Chapter 4

Interdependence of Organisms and Environments

Standard:
SB5.c

Chapter 4 • Lesson 12

Stability and Change in Ecosystems

Key Terms • biosphere • ecology • population • community • niche • ecosystem • biome • biotic factor • abiotic factor • homeostasis • biodiversity

Getting the Idea

Ecologists study organisms and the ways they interact with each other and with their environments. These interactions can result in stability, but environments often undergo changes, sometimes suddenly and with little warning. The impact of change on living things in the environment depends in part on the severity of the change.

Organization in Earth's Biosphere

The **biosphere** is the thin region near Earth's surface that supports all life. It includes all of Earth's organisms and the environments—land, water, or air—in which they live. Organisms interact with each other and with the nonliving components of their environment. **Ecology** is the science that studies the interactions among organisms and between organisms and their environments. *Ecologists* are scientists who study ecology.

As shown in the diagram below, an individual organism in the living world is actually a member of five levels of organization. Each level is interdependent with the others, and organisms interact with each other at all five levels. Ecologists must study all the levels to gain a complete understanding of how organisms and their environments interact.

Organism → Population → Community → Ecosystem → Biome

Ecologists begin their research at the first level of ecological organization: the organism. To learn about individual organisms, ecologists study such things as their feeding habits, daily movements, mating patterns, and general behavior.

The next level of ecological organization is the population. A **population** includes all the organisms of a species that live in an area at the same time. Examples of populations include all the eastern hemlock trees in a forest or all the largemouth bass living in a river. When studying populations, ecologists often focus on population size and density and the rates of population growth.

The third level of ecological organization is the community. A **community** is made up of all the populations that inhabit and interact in the same area at the same time. For example, a meadow community would include the different grasses, shrubs, insects, rodents, bacteria, fungi, and any other organisms that live in the meadow.

Ecologists often study the interactions among populations within a community. For example, they may look for ways that the addition or loss of one population affects other populations in the area. A **niche** is the role a population plays within a community. When scientists describe a niche, they might include what a species eats and how it interacts with other parts of the ecosystem. The place where a species lives is called its *habitat.*

The next level of ecological organization is the ecosystem. An **ecosystem** consists of all the populations in an area and the nonliving parts of their environment. For example, a forest ecosystem includes all the plants, animals, and other organisms that live in the forest. It also includes all the nonliving factors in that forest. For example, an ecosystem includes the soil in which the plants grow, the water they absorb through their roots, the air from which they get carbon dioxide, and the sunlight their leaves absorb. Ecologists study interactions between the living and nonliving parts of an ecosystem to identify how a change in any of them may affect other components of the ecosystem.

Finally, the top level of ecological organization is the biome. A **biome** is a group of ecosystems that have similar climates and similar types of plant life. *Climate* is the weather conditions in an area over a long time. The most important aspects of climate are temperature and the amount and types of precipitation. Examples of biomes include deserts, grasslands, and tropical rain forests.

Biotic and Abiotic Factors

You would be unlikely to see a king penguin in Georgia, outside of a zoo. Similarly, you would not find Georgia's state reptile, the gopher tortoise, walking across an ice sheet in Antarctica. This is because different organisms are suited to different environments. King penguins, for example, are well suited to swimming in cold water. The structures and behaviors that make an organism suited to its environment are called *adaptations.*

Ecologists know that both the living and nonliving parts of an environment determine which organisms live there. An organism in an ecosystem, or the remains or wastes of an organism, is a **biotic factor**. Biotic factors include the other organisms with which an individual organism might interact. These can include predators, prey, and organisms that compete for the same resources. An **abiotic factor** is a nonliving aspect of an environment. Abiotic factors include the physical characteristics of an area such as the amount of light the area receives, the temperature range, the amount of precipitation, and the type of soil.

To survive, organisms must get everything they need from their environments. Every ecosystem has both biotic factors and abiotic factors. The chart below lists examples of each type of factor.

Examples of Biotic and Abiotic Factors

Biotic Factors	Abiotic Factors
Plants	Climate
Animals	Light
Fungi	Soil
Bacteria	Water
	Air

Ecosystem Stability

Scientists study interactions among the biotic and abiotic factors of an ecosystem to identify how a change in any component may affect other components.

An ecosystem may remain stable for long periods of time. Yet a stable ecosystem is not static, or unchanging. Instead, it changes constantly in limited ways. For example, in a stable ecosystem, population sizes change in predictable patterns. New individuals are born and existing individuals die. Some individuals enter from other ecosystems, and other individuals leave. A stable ecosystem also has predictable changes in resources. For example, the amount of water may change seasonally due to patterns of rainfall.

To remain stable, an ecosystem requires a constant input of energy. Solar energy flows into an ecosystem and adds heat and light. This warming is vital, as biochemical reactions in living things occur only within certain temperature ranges. Solar energy is also captured by photosynthetic plants. The plants convert the energy to a chemical form. Plants and the organisms that consume them use this chemical energy to support their life functions. The input of energy changes within limits, however. For example, the sunlight available to an area usually fluctuates with the seasons.

Just as an organism maintains homeostasis, an area's biotic and abiotic factors must respond to change to keep an ecosystem's conditions stable. **Homeostasis** in an ecosystem is the balancing of the ecosystem's biotic and abiotic factors to maintain stability.

Population sizes fluctuate in response to changes in one or more factors. For example, consider a plant population whose size increases due to increased rainfall. As a result, competition increases for other resources, such as nutrients in the soil. If these resources are limited, only some individuals will survive. As a result, the population size will soon decrease to its original level. Despite regular changes in a stable ecosystem, its basic features stay the same. An ecosystem can remain stable for hundreds or thousands of years.

The stability of an ecosystem is related to its biodiversity. **Biodiversity** is a measure of the number of different kinds of organisms living in a specific area. Greater biodiversity produces a more stable ecosystem. An ecosystem with many diverse types of organisms is more likely to rebound from a change in a biotic or abiotic factor. For example, in the early 1900s, a disease called chestnut blight killed most of the chestnut trees in North American forests. But these forests also contained many other tree species. As a result, many animals were still able to use trees for shelter or food. The interactions among organisms continued in very similar forms, so the forest ecosystems remained largely stable. A less diverse ecosystem with fewer tree species might have been disrupted.

An ecosystem can be described by its tolerance for change. More stable ecosystems can withstand greater environmental change. Less stable ecosystems are more likely to be disrupted by natural events or by human activities.

Some natural changes to ecosystems are fairly limited, such as damage from a storm or deaths in a population due to a disease. Other natural events can cause severe change. Examples of such events include volcanic eruptions, wildfires, droughts, and long-term climate change. Like natural changes, changes caused by humans can be limited, such as damage to a habitat, or severe, such as extinction of a species. You will learn more about the effects of human activities on ecosystems in Lesson 16. A severe change in one or more factors may make stability impossible to maintain.

Predictions explain what might happen under certain conditions. In science, a prediction is not just a guess. Instead, a prediction is based on previous observations, patterns, and evidence. You can construct a scientific argument that predicts what is likely to happen under certain environmental conditions. Like all scientific arguments, your prediction should include evidence and reasoning to support it.

Review the types of environmental change described in the lesson. Select one type of change and research it. Then write an argument, supported by evidence from your research, that predicts the impact of that change on the abiotic and biotic factors in a specific ecosystem. Exchange predictions with a partner and evaluate each other's arguments.

Type of change:

Prediction of impact of change supported by evidence:

Lesson Review

1. Which list orders the levels of ecological organization from simplest to most complex?

   A. biome, ecosystem, community, population, organism

   B. community, ecosystem, biome, organism, population

   C. organism, population, biome, ecosystem, community

   D. organism, population, community, ecosystem, biome

2. Corals live near the ocean surface in some warm regions of the world. The corals provide a home for algae. The algae, in turn, produce food that is used by the corals. Which is a biotic factor in this ecosystem?

   A. the amount of sunlight that reaches the coral

   B. the coral population

   C. the salt content of the water

   D. the temperature of the water

3. Which biotic factor would be **most** effective in maintaining homeostasis in an ecosystem?

   A. the absence of large trees

   B. the presence of many ponds

   C. the presence of many species

   D. the absence of predators

4. In a grassland ecosystem, as vegetation grows, reproduces, and dies, the amount of soil increases. Over time, as the remains of plants and animals decompose (break down), nutrients increase in the soil. Which statement **best** describes how the stability of the ecosystem will be affected?

   A. Biodiversity will likely decrease, which will decrease the stability of the ecosystem.

   B. Biodiversity will likely decrease, which will increase the stability of the ecosystem.

   C. Biodiversity will likely increase, which will decrease the stability of the ecosystem.

   D. Biodiversity will likely increase, which will increase the stability of the ecosystem.

Standard:
SB5.b

The Flow of Energy in Ecosystems

Key Terms • producer • autotroph • consumer • heterotroph • primary consumer • secondary consumer • tertiary consumer • decomposer • food chain • food web • trophic level • herbivore • carnivore • omnivore • biomass • energy pyramid

Getting the Idea

All organisms need materials and energy to carry out their life processes. The materials needed to sustain life are recycled between organisms and their physical environment. Energy, however, is not recycled, so a continuous supply is needed. The sun is the main source of energy for living things.

The Path of Energy in Ecosystems

Organisms need a constant supply of energy to maintain the chemical and physical organization of their bodies. The main source of this energy is the sun. Energy enters an ecosystem through organisms that make their own food. From them, energy flows to other organisms.

A **producer** is an organism that captures energy from a primary source, usually the sun, and converts it to chemical energy. This energy is stored in the bonds of glucose and other simple food molecules. Like all organisms, producers carry out cellular respiration to release the energy contained in these molecules. They use the energy to carry out their life processes. Plants, algae, and some kinds of bacteria are producers. A producer is also called an **autotroph**, which means an organism that feeds itself.

Almost all producers are photosynthetic organisms. Recall that photosynthesis is a process in which organisms use energy from the sun to make food. In this process, producers convert light energy into chemical energy. A few producers do not use sunlight to make their food. These producers are chemosynthetic bacteria and archaea, which use energy from chemical reactions to make organic molecules.

