat
(noun) the place where a plant or animal naturally lives

Scientific Vocabulary

savanna
(noun) a large flat area of land with grass and few trees

Read to Learn

How do living things interact in an ecosystem?

More than one population can live in the same habitat. For example, giraffes and two types of antelopes—kudus and steenboks—live in the African savanna. All three populations feed on trees. How can these three populations share the same habitat?

The members of each population use resources in their habitat. They use water, food, shelter, and other resources. However, each population uses the resources in a different way. Giraffes feed at the tops of the trees. Kudus eat from mid-level branches. Steenboks feed on the lowest branches of trees and shrubs.

How do some organisms benefit in relationships?

There are different kinds of relationships within communities. For example, bees and bee balm flowers both benefit from their relationship. Fleas benefit from their relationship with dogs, but dogs are harmed by their relationship with fleas. Some relationships have different outcomes and benefits.

What are the different types of symbiotic relationships?

Some species have such close relationships that they are almost always found living together. **Symbiosis** (sihm bee OH sus) *is a close, long-term relationship between two species that usually involves an exchange of food or energy.*

Communities around the world have symbiotic relationships. For example, coral reef communities often include the different types of symbiosis. Many of the organisms in these communities have some type of symbiotic relationship. These organisms include clownfish, sea anemones, and even tiny copepods.

There are three types of symbiosis. They are commensalism, parasitism, and mutualism.

Commensalism *A symbiotic relationship that benefits one species but does not harm or benefit the other is* **commensalism**. For example, plants called epiphytes (EH puh fites) grow on the trunks of trees. The roots of an epiphyte anchor it to the tree. The plant absorbs nutrients from the air. The epiphytes benefit by getting living space and sunlight. The trees are neither helped nor harmed by the plants.

Parasitism *A symbiotic relationship that benefits one species and harms the other is* **parasitism**. The species that benefits is the parasite. The species that is harmed is the host. For example, the Striga plant's roots grow into a host plant, robbing it of water and nutrients.

Heartworms, tapeworms, fleas, and lice are parasites. They feed on a host organism, such as a human or a dog. The parasite benefits by getting food. The host is harmed by losing blood. The host is usually not killed, but it can be weakened. A good example is heartworms in dogs. These parasites can cause the dog's heart to work harder. The heart can fail after time, killing the host.

Mutualism *A symbiotic relationship in which both partners benefit is called* **mutualism**. Boxer crabs and sea anemones live in tropical coral reef communities. They have a mutualistic partnership. The crabs carry sea anemones in their claws. The sea anemones have stinging cells that help the crabs fight off predators. The sea anemones eat leftovers from the crabs' meals. Both partners benefit.

Academic Vocabulary

benefit
(verb) to be useful or helpful to someone or something

Scientific Vocabulary

parasite
(noun) plant or animal that gets food by living in or on another plant or animal

What other types of relationships exist in ecosystems?

The populations that make up a community interact with each other in many ways. Some species have feeding relationships. They either eat or are eaten by another species. Some species interact with another species to get the food or shelter they need.

Academic Vocabulary

cooperative
(adjective) involving two or more people or groups working together to do something

Cooperative Relationships The members of some populations work together in cooperative relationships for their survival. For example, leafcutter ants cooperate with each other to grow food. First, they work together to cut apart leaves and carry them to their underground nest. The ants clean, crush, and compost them. Fungus then grows on the leaves. The ants eat the fungus.

Cooperative relationships can be found in many different populations across the world. Meerkats cooperate to raise young and watch for danger. Squirrel monkeys live in groups. They cooperate with each other as they hunt for food and watch for danger.

Predator-Prey Relationships Squirrel monkeys fight over fruit. They do not notice the harpy eagle flying above. Suddenly, the harpy eagle swoops down and grabs a monkey. The eagles and the monkeys have a predator-prey relationship. The eagle, like other predators, hunts other animals for food. The hunted animals, such as the monkey, are called prey. Predators help keep prey populations from growing too large.

Predators are one factor that keeps a prey population from reaching the carrying capacity of the ecosystem. Predators often catch weak or injured members of a prey population. The elimination of the weak members leaves more resources for the remaining members. This keeps the prey population healthy.

Scientific Vocabulary

resource
(noun) substance or object in the environment needed by an organism for growth, life, and reproduction

Competitive Relationships At times, there are not enough resources for every organism in a community. This causes competition. Competition describes interactions between two organisms that need the same resource at the same time. These resources include food, water, and shelter. When there are not enough resources available to survive, there is more competition in a community. In the Kalahari Desert, water is scarce. There, the meerkats compete with other animals and with each other for resources such as food and water.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Dynamic Ecosystems

Changing Ecosystems

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	An ecosystem never changes.	
	Nothing grows in the area where a volcano has erupted.	

Key Concept

- How do changes to ecosystems affect the organisms that live there?

Read to Learn

How do land ecosystems change?

Weeds sometimes grow up through cracks in a sidewalk. Over time, the weeds will break apart the sidewalk. Shrubs and vines will sprout and grow. Their leaves and branches will grow large enough to cover the sidewalk. Eventually, trees could start to grow there. This process is an example of ecological succession.