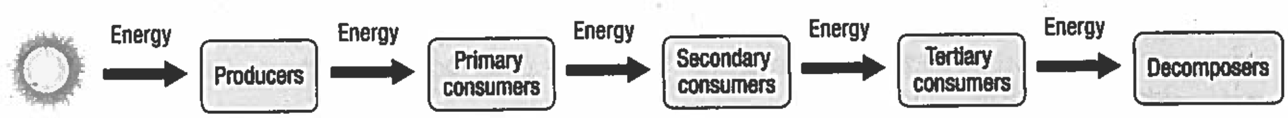
When a producer is eaten, the energy and materials in the cells and tissues of the producer are transferred to the organism that eats it. A **consumer** is an organism that obtains its energy by eating other organisms. This type of organism is also called a **heterotroph**, which means an organism that feeds on other organisms. Consumers' bodies break down the compounds in the organisms they eat into simpler substances during the process of cellular respiration. These simpler substances can be transported to cells and used for energy or to make new molecules, such as complex carbohydrates, proteins, and fats.

Consumers are grouped into categories based on their feeding habits. A **primary consumer**, such as a rabbit, a cardinal, or a white-tailed deer, is a consumer that eats producers. A **secondary consumer**, such as a river otter, a red-tailed hawk, or a great blue heron, is a consumer that eats primary consumers. A **tertiary consumer**, such as a tiger or a crocodile, is a consumer that eats secondary consumers.

A third group of organisms found in all ecosystems is made up of decomposers. A **decomposer** is an organism that obtains energy from the wastes or remains of other organisms, such as fallen leaves or dead animals. To obtain their energy, decomposers break down complex molecules into simpler molecules. As you will learn in the next lesson, decomposition is one of the processes by which elements such as carbon and nitrogen cycle through the biosphere.

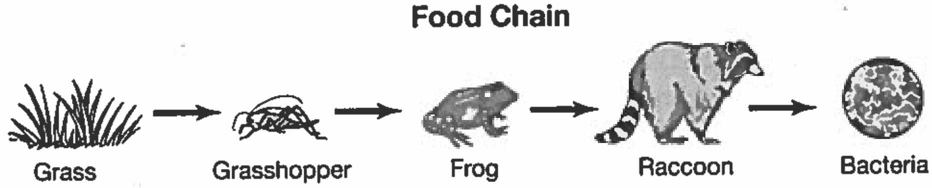
Fungi, such as mushrooms, and many soil bacteria are decomposers. Fungi are the main decomposers of plant matter, and bacteria are the main decomposers of animal matter. Decomposers secrete enzymes that break down their food outside their bodies. Then these organisms absorb the nutrients that are released.

The diagram below shows the typical flow of energy through groups of organisms in an ecosystem.



The path of food and energy from producer to consumer to decomposer is a called a **food chain.** An example of a simple food chain is shown below. The arrows in the diagram show the direction in which energy flows from one organism to the next. The energy travels in only one direction. Unlike matter, energy does not cycle through an ecosystem.

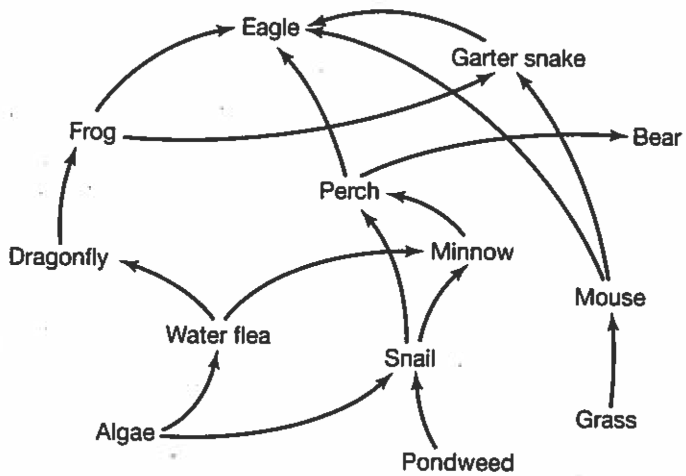
Food Chain



Organisms usually do not eat just one type of food, so food chains are rarely an accurate model of energy flow within an entire ecosystem. Chains that are interconnected through multiple feeding relationships make up a **food web.**

A sample food web is shown below. In this food web, algae, pondweed, and grass are producers. All the other organisms are consumers.

Food Web



Food chain and food web diagrams do not always show the decomposers. However, although an ecosystem can exist without consumers, no ecosystem can survive without producers and decomposers. The simplest food chain is producer → decomposer. The producer captures the energy that drives the system, and the decomposer breaks down wastes into molecules that the producer can use for growth and repair.

Trophic Levels

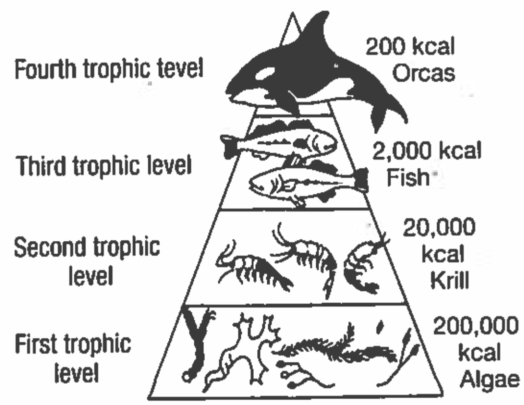
Energy changes form as it flows through an ecosystem. Light energy from the sun is converted to chemical energy (food) by producers. Producers use some of the energy to carry out their life processes and store the rest in their tissues. Primary consumers that feed on the producers use some of the energy for cellular processes and transform some into mechanical energy (movement). Some energy is also transformed into heat, which is released into the environment. Although the total amount of energy in the universe always remains the same, this released heat energy cannot be used by other organisms and is considered "lost."

A **trophic level** is a feeding level in an ecosystem. Producers make up the first trophic level. The second trophic level is made up of primary consumers. A consumer such as a rabbit or a cow, which eats only or mostly plants or plant products, is called an **herbivore.** Herbivores are primary consumers. A consumer such as a fox, otter, or red-tailed hawk, which eats only or mostly other consumers, is called a **carnivore.** A carnivore can be a secondary or tertiary consumer. A consumer that eat both plants and animals is an **omnivore.** Examples of omnivores are raccoons, bears, and humans. An omnivore may be a primary, secondary, or tertiary consumer, depending on its place in a particular food chain.

Biomass is the amount of living matter in an ecosystem. Producers make up most of the biomass in any ecosystem. Primary consumers have less biomass than producers, and secondary consumers have even less biomass. The least biomass is usually at the highest trophic level.

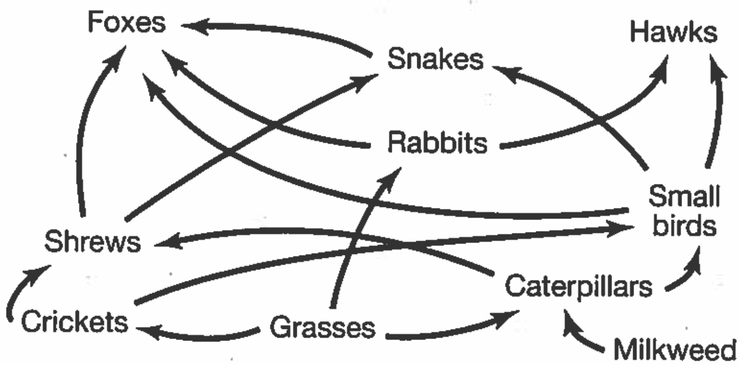
An **energy pyramid** is a model that shows the available energy at each trophic level in an ecosystem. Only about 10 percent of the energy at any trophic level is passed to the next level. Organisms at each level use much of the energy or release it into the environment as heat. Energy stored in body parts such as bones or teeth may not be passed on.

The energy pyramid below shows the trophic levels for an ocean ecosystem. Energy is given in units of kilocalories (kcal).



The small percentage of energy that passes from one trophic level to the next limits the number of organisms that can exist at each trophic level. The energy decrease also limits the number of feeding levels that can exist. In many ecosystems, the numbers of organisms at different levels show a pyramidal relationship similar to the differences in the amounts of energy at those levels. However, this is not always the case. For example, many insects may feed on a single tree. So, while the amount of energy decreases at each trophic level, the number of organisms may not.

A scientific model is a simplified representation of a natural phenomenon. To be useful, a model must accurately represent the components of the phenomenon as well as the relationships among them. A food web and an energy pyramid are both scientific models that can be used to analyze the flow of energy within ecosystems. The food web below shows the feeding relationships among several organisms in a meadow ecosystem.



Assume that the amount of energy represented by the producers in this food web is 125,000 kilocalories (kcal). In the space below, develop an energy pyramid that models the feeding relationships in the food web. Arrange the components of the food web according to energy flow. Write the name of each kind of organism in the correct trophic level. Compare the quantity of energy available at each level by adding the amount of available energy to each level of your model.

Lesson Review

1. Which sequence shows the transfer of energy within an ecosystem?

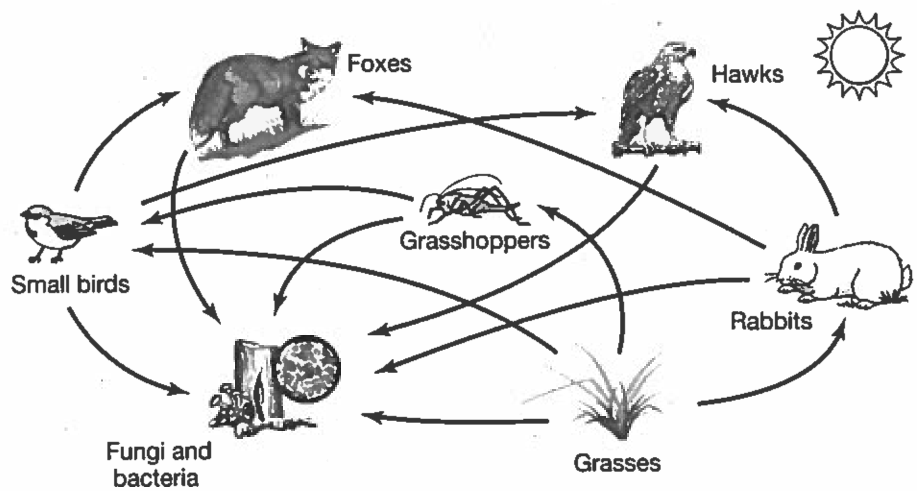
   A. carnivore → herbivore → decomposer → omnivore

   B. omnivore → carnivore → herbivore → primary consumer

   C. producer → decomposer → herbivore → omnivore

   D. producer → herbivore → carnivore → decomposer

2. The diagram below shows a simple food web.



Which of these food chains is included in the food web?