Ecological Succession *The process of one ecological community gradually changing into another is called* **ecological succession.** Ecological succession occurs in a series of steps. These steps can be predicted. For example, small plants usually grow in an ecosystem before trees do. Change usually happens slowly. You might not notice the differences from day to day.

A climax community is the final stage of ecological succession in a land ecosystem. *A* **climax community** *is a stable community that no longer goes through major ecological changes.* Climax communities differ depending on the type of biome they are in. Mature grassland, for example, is the climax community of a grassland. Climax communities are usually stable over hundreds of years. As plants die, new plants of the same species grow, as long as the climate stays the same.

Study Coach

Create a Quiz Create a quiz about how ecosystems change. Exchange quizzes with a partner. After taking the quizzes, discuss the answers.

Scientific Vocabulary

ecological
(adjective) connected with the relationships of living things and their environment

Scientific Vocabulary

mature
(adjective) fully grown and developed

Scientific Vocabulary

landscape
(noun) an area of land that has a particular quality or appearance

Science Use v. Common Use

pioneer
Science Use the first species that colonize new or undisturbed land

Common Use the first human settlers in an area

Scientific Vocabulary

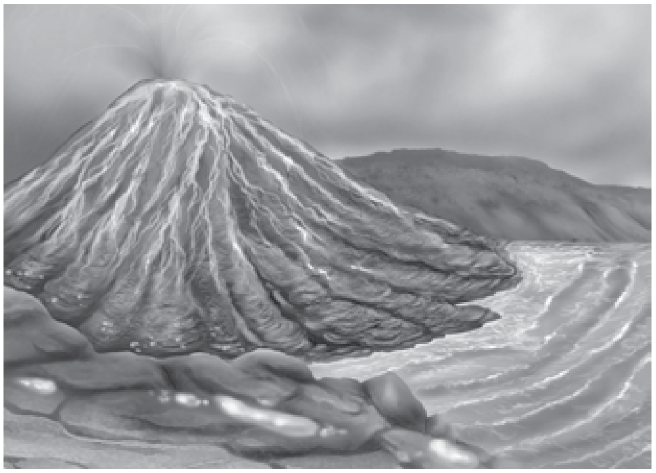
lichen
(noun) a structure formed when fungi and certain other organisms grow together

Academic Vocabulary

release
(verb) to set free or let go

Primary Succession What do you think happens to a lava-filled landscape when a volcanic eruption is over? Volcanic lava eventually becomes new soil. This new soil supports plant growth. Ecological succession in new areas of land with little or no soil—such as on a lava flow, a sand dune, or an area of exposed rock—is called primary succession. The first species that colonize new or undisturbed land are pioneer species. Lichens and mosses are examples of pioneer species.

The figures below and on the next page show what happens to an area during and after a volcanic eruption.



A volcano erupts. Molten lava flows over the ground and into the water. The eruption ends. The lava cools and hardens into bare rock.

Lichen spores are carried on the wind. They settle on the rock. Lichens release acid that helps break down the rock and create soil. As they die and decay, lichens add nutrients to the soil.

Airborne spores from mosses and ferns settle on the thin soil. When the spores die, they add to the soil. The soil becomes thick enough to hold water. Insects and other small organisms begin living in the area.

After many years, the soil is deep. It has enough nutrients for grasses, wildflowers, shrubs, and trees to grow. The new ecosystem provides habitats for animals. Eventually, a climax community develops.

An important point to remember about primary succession is the types of changes that occur at each stage of the process. As different species of plants begin to grow and different species of animals begin living in the area, the composition of the soil changes. This is because when the plants and animals die, their remains add different nutrients to the soil. The changing soil composition can support new species of plants and, thus, new species of animals.

In addition, as different species of plants grow taller, the amount of shade in the area changes. The amount of shade affects the species of plants that can grow there.

Academic Vocabulary

develop
(verb) to grow or become bigger or more advanced

Academic Vocabulary

primary
(adjective) most important; happening or coming first

Academic Vocabulary
occur
(verb) *to happen*

Secondary Succession Secondary succession occurs in areas where existing ecosystems have been disturbed or destroyed. One example is forestland in New England. Early colonists cleared the land hundreds of years ago. Some of the cleared land was not planted with crops. This land gradually grew back to a climax forest community of beech and maple trees.

The figures below and on the next page show what happens to an area of land as it is cleared and after it is cleared.

Settlers in North America cleared many acres of forests. They cleared them to plant their crops. People stopped planting crops on some of the land. The forests began to grow back.

Seeds of plants, such as grasses and wildflowers, began to sprout and grow. Shrubs and trees started growing. These plants were habitats for insects and other small animals, such as mice.

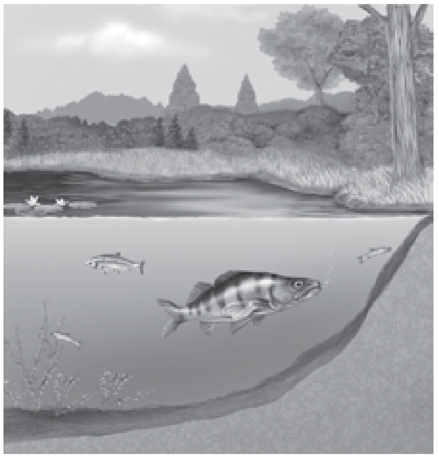
The first trees in the area to grow tall were white pines and poplars. They provided shade and protection for other trees. These other trees, such as beeches and maples, grew more slowly.