A. grasses → small birds → foxes → fungi and bacteria

B. fungi and bacteria → grasshoppers → grasses

C. fungi and bacteria → small birds → grasses

D. grasses → rabbits → foxes → hawks

3. About how much energy is available at the third trophic level if the first trophic level has 300,000 kilocalories of available energy?

A. about 300 kilocalories

B. about 3000 kilocalories

C. about 30,000 kilocalories

D. about 300,000 kilocalories

4. How do scientists account for the decrease in available energy from one trophic level to the next higher trophic level?

A. The energy is available to organisms at lower trophic levels.

B. The energy of the sun cannot be fully exploited by producers.

C. The energy is stored in energy-dense molecules for decomposers.

D. The energy is used by organisms for life functions or is lost as heat.

Chapter 4 • Lesson 14

Cycles of Matter in Ecosystems

Key Terms • water cycle • evaporation • transpiration • condensation • precipitation • carbon cycle • carbon-oxygen cycle • nitrogen cycle • nitrogen fixation • denitrification • phosphorus cycle

Getting the Idea

Unlike energy, which flows in one direction in an ecosystem, matter cycles through the environment. Matter is continuously recycled among the living and nonliving parts of ecosystems through the feeding relationships and life processes of organisms and as a result of physical processes.

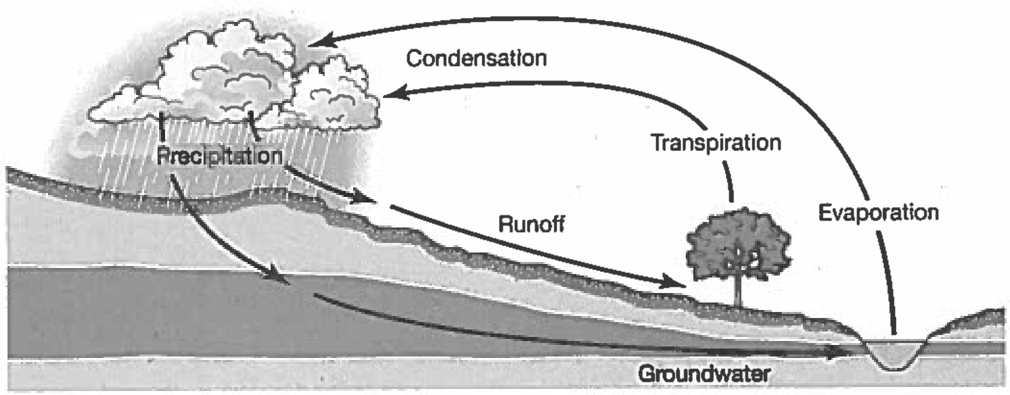
Essential for Life

The elements carbon (C), oxygen (O), hydrogen (H), nitrogen (N), and phosphorus (P) are essential to living things and their activities. Matter containing these elements cycles through the living and nonliving parts of ecosystems.

The Water Cycle

Water (H_2O) is made up of hydrogen and oxygen. Water is a vital nonliving component of ecosystems. Earth has an enormous supply of water that continuously cycles among Earth's atmosphere, surface, and organisms. The continuous movement of water and its natural changes from one form to another is called the **water cycle**. The diagram below shows its main processes.

The Water Cycle



As the sun heats bodies of water on Earth's surface, water vapor enters the atmosphere through evaporation. **Evaporation** is the change of a liquid to a gas at the surface of the liquid—in this case, the change of liquid water to water vapor. Water also enters the atmosphere from organisms. Recall that water is a waste product of cellular respiration. Many animals release the water vapor formed during cellular respiration when they exhale. Plants release excess water by transpiration. **Transpiration** is the release of water vapor through the stomata, or openings, in a plant's leaves.

Water vapor in the atmosphere cools and changes to a liquid through **condensation.** Some of this liquid water falls back to Earth as **precipitation**—water that falls from the atmosphere in the form of rain, hail, snow, or sleet. After falling, the water may flow over the surface (runoff) or be stored or flow underground (groundwater). All of these processes are continuous.

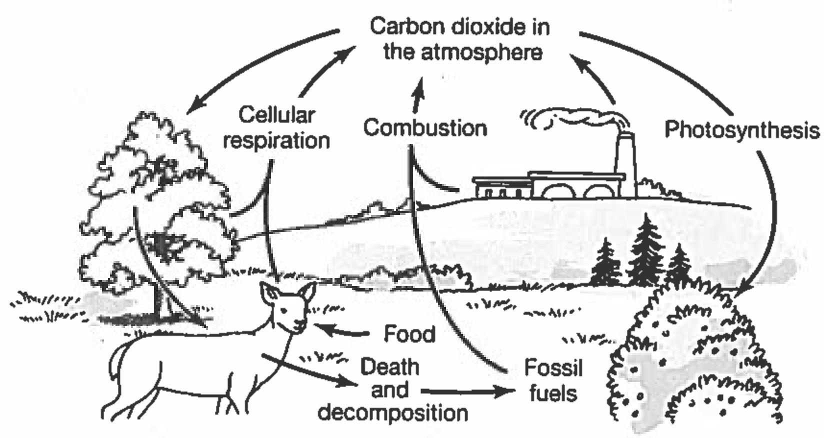
The Carbon Cycle

Like water, carbon moves in a continuous cycle among organisms and the environment. The continuous transfer of carbon between organisms and the nonliving parts of the environment is known as the **carbon cycle.** All organisms contain carbon. Carbon is also present in the atmosphere, mainly as a component of carbon dioxide (CO_2).

Recall that plants use photosynthesis to convert carbon dioxide from the atmosphere into carbohydrates, which supply the plants with energy. In the previous lesson, you saw how energy moves between organisms through their feeding relationships. This energy is stored in the chemical bonds of the carbohydrates made during photosynthesis. The carbon in the carbohydrates also moves between organisms through their feeding relationships.

Decomposers release CO_2 into the soil when they break down the wastes and remains of organisms. Much of this CO_2 diffuses from the soil into the atmosphere. Carbon also enters the atmosphere in the CO_2 that is a byproduct of cellular respiration. The combustion (burning) of fossil fuels also plays a major role. Coal, oil, and natural gas are called fossil fuels because they formed from the remains of ancient organisms. Burning fossil fuels releases the carbon that was stored in those organisms. It combines with oxygen to form CO_2.

The Carbon Cycle



The Carbon-Oxygen Cycle

Carbon dioxide is made up of carbon and oxygen. As carbon dioxide breaks down and re-forms, oxygen also cycles through organisms and the environment. For example, plants release oxygen to the air when they carry out photosynthesis. Organisms take in this oxygen and use it in cellular respiration, returning carbon dioxide to the environment. Since burning requires oxygen, combustion also cycles oxygen through the environment. As these examples show, the same processes that cycle carbon through the environment also cycle oxygen. Therefore, the movements of carbon dioxide and oxygen through the environment are often studied as a single cycle called the **carbon-oxygen cycle.**

Look back at what you learned earlier to review the inputs and outputs of photosynthesis and cellular respiration. Then, in the space below, construct a diagram that models how the inputs and outputs of these processes are involved in the carbon-oxygen cycle. Refer to the model of the carbon cycle on the previous page, but use only labels and arrows. Include the following labels at appropriate places: "CO_2" (carbon dioxide), "O_2" (oxygen gas), and "$C_6H_{12}O_6$" (glucose).

Using your completed model, explain the need for the cycling of carbon in ecosystems.

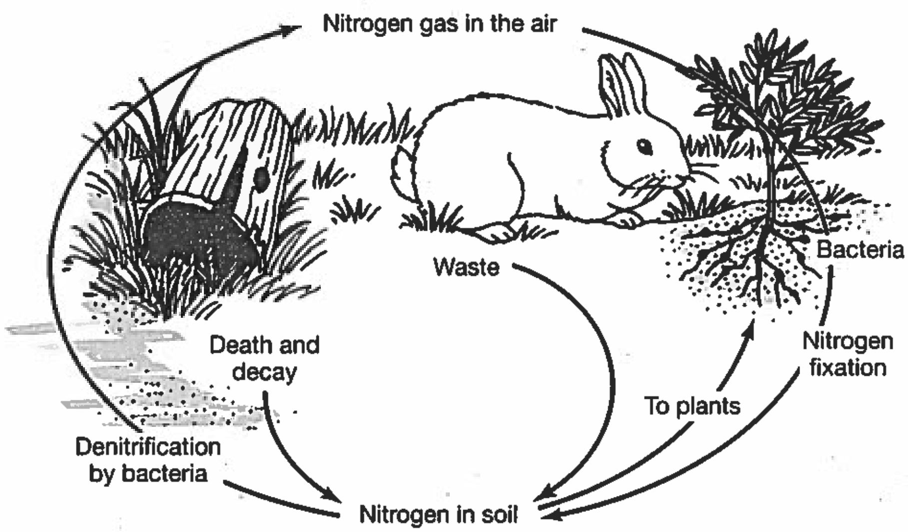
The Nitrogen Cycle

The **nitrogen cycle** is the continuous movement of nitrogen among organisms and the environment. Recall that nitrogen is an essential component in amino acids and proteins as well as in nucleic acids and ATP.

Nitrogen gas (N_2) makes up about 78 percent of Earth's atmosphere. However, most organisms cannot use nitrogen in this form. **Nitrogen fixation** is a process in which certain soil bacteria break down nitrogen gas from the atmosphere and convert it into nitrogen-containing compounds. These compounds are easily absorbed by the roots of plants. Some nitrogen-fixing bacteria live on the roots of plants such as beans and peanuts. The bacteria convert nitrogen gas in exchange for carbohydrates. When animals consume the plants, the animals get the nitrogen, which is passed through food chains to other animals and then to decomposers.

When organisms die, the nitrogen in their cells and tissues is returned to the environment. Under certain conditions in the soil and in marine environments, bacteria convert nitrogen compounds into nitrogen gas. This process, called **denitrification**, returns nitrogen to the atmosphere.

The Nitrogen Cycle



The Phosphorus Cycle

The **phosphorus cycle** is the continuous movement of phosphorus through rocks, soil, water, and organisms. Unlike the other cycles described in this lesson, phosphorus does not cycle through the atmosphere. However, like hydrogen, carbon, oxygen, and nitrogen, phosphorus is essential to living things. It is a component of DNA, RNA, and ATP. Phosphorus is also part of the structure of cell membranes, teeth, and bones.

Phosphorus is found in rocks, soil, water, and ocean sediments. The phosphorus cycle is very slow. Over time, weathering and erosion release phosphorus from rocks. The phosphorus is in the form of phosphates. Plants take up phosphates dissolved in water. Herbivores consume the plants, and the phosphorus is passed on to higher trophic levels. Decomposition returns phosphorus to soil and water. Water that flows into the ocean carries phosphorus-containing sediments, which, over millions of years, can form new rock.

Lesson Review

1. Which processes return water vapor to the atmosphere?
   - **A.** evaporation and condensation
   - **B.** precipitation and condensation
   - **C.** transpiration and evaporation
   - **D.** transpiration and precipitation

2. Organisms that perform nitrogen fixation belong to which group?
   - **A.** fungi
   - **B.** plants
   - **C.** animals
   - **D.** bacteria

3. Which process is a source of phosphorus in ecosystems?
   - **A.** erosion of rock by water
   - **B.** fixation by bacteria in soil
   - **C.** respiration by plants and animals
   - **D.** photosynthesis by plants and algae

4. Which is one way in which photosynthesis is involved in the carbon cycle?
   - **A.** Photosynthesis produces CO_2, which is released into the atmosphere.
   - **B.** Photosynthesis returns carbon from organisms to the soil.
   - **C.** Photosynthesis releases glucose into the atmosphere.
   - **D.** Photosynthesis uses CO_2 from the atmosphere.

Standard:
SB5.a

Population Dynamics and Biodiversity

Key Terms • population • limiting factor • population density • density-dependent limiting factor • density-independent limiting factor • carrying capacity • exponential growth • logistic growth • biodiversity • keystone species

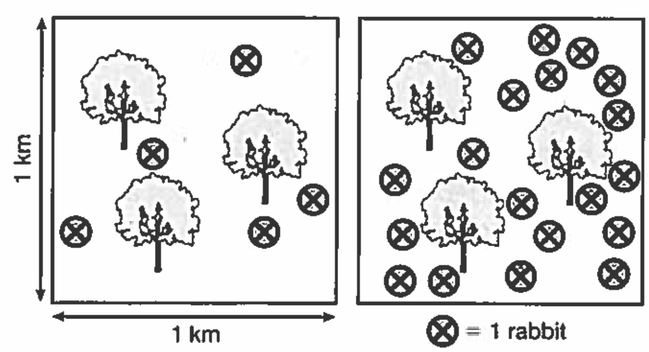
Getting the Idea

Groups of living organisms interact with one another and with the resources in their environments. These interactions and the amount of resources available affect the sizes of populations found in an ecosystem. These factors also influence the number and variety of different populations that can survive in an environment.

Limiting Factors

Recall that a **population** is made up of all the organisms of a species that live in an area at the same time. One way a population can be described is by its size. The numbers of births, deaths, and individuals moving into or out of a population affect its size. In an ecosystem, population sizes change over time. However, most populations stabilize rather than grow endlessly. As a population grows, it puts more demands on its ecosystem. For example, a larger population of white-tailed deer needs more food than a smaller population does. If the ecosystem does not provide enough resources to feed a large population, some deer will die or leave the area. As a result, the population size will decrease. In this example, the size of the deer population is limited by the food supply. Any component of an ecosystem that can slow the growth of a population is called a **limiting factor**. In addition to food, limiting factors include the supply of water, oxygen, and sunlight, as well as relationships with other organisms.

A population also can be described by its density. **Population density** is the number of individuals per unit of area. The population of rabbits in the right-hand diagram below is almost four times as dense as the population in the left-hand diagram.



There are two main types of limiting factors—density-dependent and density-independent.

Density-Dependent Limiting Factors

The effects of a **density-dependent limiting factor** increase as population density increases. Increasing population density is called crowding. Crowding can cause stress to individual organisms.

Most density-dependent limiting factors are biotic, involving relationships among organisms. These limiting factors include competition, predation, parasitism, and disease. Organisms of the same or different species compete for the same resources. The denser a population, the greater the competition for resources is among its members. For example, widely spaced trees each have more access to sunlight, soil, and water than do trees that are growing close together. Crowded trees must compete for the resources they need to survive.

Predation is a feeding relationship in which one animal kills and eats another. Coyotes feeding on white-tailed deer is an example of predation. Like competition, predation has a greater effect in dense populations than in less dense populations. If the predator population in a certain area grows too large, there will not be enough prey to support it. Similarly, increases in numbers of predators in an area keep prey populations from growing. Numbers of prey are a limiting factor for predators, and numbers of predators are a limiting factor for prey. Predator and prey population sizes tend to change in response to each other in a continuous cycle.

Parasitism is a symbiotic relationship in which one species benefits at the expense of another. For example, a tick or leech attaches to a host animal and feeds on its blood. The host animal provides the parasite with nutrients. For the host, this is a loss of resources. As in predator-prey relationships, numbers of hosts are a limiting factor for parasites, and numbers of parasites are a limiting factor for hosts.

Diseases spread by pathogens are also density-dependent limiting factors. A pathogen is a bacterium, fungus, or virus that can cause disease. In dense populations, pathogens can spread quickly. For example, Dutch elm disease, which is caused by a fungus, was first observed in elm trees in the United States in the 1930s. At the time, elm trees were common in forests and along tree-lined streets in towns and cities. Dense populations of elms provided a habitat for beetles that spread the fungus. The fungus also spread from the roots of diseased trees to the roots of other elms nearby. Because the trees were close together, the disease spread rapidly, killing a large percentage of the elm trees in the United States within a few decades. Diseases caused by pathogens also spread quickly in dense human and animal populations. For example, influenza (flu) is caused by a virus that is spread by coughing, sneezing, and even talking. Influenza spreads fastest in cities, where people live close together.

Density-Independent Limiting Factors

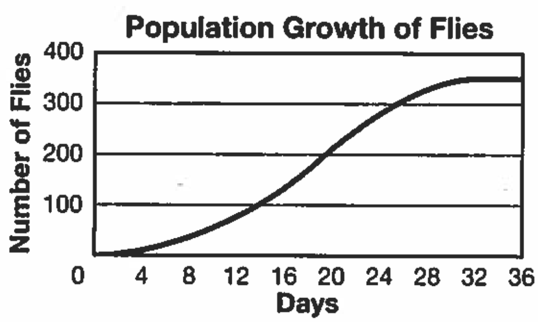
A **density-independent limiting factor** is a factor whose effect on population size is not affected by population density. Density-independent limiting factors are mostly abiotic. Examples include weather conditions, pollution, and natural disasters such as forest fires, floods, and droughts. Usually, these events decrease all populations by the same proportion. However, a severe event can wipe out entire populations. For example, a long drought may kill many populations of plants and animals in an area. Populations of organisms that feed on those species will decline or die out. Some populations may remain small. Others may recover to their previous sizes over time.

Carrying Capacity

The largest population that an ecosystem can support over a long period of time is its **carrying capacity**. The habitats and needs of each species differ. As a result, the carrying capacity of an ecosystem is different for each species.

The carrying capacity of an ecosystem depends on several factors, including the number of organisms living in the ecosystem, the size of the ecosystem, and the available resources. An ecosystem with many resources, such as a tropical rain forest, has a large carrying capacity. By contrast, a desert has a much lower carrying capacity because much less water is available. Area also affects carrying capacity. A large area of rain forest has a larger carrying capacity than a small plot of rain forest.

The activities of a population up to the carrying capacity do not harm an ecosystem. Otherwise, it could not continue to support the population. Note that if conditions in the environment change, the carrying capacity may also change. A population stops growing when it reaches the carrying capacity of its ecosystem. At that point, population size tends to stabilize, or level off. The graph below shows the effect of carrying capacity on a fly population. Initially, the population is small, and resources are plentiful. As a result, most of the flies survive and reproduce. The population grows rapidly. In about a month, the fly population reaches the carrying capacity of the ecosystem. At that point, the population stops growing and levels off.



Think about abiotic limiting factors that affect carrying capacity in ecosystems, for example space, water, sunlight, temperature, or pollution. Then plan an investigation to gather data about the effect of one abiotic limiting factor on the population of a plant species. Choose a plant that you can grow from seed, for example beans, radishes, spinach, zinnias, or marigolds. Answer the questions on the next page to plan an investigation about a specific factor that would affect the population size of that plant species.

Which abiotic factor will you investigate, and what species will you use?

Identify a testable question for your investigation.

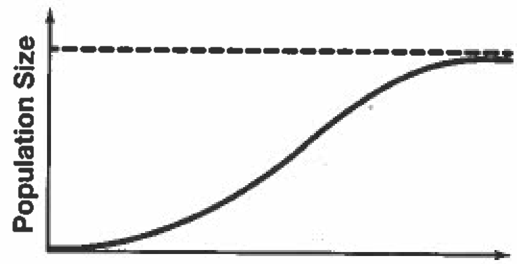
Use your question to develop a hypothesis.