Eventually, a climax community of beech and maple trees grew. Older trees died. However, new beech and maple trees grew and replaced them.

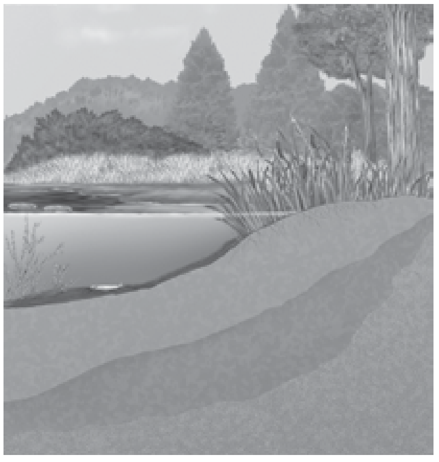
Different types of events can trigger secondary succession. These events damage or kill plants and animals in an area but leave the soil mainly intact. Events that lead to secondary succession include hurricanes and forest fires. Events that are not natural disasters, such as the harvest of a crop, also bring about secondary succession.

How do aquatic ecosystems change?

Like land ecosystems, freshwater ecosystems change over time. They change in a natural, predictable process. This process is called aquatic succession. The figures below and on the next page show aquatic succession.



Aquatic succession begins with a body of water, such as a pond, lake, or wetland.



Academic Vocabulary

transport
(verb) to take something or someone from one place to another

Sediment is any material that is broken down by the process of weathering and erosion. Sediments are transported by wind, water, or gravity. They are usually transported by water. Rainwater and runoff can move sediment into streams, ponds, lakes, and wetlands.

The sediments create soil. Over time, the soil builds up at the bottom of the pond, lake, or wetland. The soil begins to fill the body of water.

Eventually, the body of water fills completely with soil. The water disappears. The area becomes land. A land ecosystem develops.

Environmental Connection Sediment in water has some negative effects. It can damage stream habitats, change coastlines, clog waterways, and cause flooding. It can also cause habitat loss and changes in the nutrients available for organisms to use.

Sediment that is suspended in water might make it hard for animals to see underwater. Animals might have trouble finding food. Sediment in water may also prevent light from reaching plants that need sunlight for food. Sediment that has collected on the bottoms of rivers and streams may cover habitats of fish or other animals.

Eutrophication Like sediment, decaying organisms fall to the bottom of a body of water. They add nutrients to the water. **Eutrophication** *is the process of a body of water becoming nutrient rich.*

Eutrophication is a natural part of aquatic succession. However, humans also contribute to eutrophication. The fertilizers that farmers use on crops and waste from farm animals can be very high in nutrients. Other forms of pollution can also contain many nutrients. When fertilizers and pollution run off into a pond or lake, concentrations of nutrients increase.

Using the nutrients, large populations of algae and microscopic organisms can grow. These organisms use up most of the dissolved oxygen in the water. Less oxygen is available for the fish and other organisms that live in the water.

As a result, many of these organisms die. Their bodies decay and add to the buildup of the soil. This speeds up succession.

Word Origin
eutrophication
from Greek *eutrophos*, means "nourishing"

Scientific Vocabulary
microscopic
(adjective) able to be seen only through a microscope

How do changing ecosystems affect populations?

Academic Vocabulary
dynamic
(adjective) characterized by constant change

Populations of organisms need food and shelter. For these, they depend on resources in their ecosystems. **Dynamic equilibrium** *is the balance between different parts of the ecosystem.* As you have learned, environments change. The change can last for years.

After such a change happens, the balance in an ecosystem is lost. Individual organisms of a species might not be able to find the resources they need to survive. These changes may disrupt all areas of the ecosystem.

Scientific Vocabulary
eruption
(noun) an explosion, usually of volcanic rock

Effects of Change Natural disruptions can cause massive amounts of damage to an ecosystem. Natural disruptions include forest fires, floods, volcanic eruptions, and disease. Some natural disruptions, such as mountain formation, may not happen suddenly. They might happen over many years.

Organisms might have difficulty adapting to sudden disruptions. For example, a drought might reduce plant growth. This disruption would make less food available for organisms that eat plants. Less food might lead to a decrease in the size of plant-eater populations.

Suppose that a forest fire forces animals to live closer together in the remaining forest. This disruption might give predators easier access to prey. Prey populations might decrease. The forest fire might force organisms to compete more fiercely for resources. In addition, animals living closer together might transmit disease more easily from one individual to another.

In some cases, natural disruptions have benefits. Sometimes disturbances control the size of populations. Sometimes they allow new growth of plant life.

How does human activity cause disruptions in ecosystems?

Academic Vocabulary
estimate
(verb) to determine roughly the size, nature, or extent of something

The human population is growing quickly. Scientists estimate that there were about 300 million humans on Earth a thousand years ago. Today there are more than 7 billion humans on Earth. By 2050, there could be more than 9 billion. No one knows when the human population will reach Earth's carrying capacity. Some scientists estimate that Earth's carrying capacity is about 11 billion.