Plan and describe an investigation to test your hypothesis.

Scientists use mathematics to model the growth of populations. The graphs below are based on two mathematical models of population growth. They represent growth patterns under different environmental conditions. The graph on the left shows **exponential growth**. The population increases without limits, under ideal conditions. Note that this J-shaped graph closely models the early growth of the fly population shown on the previous page. However, the graph of exponential growth models the fly population less closely as time goes on. The growth of the fly population is more like the S-shaped graph on the right below. This graph shows **logistic growth**. In this model, the population increases at first, but then its growth slows. Finally, it stabilizes as it approaches the dashed line. This line represents the ecosystem's carrying capacity.

Exponential Growth

Logistic Growth



Scientists used mathematical models of population growth to generate data for two populations of bacteria. Study the data in the tables.

Population 1

Time (hours)	Population (no. of individuals)
0	1
2	4
4	16
6	64
8	256
10	1024
12	4096
14	16,384
16	65,536
18	262,144
20	1,048,576
22	4,194,304
24	16,777,216

Population 2

Time (hours)	Population (millions)
0	0.5
2	3.7
4	27.2
6	193.9
8	1148.2
10	3438.8
12	4710.6
14	4958.8
16	4994.4
18	4999.2
20	4999.9
22	5000.0
24	5000.0

Identify the type of growth model shown in each table.

Does either model have an upper limit for population as time increases? Cite evidence from the tables to support your answer.

Which table better demonstrates real population changes over time? Explain your answer.

The data in both tables could be used to create graphs. Describe the shape of each graph.

Knowing an environment's carrying capacity is important to conservationists trying to protect and manage wildlife populations. Maintaining a healthy population requires enough organisms for genetic variety. Some individuals or species need large tracts of land to survive and breed. Others can flourish in a small area. Biologists can use information about carrying capacity to decide how much habitat must be conserved to protect a given species. Also recall that **biodiversity**, the number of different kinds of organisms living in an area, impacts the health of an ecosystem as a whole. An ecosystem with high biodiversity is more likely to have species whose populations can increase as the population of a competing species decreases.

A **keystone species** is a species that plays a critical role in the community structure of an ecosystem. For example, the gopher tortoise is a keystone species in Georgia's coastal plain. The health of a keystone species is one indicator of the health of the ecosystem it inhabits.

Lesson Review

1. Which of these factors will affect a population regardless of the population's density?
   - **A.** competition
   - **B.** disease
   - **C.** flooding
   - **D.** parasitism

2. A researcher uses a logistic model of population growth. Which statement **best** describes the relationship between time and population size in a logistic growth model?
   - **A.** Over time, population size increases without limit.
   - **B.** Over time, population size increases and then levels off to a maximum value.
   - **C.** Over time, population size decreases and then levels off to a minimum value.
   - **D.** Population size is not related to the passage of time.

3. As limiting factors, how do diseases differ from forest fires?
   - **A.** Diseases can slow the growth of a population.
   - **B.** Diseases increase the carrying capacity of an ecosystem.
   - **C.** Diseases reduce all populations in an ecosystem by the same proportion.
   - **D.** Diseases have a greater effect on a dense population than on one that is less dense.

4. Which statement **best** describes an exponential model of population growth?
   - **A.** It assumes that the population size levels off.
   - **B.** It assumes that only the best-adapted organisms reproduce.
   - **C.** It assumes an environment that includes no limiting factors.
   - **D.** It assumes that the population does not exceed the carrying capacity.

Standard:
SB5.d

Chapter 4 • Lesson 16

How Human Activities Impact the Environment

Key Terms • natural resource • renewable resource • nonrenewable resource • pollution • nonnative species • greenhouse effect • greenhouse gas

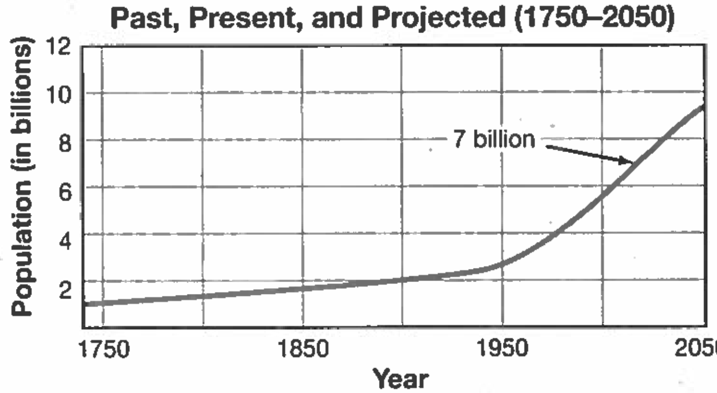
Getting the Idea

Humans are a part of every ecosystem in which they live. Like populations of other organisms, the human population can grow until it reaches the carrying capacity of the ecosystem. As the population grows, human activities can have greater impacts on the environment.

Human Population Growth

A major challenge to the environment is human population growth. Over the last 200 years, the total human population of the world has grown exponentially. Although the rate of growth is slowing, the number of births each year continues to exceed the number of deaths. The graph below shows how the total human population has grown over time. The graph also shows how the population is expected to grow over the next few decades.

World Population Growth
Past, Present, and Projected (1750–2050)



Continued growth will bring the human population closer to Earth's carrying capacity. Recall that the carrying capacity of an ecosystem is the largest population that it can support. The carrying capacity for humans is limited by available energy, drinkable water, and nutrients. Researchers are trying to address these limits. Their efforts include developing new energy resources, improving the efficiency of existing energy sources, recycling and conserving water, and increasing agricultural productivity. So far, however, Earth's carrying capacity is not increasing as fast as the population is growing.

Use of Natural Resources and Habitat Reduction

As the human population grows, people use more natural resources. A **natural resource** is a product of the environment that is useful to humans. Land, water, and air are all natural resources. Organisms are also natural resources. Earth's supply of many natural resources is limited, and people sometimes use more of a resource than they need. Human use of resources can also affect other organisms

A **renewable resource** is a product of the environment that can be replaced through natural processes within a human lifetime. Such resources include trees, which can be replaced after they are cut, and fresh water, which can be purified and reused repeatedly. A **nonrenewable resource** is a product of the environment that exists in limited amounts and cannot be replaced for human use within a human lifetime. Fossil fuels are nonrenewable natural resources. Recall that fossil fuels take millions of years to form. They cannot be replaced as fast as people use them. Soil is also considered nonrenewable because it takes a long time to form. Metals such as copper, gold, and iron are nonrenewable resources, along with minerals, such as phosphorus, that cycle through the environment very slowly.

Every person on Earth uses resources. In the space below, record resources you have used in the past week. Consider the definitions of *renewable resource* and *nonrenewable resource* as you complete the table.

Use of Renewable and Nonrenewable Resources

Nonrenewable Resource	How I Used It	Renewable Resource	How I Used It

When humans use the resources in an ecosystem, human actions can physically alter the ecosystem and harm the species living there. For example, people often clear land for mining. They also clear land and fill wetlands to make space available for construction or farming. As a result, the organisms living in those areas lose their habitats. Organisms that are unable to move to another area may not survive.

Deforestation—the removal of all or most trees in an area of forest—is done to obtain wood or to clear the land for human use. However, forests are vitally important to the global ecosystem because they help maintain the proper atmospheric balance of carbon dioxide and oxygen. Forests also moderate temperatures, provide habitats for plants and animals and other organisms, and reduce soil erosion. Deforestation has a wide range of adverse effects on the environment.

Pollution

Pollution is the release of harmful substances, or pollutants, into the environment. Many human activities cause pollution, which can affect the air, soil, or water.

Burning fossil fuels produces pollutants such as compounds of sulfur and nitrogen. These compounds can combine with water in the atmosphere to produce acid rain. Acid rain is rain that has a pH lower than 5.6. Acid rain can harm ecosystems by damaging plants. This damage, in turn, is harmful to animals that feed on the plants. Acid rain can also change the pH levels of aquatic habitats, which can kill off, reduce, or change the populations of species that live in those habitats. Burning fuels can also put smoke into the air. Smoke is made up of solid particles that can harm humans and other organisms.

The improper disposal of solid wastes and chemicals and the reckless use of chemicals can pollute water and soil. Oil spills can pollute lakes, rivers, and oceans. Pollutants released on land or in water can alter ecosystems and make them unfit for the organisms that normally live there. Pollutants can also make fresh water unusable for drinking, cooking, irrigation, and even manufacturing.

Another form of pollution occurs when excess nutrients from sewage or fertilizer enter a body of water. The nutrients, usually nitrogen compounds, can cause an algal bloom, a population explosion of algae. As they use up the nutrients, the algae exceed the carrying capacity of the environment and begin to die in large numbers. When the algae die, decomposers become active and begin to use more oxygen. Decomposition of the dead algae decreases the oxygen available to other organisms, such as fish.

Pesticides are chemicals that are used to kill pest animals, such as certain insects and rodents. The use of pesticides helps reduce disease and increase food production worldwide. However, pesticides can make an ecosystem unstable by sickening or killing animals other than the target pests. For example, pesticides used on lawns and fields can harm beneficial insects, such as bees, which pollinate crops and many other plants. Runoff can carry pesticides into bodies of water, where they may harm aquatic plants and animals. Herbicides—chemicals used to control agricultural weeds—can become pollutants in similar ways.

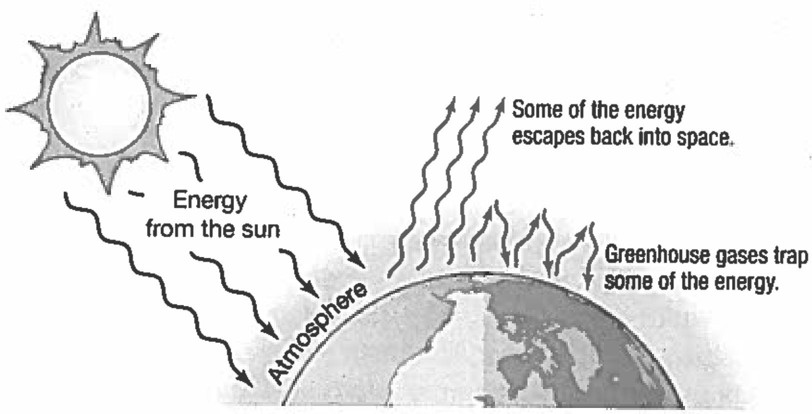
Introduction of Nonnative Species

A **nonnative species** is a species that is introduced into an ecosystem by human activity. Sometimes the species is introduced intentionally. For example, people may plant new flowers and vegetables in their gardens. The plants may then spread to neighboring environments. Animal species are introduced when people release unwanted pets into the wild. Sometimes a species is introduced unintentionally, when humans accidentally carry species to new environments. For example, insects may be transported around the world in luggage or in shipments of food. Rodents that make their way onto ships can be transported from their native habitat to a new location.

An invasive species is a nonnative species that thrives in its new environment at the expense of native species. If a nonnative species is very successful in its new environment, it can outcompete native species and even bring about their extinction. One well-known example of an invasive species is a vine called kudzu. In the late 1800s, this plant was imported from Asia to help control soil erosion in southern states. Although the plant is well suited to this job, kudzu has also outcompeted native plants for resources. Kudzu grows rapidly, and few animals feed on it. In forested areas, kudzu quickly overtakes and smothers small ground plants. As the kudzu continues growing, it climbs tall trees. In time, climbing kudzu vines become large and dense enough to kill the trees. Kudzu has been called "the plant that ate the South."

Global Warming

Temperature is an important abiotic factor affecting Earth's ecosystems. Earth's average temperature is the result of both the sun's energy and the atmosphere. The **greenhouse effect** is an effect of the atmosphere that keeps Earth at a temperature that is suitable for life. Much of the sun's energy that reaches Earth's surface is reflected back toward space. As shown in the diagram below, gases in the atmosphere prevent some of this energy from escaping. They trap some of the reflected energy near Earth's surface, in somewhat the same way that a glass greenhouse holds heat. A **greenhouse gas** is a gas that produces the greenhouse effect. Water vapor, methane, and carbon dioxide are examples of greenhouse gases.



Recall that one of the gases released by burning fuels is carbon dioxide. Since the Industrial Revolution, the amount of carbon dioxide in the atmosphere has increased, largely because of the increased use of fossil fuels. Deforestation also affects carbon dioxide levels and the carbon cycle because it reduces the number of plants that take in carbon dioxide from the air.

New technologies have been developed to convert biomass into fuels. These technologies involve biochemical conversion—the use of microorganisms and catalysts to change organic matter into other chemical forms such as fuels. Ethanol and biodiesel are examples. Such fuels can replace some fossil fuels, but burning biofuels still releases carbon dioxide and other greenhouse gases.

Scientists think that increased levels of carbon dioxide are a major cause of a form of climate change known as global warming. Global warming is an increase in average atmospheric temperatures around the world. Rising temperatures appear to be harming ecosystems. For example, polar ice caps, sea ice, and glaciers are melting and not being replaced by fresh ice. Sea ice is an important part of a polar bear's habitat, so the loss of ice is threatening polar bear populations. Some scientists are concerned that the melting of ice caps will lead to a rapid rise in sea levels and flood many coastal cities. Global warming is also expected to cause more droughts, floods, and other extreme weather events that can damage or destroy ecosystems.

Conservation and Sustainable Practices

People are becoming more aware of how human actions can harm the environment. To help reduce their impact on the environment, many people now try to conserve natural resources through reducing, reusing, and recycling.

Reducing means using less of a resource or not using a resource at all. For example, you can reduce fossil fuel use by riding a bicycle or walking instead of traveling by car. Reducing the use of a natural resource helps conserve that resource. Reducing the use of resources also protects the environment by decreasing activities that can harm environments and destroy habitats, such as mining or clearing forests, and by reducing the amount of wastes that must be disposed of in landfills.

Reusing means finding ways to use products again. For example, refilling a plastic water bottle with tap water conserves fossil fuel resources because oil is used to make plastics. Reusing cardboard boxes to store items in your home helps conserve trees and decrease the amount of waste that ends up in the environment.

Recycling is the processing of an existing product so the material can be used in a new product. Many objects made from metals, glass, paper, and plastic are now recycled. For example, glass bottles can be melted down to make new bottles or windows. Paper can be recycled so that fewer trees must be cut down to make paper. Recycling aluminum cans to make new cans or other products decreases the need for mining to obtain aluminum ores. Recycling aluminum also uses less energy than processing aluminum ore into usable products. When recycling saves energy, it reduces the need to burn fossil fuels.

Another way to conserve resources is through sustainable development. *Sustainable development* is the use of resources in ways that do not destroy or deplete them for future generations. For example, although trees are renewable resources, it takes many years for a tree to grow from a seedling to a mature adult. Sustainable forestry methods enable people to obtain the wood they need while protecting forest ecosystems. To protect a forest, people do not cut all the trees in an area. Instead, they harvest only certain trees, such as those that are old, diseased, or growing in an area where they are overcrowded. As these trees are removed, seedlings can be planted to take their place. Such practices enable people to use resources now and ensure their availability in the future.

Costs and Benefits of Conserving Resources

Most methods used to conserve resources have both benefits and costs. For example, fossil fuels are currently the main resource that humans use for energy. The gasoline used in cars and other motor vehicles, the oil and natural gas used to heat homes, and the coal used to generate electricity in power plants are all fossil fuels. Fossil fuels are nonrenewable and exist in limited amounts. Using these resources also causes pollution. Reducing the use of fossil fuels can both make the supply last longer and improve air quality by reducing pollution.

The use of fossil fuels to produce electricity can be decreased by using other energy sources, such as solar energy, wind energy, nuclear power, and hydroelectric power. However, there are trade-offs in using each of these alternative energy resources. For example, solar panels can be costly to install. They are also large and cannot be used everywhere. There are also limits on the use of turbines to generate electricity from wind. Many areas do not have the sustained winds needed to turn the turbines.

Some automobile makers produce cars that run on electricity instead of gasoline. Some of these cars use electricity from a home outlet to recharge batteries that power the car. A benefit of these cars is that they do not release pollutants into the air. However, the cars currently cost more to buy than similar cars that run on gasoline. Also, the electricity used to charge the batteries may have been generated using fossil fuels. It is also not as easy to recharge an electric car along the road as to fill the tank of a gasoline-powered car.

Engineering is the application of scientific principles to design a solution to a particular problem. As with the process of scientific investigation, the engineering design process involves steps such as the ones listed here, although the process is not as tidy as this list suggests.

- Identify, state, and research the problem
- Brainstorm possible solutions
- List constraints for the solution
- Choose one solution and construct prototype
- Test prototype and evaluate results
- Improve or redesign prototype and re-test

Engineering solutions can be designed to help reduce the impact of human activities on the environment. For example, you read that biochemical conversion is a solution that can reduce the use of fossil fuels. Look back at the table on page 129, in which you recorded natural resources you used in the past week. Select one of these resources. Then, answer the following questions to design a solution to reduce either the use of that resource or its environmental impact.

What resource is the focus of your solution?

How do you use that resource?

How does the use of that resource impact the environment?

Use your responses to the first three questions to identify and state a problem related to the resource.

Brainstorm at least two ideas for devices or solutions that could solve the problem you identified.

List two constraints—that is, factors that might limit your design.

Evaluate your design ideas. Select the idea that is most likely to be successful. Explain the reasons for your choice.

Explain how the idea you chose would reduce the impact of a human activity on the environment.

Lesson Review

1. Which is an example of a renewable resource?

   A. copper

   B. coal

   C. phosphorus

   D. water

2. How does deforestation contribute to global warming?

   A. It decreases the amount of carbon dioxide in the atmosphere.

   B. It increases the amount of carbon dioxide in the atmosphere.

   C. It decreases the amount of oxygen in the atmosphere.

   D. It increases the amount of oxygen in the atmosphere.

3. Which practice limits the effects of a human activity on the environment?

   A. harvesting all the oak trees in a forest

   B sending used aluminum cans to a landfill

   C using wind turbines to generate electric power

   D. allowing nutrients from fertilizer to enter a river

4. Which statement **best** describes conservation efforts?

   A. Methods of conserving resources have both costs and benefits.

   B. Methods of conserving resources all have the same costs and benefits.

   C. The benefits of conserving resources always outweigh the costs.

   D. Many methods of conserving resources have only benefits.

Standard:
SB5.e

Adaptations

Key Terms • adaptation • camouflage • mimicry • innate behavior • reflex • instinct • migration • hibernation • estivation • tropism • phototropism • geotropism • thigmotropism

Getting the Idea

Animals, plants, and other organisms live in many kinds of environments, and those environments are constantly changing. Living things have structures and behaviors that help them survive in both stable and changing environments.

Adaptations

All living things have adaptations. An **adaptation** is a heritable trait that increases an organism's chance of survival or reproduction. Adaptations can be structural (related to an organism's form), physiological (related to the way its body works), or behavioral.

Recall that ecosystems frequently change. Abiotic factors, such as temperature or pH, can vary. Events such as fires and droughts can occur. When the environment changes, some organisms in a population may have adaptations that enable them to survive. Other members of a population might not be able to survive in the changed conditions.

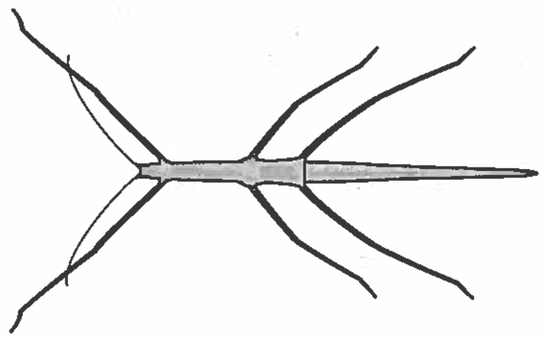
Structural Adaptations of Animals

The shape of a bird's beak is a structural adaptation that allows it to eat specific types of food. Chickens have short, pointed beaks that are well adapted to pecking insects and seeds from the ground. Woodpeckers have long, pointed beaks, so they can make holes in tree branches to find insects. A hummingbird's long, curved beak lets it drink nectar from flowers.