As the human population grows, people use increasing amounts of resources. All this human activity disrupts ecosystems in many different ways.

Resource Extraction Resource extraction refers to any activity that takes resources from nature. Resources such as water help people survive. Resources such as oil help the economy.

However, in many instances human extraction of these materials causes problems. For example, people need houses and roads. They need to grow food. To accomplish these goals, they clear land of trees and other plants. Deforestation means that less living space, food, and other resources are available for other species. Deforestation disrupts forest ecosystems.

Scientific Vocabulary
deforestation
(noun) the act of cutting down or burning large areas of forest

Pollution Pollution occurs when contaminants are brought into an environment and cause negative change. Through human activity, contaminants enter ecosystems and cause damage. For example, people drill for oil. Oil spills on land damage and kill plants and animals. They make ecosystems unlivable. Oil spills also happen while oil is being transported to factories. If ships spill oil, aquatic ecosystems are harmed. Oil can kill fish, birds, and other organisms.

People use energy to heat and cool homes. They use it to fuel cars, airplanes, and other forms of transportation. They use it to produce electricity. This energy use adds pollution to the air and water. The pollution affects other populations of organisms.

Nonnative Species A nonnative species is a species that is living outside of its natural range. Often, people introduce nonnative species into an ecosystem intentionally. They want to add a plant to their gardens, or they want to use an animal to control the population of another animal. Sometimes, people unintentionally introduce nonnative species. The nonnative organisms travel in packing materials or in the ballast water carried by ships.

Nonnative species compete with native species for resources. Sometimes, nonnative species crowd out native species. Native species die or are forced to move into another habitat. For example, people unintentionally introduced brown tree snakes on the island of Guam. The snakes eat the animals that are native to the island. The snakes have caused populations of native forest animals to decline.

Word Origin
habitat
from Latin *habitus,* means "to live, dwell"

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Biodiversity in Ecosystems

Benefits of Biodiversity

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Humans benefit from biodiversity.	
	Biodiversity cannot be measured.	

Key Concept

- Why is biodiveristy important?

Read to Learn

What is biodiversity?

The rain forests of Madagascar are some of the most biodiverse places on Earth. Many kinds of plants and animals live there. But what exactly is biodiversity?

Biodiversity *The number and variety of living things found is a specific region, such as a small pond, a grassy field, a desert, or all of Earth, is called* **biodiversity.** What is the biodiversity of Earth? So far, scientists have identified about 2 million species. *A* **species** *is a group of organisms that have similar traits and are able to produce fertile offspring.* The graph on the next page shows the variety of living things on Earth.

Types of Biodiversity If you look at your friends, you can observe many different traits. These traits include eye color, hair texture, and height. *The variety of genes or inherited traits that are present in a population make up its* **genetic diversity.**

There is also diversity among the species that live in an ecological community. *The number of different species and the quantity of each species in an ecological community is called* **species diversity.**

Another type of biodiversity is diversity among ecosystems. *The variety of ecosystems in the biosphere is called* **ecosystem diversity.** Different ecosystems have different abiotic factors. They support different kinds of living things.

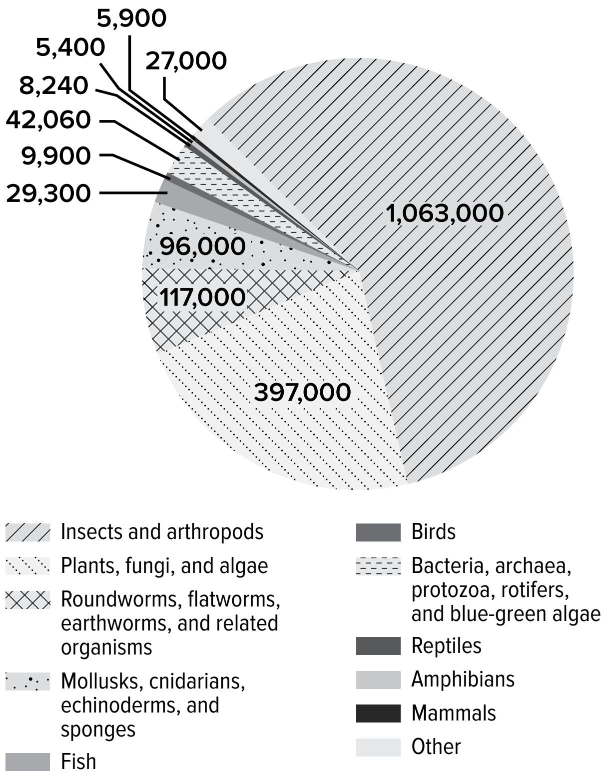
Mark the Text

Building Vocabulary As you read, underline the words and phrases that you do not understand. When you finish reading, discuss these words and phrases with another student or your teacher.

Academic Vocabulary

diversity
(noun) the state of having different types of things or people

Number of Known Species by Taxonomic Group



How do scientists measure biodiversity?

The first step in measuring biodiversity is collecting data about the number and types of living things in an area. There a variety of methods that are used to collect this data.