Many structural adaptations in animals are mechanical defenses. A mechanical defense is a physical structure that helps protect an organism from a predator. Shells, sharp claws, stingers, and tusks are some common examples of mechanical defenses. Camouflage is a common mechanical defense of animals. **Camouflage** is a coloring or pattern that enables an organism to blend in with its surroundings. Three types of camouflage are countershading, cryptic coloration, and disruptive coloration.

Countershading is a pattern in which an animal has two different colors of skin or fur. Many fish, for example, are light-colored on their bottom side and dark on top. The lighter underside helps the fish hide from predators beneath it when it swims near the surface, where sunlight shines through the water. The darker color on top helps the fish blend into the darkness of the water when viewed from above. Cryptic coloration is a color or pattern that matches the animal's background. Chameleons, geckos, tree frogs, leafhoppers, and praying mantises are animals with cryptic coloration. Disruptive coloration is a type of camouflage in which patterns of color break up an animal's silhouette. Leopards and zebras are animals with this type of defense.

Mimicry is another defensive adaptation. **Mimicry** is an organism's resemblance to an object in its surroundings or to another organism. Mimicking an object can help an animal hide. This can make an animal a more efficient predator or help it escape from predators.



Insects called walking sticks, like the one shown here, are examples of mimicry. These insects live on shrubs and eat their leaves. Their long, slender bodies and long legs help them look like the thin branches of the shrubs on which they feed. Most walking sticks are green or brown, which also helps them look like twigs or branches. Looking like a branch helps conceal a walking stick from birds and other predators.

Some animals mimic other animals. The king snake is a nonpoisonous snake of the southern and eastern United States. Its markings resemble those of poisonous coral snakes that live in the same area. These markings protect the king snake from predators that will not attack coral snakes.

Many animals have chemical defenses against predators. Skunks are well known for their chemical defense. When a skunk feels threatened, it emits a foul-smelling chemical from a gland near its tail. Squid and octopuses use ink to protect themselves from predators. When threatened, these animals emit a stream of ink. The ink conceals the animal briefly and often scares and confuses predators, giving the squid or octopus a chance to escape.

Behavioral Adaptations of Animals

Recall that some adaptations are behaviors. Like physical traits, behaviors can be inherited. The behavioral responses are controlled by an animal's hormones and nervous system. Inherited behaviors are also called **innate behaviors.**

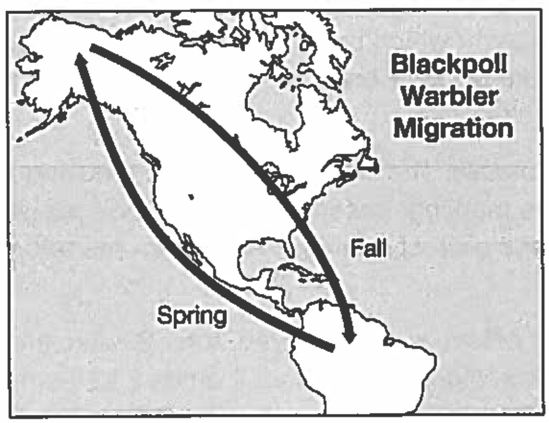
A **reflex** is an involuntary response to a stimulus. Reflexes are automatic responses that require no thinking or decisions. Some reflexes help protect an animal. Shivering when you are cold is an example of a reflex. Pulling your hand away from a hot object is also a reflex.

An **instinct** is a complicated pattern of innate behaviors. Examples of instincts are an insect's ability to fly and a bird's ability to build a nest. Courtship rituals such as dancing by some species of birds and the flashing of distinct patterns of light by fireflies are also instinctive. Animals often have some control over instinctive behavior. For example, a bee has an instinct for flight, but it can choose when and where to fly.

Migration

Migration, the instinctive seasonal movement of a species, is a common behavioral adaptation. Migration is triggered partly by hormones produced by the animal in response to changing environmental conditions, such as length of day. Animals may also migrate in response to stresses such as overcrowding or a decrease in their food supply.

Most animals migrate to find food, water, or breeding grounds when resources are scarce, such as during harsh winters or dry seasons. Many mammals, such as the wildebeest of the Serengeti Plain in Africa, migrate every year. More than a million wildebeests move in an enormous loop, following seasonal rains. Elephant seals migrate between the coast of California and remote islands in the Pacific. These seals travel about 20,000 kilometers each year. Some insects also migrate. Monarch butterflies from the eastern United States travel to Mexico for the winter. Many species of birds migrate. Each autumn, a bird called the blackpoll warbler migrates from Alaska to the northern part of South America. In spring, when more food is available in the north, the warbler returns to Alaska.



Hibernation and Estivation

Some animals hibernate to survive harsh winters. **Hibernation** is the spending of winter in an inactive or dormant state. Hibernation is a behavior that helps animals conserve energy. Their metabolism and body temperature decrease, and their breathing slows. Animals that hibernate include bats, hedgehogs, chipmunks, rattlesnakes, and most marsupials. The period of hibernation ranges from only a few days to several months, depending on the animal and the environment.

Estivation is a reduction in an animal's rate of metabolism in response to extreme heat and lack of water. Like hibernation, estivation is a form of dormancy to save energy, but estivation occurs in summer, not winter. Animals that estivate include many amphibians and reptiles, some insects and land snails, and a few mammals.

Structural Adaptations in Plants

Many adaptations in plants are structural. The structural adaptations of plants can be seen in their leaves, stems, roots, flowers, and seeds. These adaptations help plants survive adverse or changing environmental conditions, and some adaptations help plants reproduce.

In most plants, leaves are the site of photosynthesis. Many plants, such as deciduous trees, have broad, flat leaves that are well suited to capturing sunlight. These leaves also have small openings on their undersides that allow the plant to exchange gases and water with the air. In autumn, deciduous trees drop their leaves and become dormant. Dropping leaves is an adaptation that allows the trees to conserve water and energy during the winter.

Conifers, such as pines and spruce, are cone-bearing trees that often grow in areas that have cold winters. Most conifers have needle-shaped leaves covered by a waxy coating. The thin shape of the leaves and the waxy coating are adaptations that help prevent water loss. Conifers have soft, flexible branches. This adaptation allows the branches to bend, rather than break, under the weight of heavy snow or ice. Many conifers also have trunks covered by a thick layer of bark. The bark helps protect the inner tissues of the trunk from damage by wildfires.

Most cacti live in hot, dry environments. The leaves of cacti are typically modified into spines, which minimize water loss. Cactus spines are not true leaves, so photosynthesis is performed in the stems. The thick stems also store water, and the sharp spines protect the cactus from plant-eating animals.

Many plants have spines, thorns, or other structures as mechanical defenses. Like animals, many plants also have chemical defenses. Substances in the plants may poison or paralyze consumers, or the plants may taste bad or cause stinging sensations

The roots and stems of many plants are adapted to store food. This stored food allows the plants to survive underground during winter or periods of drought. For example, in spring, daffodils, irises, crocuses, and tulips sprout from bulbs, which are underground storage structures.

Flowers are reproductive organs in which the seeds of flowering plants are made. (Conifers form their seeds in cones.) Before a flowering plant can form seeds, pollination must take place. Pollination is the transfer of pollen (male gametes) from a flower to the female part of the same or a different flower. The pollen is usually carried by wind or by an animal, such as an insect. Color, fragrance, and nectar are adaptations of some flowering plants to attract insects, birds, or other animal pollinators. Pollen that rubs off onto a visiting animal can then be carried to another flower.

Many seeds also have functional adaptations. For example, the seeds of some trees, such as the lodgepole pine, will germinate only after being exposed to fire. This adaptation helps the species survive if a forest fire kills all the trees in a forest. The seeds of maple trees are shaped like wings to allow them to be carried long distances by wind. The feathery seeds of the dandelion are also adapted for transport by wind.

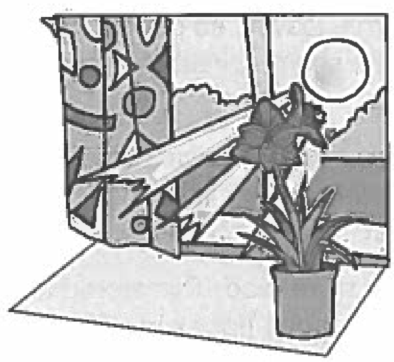
Plant Responses to Stimuli

All plants respond to changes in their environment. A stimulus is anything in an organism's internal or external environment that causes the organism to react. Stimuli include light, temperature, movement, pressure, chemicals, gravity, and sound. An organism's reaction to a stimulus is a response.

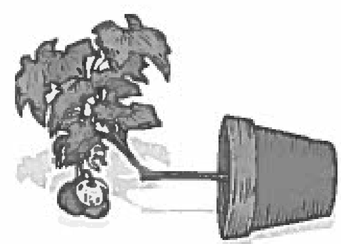
Plants respond to many different external stimuli. A **tropism** is a plant's growth in a certain direction in response to a stimulus. Growth toward a stimulus is a positive tropism. Growth away from a stimulus is a negative tropism.

Phototropism is growth in response to light. When a plant is placed near a window or other source of bright light, the plant will grow toward the light. Plants are positively phototropic to light. **Geotropism** is the response of plants to gravity. The roots of a plant are positively geotropic, so they grow down into the soil. Stems and leaves are negatively geotropic, so they grow upward, away from the soil. Geotropism also aids in the sprouting of seeds. Positive and negative tropisms are shown below.

Positive Phototropism



Negative Geotropism



Some plants respond to touch or physical contact with objects. **Thigmotropism** is a plant's response to touch. Climbing plants, such as morning glories, grapevines, and ivy, use thigmotropism to grow around or up objects that they use for support. As these plants climb, small structures called tendrils coil around objects to help support the vines.