Canopy Fogging Scientists often use canopy fogging to collect data about biodiversity of insects. It is often used in forests. A low dose of insecticide is sprayed into one or several trees. The insects fall and are collected on a large screen. Then, they are identified and counted.

Word Origin
habitat
from Latin *habitus,* meaning "to live, dwell"

Transect Sampling In this method of measuring biodiversity, scientists use a rope, string, or measuring tape as a transect line. The transect line is marked at set intervals. The transect line is placed on the ground or the surface of the habitat. At each marked interval, living things are counted. This method can be used on land and in aquatic habitats.

Mist Netting Mist nets are fine mesh nets. They are used to safely capture and count living things in ecosystems. This method is typically used to count living things that fly or swim. It is often used to counts birds, bats, and fishes.

Aerial Photos In this method of measuring biodiversity, photos are taken from above. These photos can be used to count and track organisms. This method is often used to count whales, herds of migrating animals, and types of trees in forests.

Surveys Scientists use surveys to gather data about biodiversity of some types of organisms. Scientists collect and analyze data gathered by many people. For example, data about birds can be collected by bird watchers, field technicians, and scientists.

Quadrat Sampling In quadrat sampling, the number and variety of living things in a square area are counted. The square area, called a quadrat, can range in size. The quadrat is placed at several places in a habitat. The biodiversity within the quadrat is observed and recorded.

The Biodiversity Index Scientists can use the data they gather to analyze the biodiversity in an area. The formula below is used to calculate biodiversity:

$$\text{Biodiversity Index} = \frac{\text{Number of species in an area}}{\text{Total number of individuals in the same area}}$$

Interpreting Biodiversity Index The biodiversity index of an area is always a number between 0 and 1. The closer to 0 it is, the lower the biodiversity. The closer to 1 it is, the greater the biodiversity.

The biodiversity index depends on two things: the number of species and the number of individuals. Think about a corn field. It has lots of individual corn plants, but only one species. It has a very low biodiversity index. An area with more species, but fewer individuals of each species will have a higher biodiversity index.

Why is biodiversity important?

There are many methods for collecting data about biodiversity. Why do scientists spend so much time gathering this information? Why is it important to monitor biodiversity?

Number of Species and Ecosystem Health The higher the biodiversity in an ecosystem, the healthier it is. A decrease of biodiversity in an area means the ecosystem is not functioning as well. The health of the ecosystem decreases.

Ecosystem Changes A small change in one part of an ecosystem can lead to bigger changes in another part. An ecosystem with more species is better able to respond to changes or disruptions. When an ecosystem is healthy it can respond to changes and stay stable.

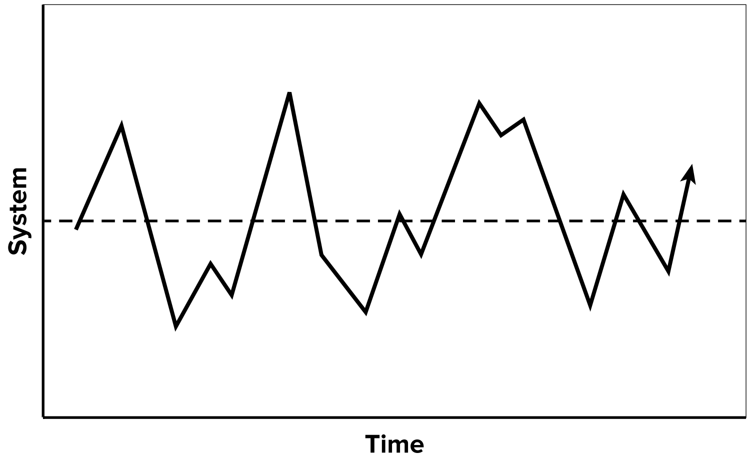
Scientific Vocabulary
survey
(noun) an act of measuring and examining an area

Scientific Vocabulary
data
(noun) information and facts

Academic Vocabulary
analyze
(verb) to examine or think about something carefully

A stable ecosystem is often described as being in a state of **dynamic equilibrium.** It means that after a change, the ecosystem returns to a balanced state. Changes, or disturbances, in an ecosystem include storms, fires, flood, drought, and human activity. These disturbances might cause a change in the amount of nutrients available, the amount of plant production, or the number of species. Dynamic equilibrium is shown in the graph below. The straight, dotted line in the middle represents a system that experiences no changes. This type of ecosystem does not exist in nature. The solid line shows natural processes bringing an ecosystem towards a balanced state while adjusting to changes.

Dynamic Equilibrium



Resilience *is the ability of an ecosystem to maintain dynamic equilibrium even with significant outside disturbances.* Even stable ecosystems might not be able to recover from a severe disturbance. Severe disturbances can change the type of ecosystem. For example, in some parts of Africa, many animals graze on the savanna grasses. If all of the grass is eaten, there are no grass roots to hold the soil in place. The ecosystem might change from a savanna to a desert.

Scientific Vocabulary
geographic
(adjective) relating to geography (the study of different places on Earth)

How does biodiversity differ between ecosystems?

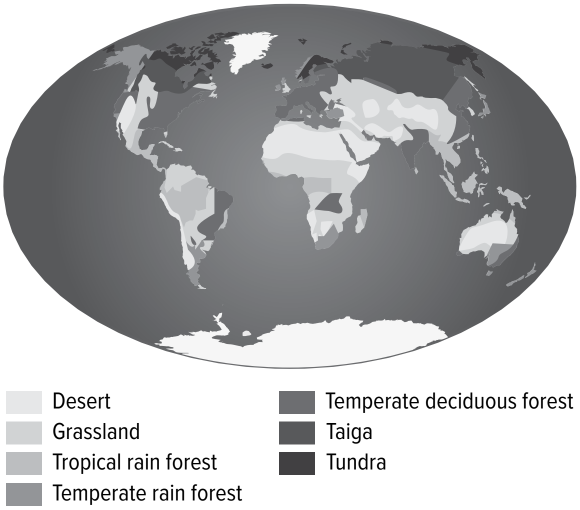
Different ecosystems have different types of plants and animals that live there. What are the characteristics of Earth's land biomes and aquatic ecosystems?

Word Origin
biotic
from Greek *biotikos,* means "fit for life"

Land Biomes Earth's continents have many different ecosystems. They range from deserts to rain forests. Scientists classify similar ecosystems in large geographic areas as biomes. *A* **biome** *is a geographic area on Earth that contains ecosystems with similar biotic and abiotic features.*

Scientific Vocabulary
abiotic
(adjective) nonliving

The abiotic factors in a biome determine which living things are found there. Earth has seven major land biomes, shown in the figure below. Areas classified as the same biome have similar climates and organisms.



Deserts *Biomes that receive very little rain are called* ***deserts.*** *Deserts are found on almost every continent.* A desert biome is shown in the figure below.

- Deserts are Earth's driest ecosystems.
- Deserts make up about one third of Earth's land mass.
- Plants can have a difficult time growing in the desert.
- Plants and animals in the desert have adaptations for the hot, dry environment in which they live.

Academic Vocabulary
dominant
(adjective) most common

Grassland *Biomes where grasses are the dominant plants are called* **grasslands.** Some of the living things in a grassland biome are shown in the figure.

- Grasslands are also called prairies, savannas, and meadows.
- Wheat, corn, oats, rye, barley, and other important cereal crops are grasses. They grow well in these areas.
- Home to many invertebrates, birds, and mammals.

Tropical Rain Forests *Forests that grow near the equator and experience heavy annual rainfall are called* **tropical rain forests.** These forests have dense growths of tall, leafy trees, as shown in the figure below.

- Tropical rain forests are warm and wet all year.
- Tropical rain forests have a high level of biodiversity.
- Insects make up the largest group of tropical animals. Larger animals include parrots, toucans, snakes, frogs, flying squirrels, fruit bats, monkeys, jaguars, and ocelots.

Temperate Rain Forests *Regions of Earth between the tropics and the polar circles are* **temperate** *regions*. Temperate rain forests are moist ecosystems located mostly in coastal areas.

- Temperate regions have relatively mild climates with distinct seasons.
- Several biomes are in temperate regions, including rain forests, which are shown in the figure.
- Temperate rain forests are moist ecosystems mostly in coastal areas and are not as warm as tropical rain forests.
- Temperate rain forests do not have as much biodiversity as tropical rain forests.

Temperate Deciduous Forests Temperate deciduous forests grow in temperate regions where winter and summer climates have more variation than those in temperate rain forests.

- Temperate deciduous forests are the most common forest ecosystems in the United States.
- Deciduous trees lose their leaves in fall.

Scientific Vocabulary

ecosystem
(noun) all the living and nonliving things in a given area

Taiga ***A taiga*** *(TI guh) is a forest biome consisting mostly of cone-bearing evergreen trees.*

Scientific Vocabulary
forest
(noun) an area where a lot of trees and plants grow

- The taiga biome, shown in the figure below, exists only in the northern hemisphere. It is also called a boreal forest.
- Reptiles and amphibians cannot survive in this biome due to the cold temperatures. There are fewer mammals and birds.

Tundra A tundra biome is cold, dry, and treeless, as shown in the figure below.

- Most tundra is located south of the North Pole. It also exists in mountainous areas at high altitudes.
- The ground in the tundra is frozen. It is difficult for deep-rooted plants to grow.
- A wide range of mammals live in the tundra. There are no reptiles or amphibians.

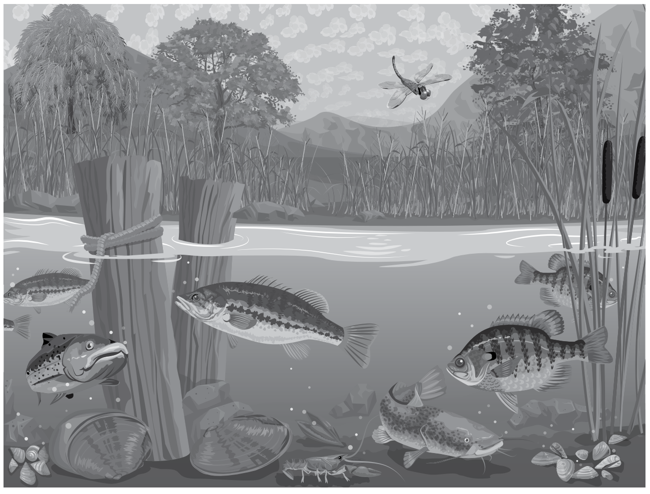
Aquatic Ecosystems There are four main types of water, or aquatic, ecosystems. They are freshwater, wetlands, estuaries, and oceans. **Wetlands** *are aquatic ecosystems that have a thin layer of water covering soil that is wet most of the time*. Wetlands contain freshwater, salt water, or both. **Estuaries** (ES chuh wer eez) *are regions along coastlines where streams or rivers flow into a body of salt water.* Most estuaries form along coastlines where freshwater in rivers mixes with salt water in oceans.

Temperature, sunlight, and dissolved oxygen gas are important abiotic factors in aquatic ecosystems. Fish and other aquatic species have adaptations that enable them to use the oxygen from the water. For example, the gills of a fish separate oxygen from water and move the oxygen into the fish's bloodstream.

Each type of ecosystem contains a unique variety of organisms. Whales, dolphins, and corals live in ocean ecosystems. Trout and some kinds of catfish live only in freshwater ecosystems. Many other organisms, such as birds and seals, depend on aquatic ecosystems for food and shelter.

Streams and Rivers Freshwater ecosystems include streams, rivers, ponds, and lakes. Streams are usually narrow, shallow, and fast-flowing. Rivers are larger, deeper, and flow more slowly.

- Stream water is often clear because soil particles are quickly washed downstream. Soil in a river can make the water muddy.
- Willows, cottonwoods, and other water-loving plants grow along streams and on riverbanks, as shown in the figure.
- Species adapted to fast-moving water include trout, salmon, crayfish, and many insects. Species adapted to slow-moving water include snails and catfish.



Word Origin
estuary
from Latin *aestruarium,* means "a tidal marsh or opening"

Ponds and Lakes Ponds and lakes contain freshwater that is not flowing downhill. These bodies of water form in low areas on land.

- Ponds are smaller and shallower than lakes.
- The surface water contains plants, algae, and microscopic organisms that use sunlight for photosynthesis.
- Living things in ponds and lakes include fish, reeds, and turtles, as shown in the figure below.

Wetlands Freshwater wetlands form at the edges of lakes and ponds and in low areas on land. Saltwater wetlands form along ocean coasts. Wetlands, shown in the figure, are among Earth's most fertile ecosystems.

- Nutrient levels and biodiversity are high.
- Plants that can live in wetlands include grasses and cattails. Few trees live in saltwater wetlands.
- Many insects, including flies, mosquitoes, dragonflies, and butterflies, live in wetlands.

Estuaries Nutrient levels and biodiversity are high in estuaries, which are shown in the figure below.

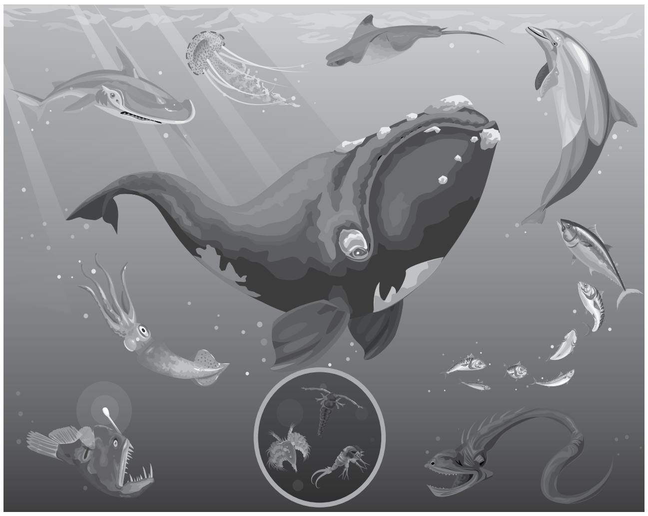
- Plants that grow in salt water include mangroves, pickleweeds, and seagrasses.
- Animals include worms, snails, and many species that people use for food, including shrimp, crabs, and clams.
- Many species of birds depend on estuaries for breeding, nesting, and feeding.

Open Oceans The open ocean, shown in the figure below, extends from the steep edges of continental shelves to the deepest parts of the ocean.

- Microscopic algae and other producers (organisms that make their own food) in the sunlit zone form the base of most ocean food chains.
- Other species in the ocean include jellyfish, tuna, mackerel, dolphins, sea cucumbers, and brittle stars.

Word Origin

producer
from Latin producer, means "lead or bring forth, draw out"



Intertidal Zones The intertidal zone, shown in the figure, is the ocean shore between the lowest low tide and the highest high tide.

- As the tide rises, the rocks and beach are covered with water. When the tide falls, the rocks and beach are exposed to air.
- Many organisms live in the intertidal zones.
- Intertidal zones provide nursery areas for many fish and crustacean species.

Coral Reefs *A* **coral reef** *is an ocean ecosystem that consists of an underwater structure made from outside skeletons of tiny, soft-bodied animals called coral.*

- Most coral reefs form in shallow tropical oceans.
- Coral reefs, as shown in the figure, provide food and shelter for many animals, including parrotfish, groupers, angelfish, eels, crabs, scallops, clams, worms, and snails.
- Grasses and algae are also found in coral reefs.

How do humans benefit from biodiversity?

Humans get many benefits from biodiversity and healthy ecosystems. When biodiversity changes, the change can affect the benefits people receive from an ecosystem. What are some of these benefits?

Ecosystem services *The benefits experienced by organisms, including humans, which are provided by healthy ecosystems are known as* **ecosystem services.** There are four main types of ecosystem services. These are supporting services, provisioning services, regulating services, and cultural services.

Supporting services *are ecosystem services that allow for the existence of all other ecosystem services.* These include primary production, water cycling, and nutrient cycling.

Ecosystem services that provide products from an ecosystem are called **provisioning services**. These services provide us with food, water, medicine, and other natural resources.

The benefits that are received through the regulation of ecosystem processes are defined as **regulating services.** Examples of regulating services include pollination of plants and water purification. Other regulating services are protection from natural disasters, erosion, and climate.

Cultural services *are the benefits that people obtain through their experiences with the ecosystem.* These differ from other services. They do not have a monetary value. These include recreational activities and the appearance of the environment.

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

Biodiversity in Ecosystems

Maintaining Biodiversity

Key Concept

- What can be done to protect biodiversity?

Mark the Text

Main Idea and Details Highlight the main idea of each paragraph. Highlight two details that support each main idea with a different color. Use your highlighted copy to review what you studied in this lesson.

Academic Vocabulary

threat
(noun) the danger that something bad will happen

Scientific Vocabulary

invasive
(adjective) intruding on someone or something in a negative way

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	Climate change causes pollution.	
	Invasive species are a threat to biodiversity.	

Read to Learn

In what ways is biodiversity threatened?

There are five major threats to biodiversity. These threats are habitat destruction, invasive species, pollution, overexploitation, and climate change.

Threats to Biodiversity What happens when smoke gets in the air or chemicals leak into soil? Smoke can make breathing difficult. Toxic chemicals that leak into soil can kill plants and soil organisms. These substances cause pollution. **Pollution** *is the contamination of the environment with substances that are harmful to life.* An **invasive species** *is an organism that is introduced into an ecosystem, either by accident or on purpose, that spreads on its own and outcompetes native species for resources, such as space, food, light, and nutrients*. **Habitat destruction** *involves cutting down forests, or generally changing a habitat so much that it is no longer useable by the organisms that live there.* For example, habitat destruction occurs when a wetland is drained. **Overexploitation** *is the overuse of animal and plant species by humans for purposes including food, medicine, or clothing.* **Climate change** *refers to changes in climate patterns over time.* Recently, Earth's average surface temperatures have increased. This is called global warming.

How can we protect biodiversity and ecosystem services?

You've read about the threats to biodiversity. Reusing materials is one way to protect biodiversity. What else can people do to protect biodiversity?

Solutions for Protecting Biodiversity There are many ways to help maintain and protect biodiversity. Many factors, such as the type of ecosystem, can affect which solution is used.

Habitat Restoration and Conservation Restoring damaged habitats and ecosystems to their original state is one way to make a difference. **Reforestation** *involves planting trees to replace trees that have been cut or burned down.* **Reclamation** *refers to the process of restoring land disturbed by mining.*

Controlling Invasive Species There are three main ways to control invasive species. The method used depends on the type of invasive species, how it reproduces and spreads, the number of organisms in an area, and the cost.

- mechanical controls use fences, barriers, weeding, or trapping
- chemical controls include herbicides and pesticides
- biological controls use other species to control invasive species

Cleaning Up and Reducing Pollution People can help reduce pollution by using fewer harmful chemicals. They should also properly dispose of wastes. One action that has reduced water pollution is the United States Clean Water Act. Living things, such as plants and bacteria, can be used to remove some chemicals from soil.

Sustaining Populations There are laws to help keep populations of organisms at sustainable levels. These include regulations related to hunting and fishing.

Reducing Impacts of Climate Change The main cause of current climate change on Earth is an increase in greenhouse gases in the atmosphere. Burning fossil fuels is the source of the increased amounts of greenhouse gases.

One way to reduce the impacts of climate change is to reduce the use of fossil fuels. Renewable sources of energy, such as solar power, wind power, and geothermal power can help. None of these energy sources release greenhouse gases. Walking, riding a bike and using public transportation can also reduce the use of fossil fuels. Recycling reduces the fuel needed for manufacturing.

Scientific Vocabulary
biological
(adjective) relating to biology or to life and living things

Scientific Vocabulary
pollution
(noun) substances that make land, water, or air dirty and not safe to use

Scientific Vocabulary
sustainable
(adjective) able to be maintained without causing harm

Academic Vocabulary
dispose of
(phrasal verb) to throw something away, to get rid of

Scientific Vocabulary
geothermal
(adjective) related to or produced by heat inside the Earth

After You Read

Reread the statements at the beginning of the lesson. Fill in the *After* column with an A if you agree with the statement or a D if you disagree. Did you change your mind?