Many plants respond to environmental conditions such as time of day and seasonal changes. For example, some cactus flowers bloom only at night. Some of those cacti are pollinated by bats, which are active at night. Other flowers, such as dandelions, open only during daylight and close again at night. Flowers on some other plants bloom only once per year.

Some types of plants respond to seasonal changes by dropping their leaves and becoming dormant. Many types of seeds also respond to unfavorable environmental conditions, such as drought, by becoming dormant. The seeds do not germinate until conditions are favorable for plant growth.

Recall that scientific explanations are constructed using evidence and reasoning. Read the scenario below and the table of adaptations that follows it. Then answer the questions to make predictions and construct scientific explanations for your predictions.

Prescribed burns are a way to clear managed forests of dead branches, undergrowth, and competing tree species through moderate, controlled fires. Prescribed burns increase the availability of nutrients to trees while reducing the risk of disease and unplanned severe fires. As with any fire, there is the risk of prescribed burns getting out of control.

A prescribed burn is done on a managed forest that has a mix of shortleaf pine and Virginia pine. During the burn, an unpredicted shift in the weather causes the fire to burn out of control at one end of the forest. A third of the forest is severely burned before it can be extinguished.

The table below lists some adaptations of shortleaf pine and Virginia pine.

Adaptations of Two Southern Pine Tree Species

Shortleaf Pine (*Pinus echinata*)	Virginia Pine (*Pinus virginiana*)
Bark is thick and insulating.	Bark is thin and scaly.
J-shaped crooks in roots sprout new trees when damaged.	Shallow roots are easily killed by damage and do not sprout.
Fallen needles burn quickly and completely with tall flames that kill other tree species.	Fallen needles burn slowly and incompletely with short flames that smolder for a long time.
Dormant buds on branches sprout new needles after moderate fire but are killed by severe fire.	New trees colonize areas disturbed by severe fire, landslide, or construction.

Predict the immediate effect of the prescribed burn on the populations of shortleaf pine and Virginia pine. Support your predictions using information about these species from the table.

Prescribed burn, shortleaf pine:

Prescribed burn, Virginia pine:

Predict the immediate effect of the severe fire on the populations of shortleaf pine and Virginia pine. Support your predictions using information about these species from the table.

Severe fire, shortleaf pine:

Severe fire, Virginia pine:

Write a paragraph advising the land owner what to expect in terms of the populations of these two tree species, five years after the fire. Include information about the two-thirds of the forest that had a successful prescribed burn and the one-third that was severely burned. Support your prediction by explaining how the two species' adaptations affected their response to both types of fire.

Lesson Review

1. The leaves of a plant have a waxy coating. In which environment does the plant **most likely** live?

   A. tropical rain forest

   B. arid grassland

   C. coastal wetland

   D. coniferous forest

2. Which is an example of a structural adaptation?

   A. the growth of a houseplant toward sunlight

   B. seeds that sprout after a forest fire

   C. dormancy of a plant during a drought

   D. the wing-shaped seeds of a tree

3. In early December, the right whale travels from the North Atlantic to the ocean near Georgia to give birth in the warm and relatively calm waters off the coast. Which behavioral adaptation does it show?

   A. hibernation

   B. migration

   C. mimicry

   D. predation

4. Which is an example of mimicry?

   A. A school of striped fish swim together, making it difficult for predators to see the edges of each fish.

   B. A fawn's coat is dappled with white spots that help it blend in with the forest.

   C. A leaf-tailed gecko looks like a dead leaf as it clings to a twig.

   D. A penguin's coloring blends in with the water surface from both above and below, while it swims.

Chapter 4 Review

1. Excess nutrients from fertilizer can cause too many algae to grow in a freshwater ecosystem. How could a system be designed to reduce this effect?

   ⓐ Develop a barrier that groundwater passes through as it enters the body of water; the barrier should allow water to pass through but filter out nitrogen and phosphorus compounds.

   ⓑ Develop a cover for the body of water that shades it through most of each day; the cover should reduce the amount of sunlight that reaches the surface of the water.

   ⓒ Develop a filtering system for the body of water that removes pesticides from the water on a regular basis.

   ⓓ Develop a pH sensor that releases substances that keep the pH of the body of water within set limits.

2. Two grassland ecosystems, Region A and Region B, have very similar climates. However, in Region B, large mammals graze on the grasses. Region A has no large mammals. Scientists randomly select areas in each ecosystem and survey the numbers and heights of the grass species in each. The table below shows the number of species of grasses observed in each region, grouped by height.

Observed Species of Grasses Grouped by Height

Plant Height	Number of Species	
	Region A	Region B
short	1	5
medium	2	7
tall	5	2

Which is the BEST prediction of how a decrease in large mammals in Region B will affect the biodiversity of Region B?

ⓐ The number of medium plant species will increase.

ⓑ The number of short plant species will increase.

ⓒ The total number of plant species will increase.

ⓓ The number of tall plant species will increase.

3. Which limiting factor will MOST LIKELY affect a tree population regardless of its density?

ⓐ competition with a nonnative tree species

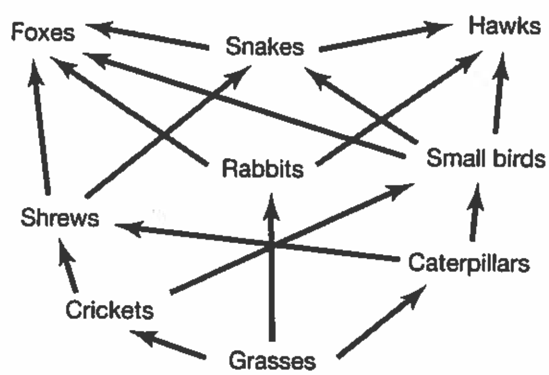
ⓑ the introduction of an insect-borne disease

ⓒ competition with individuals of its own species

ⓓ a widespread drought throughout the ecosystem

4. The diagram shows a meadow food web.

A Meadow Food Web



Part A

Which sequence describes the flow of energy through one food chain in the meadow food web?

ⓐ from grasses to rabbits to foxes

ⓑ from hawks to small birds to crickets

ⓒ from shrews to crickets to small birds

ⓓ from crickets to grasses to caterpillars

Part B

In the diagram, arrows point only away from the grasses, not toward them. Based on this evidence, what can you conclude about these organisms?

ⓐ Grasses are consumed by all the other organisms.

ⓑ Grasses are decomposers that feed on organic wastes.

ⓒ Grasses get energy from the sun, not from other organisms.

ⓓ Grasses carry out cellular respiration but not photosynthesis.

5. A field guide for an area describes all the populations present as well as the abiotic components of that region. Which level of ecological organization BEST describes the focus of this field guide?

   ⓐ biome

   ⓑ biosphere

   ⓒ community

   ⓓ ecosystem

6. Conifers are associated with snowy northern forests, but some species of conifer grow in the deserts of Arizona and New Mexico. Which of these conifer adaptations is LEAST LIKELY to support the plant's survival in a desert environment?

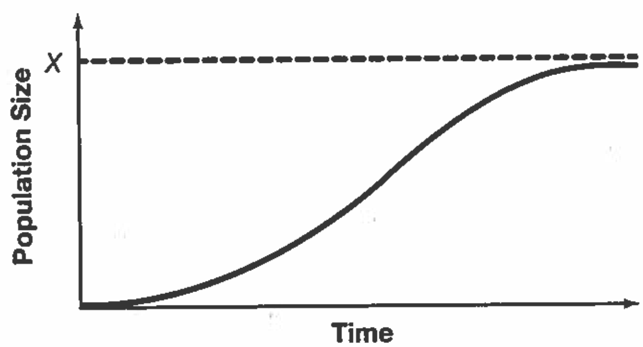
   ⓐ waxy coating on needles to reduce water loss

   ⓑ branches that bend under heavy loads

   ⓒ thick bark to protect tree during wildfires

   ⓓ wide, shallow root system to capture water

7. Students carried out an investigation related to population size. They grew a population of bacteria in a flask with a set amount of nutrients. The graph shows the general trends in the data they recorded.



   Analyze the graph. To which of these factors does the value of *X* on the graph correspond?

   ⓐ mass of nutrients provided

   ⓑ population density

   ⓒ carrying capacity

   ⓓ size of the flask

8. The trophic level of the primary consumers in an ecosystem contains 35,500 kilocalories of energy. About how much of this energy will be available to the secondary consumers?

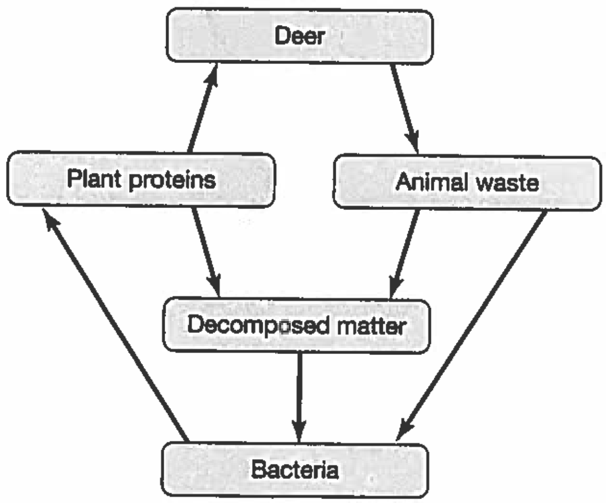
ⓐ 355 kilocalories

ⓑ 3550 kilocalories

ⓒ 35,500 kilocalories

ⓓ 355,000 kilocalories

9. The diagram shows some of the ways a certain element moves as it cycles in an ecosystem.



Which element moves through all parts of the cycle as it is shown?

ⓐ carbon

ⓑ nitrogen

ⓒ oxygen

ⓓ phosphorus

10. Suppose a short plant is growing in a forest. The trees around the plant have grown tall and created a thick canopy of leaves and branches above the plant. Which adaptation would MOST LIKELY help the short plant survive this change in its environment?

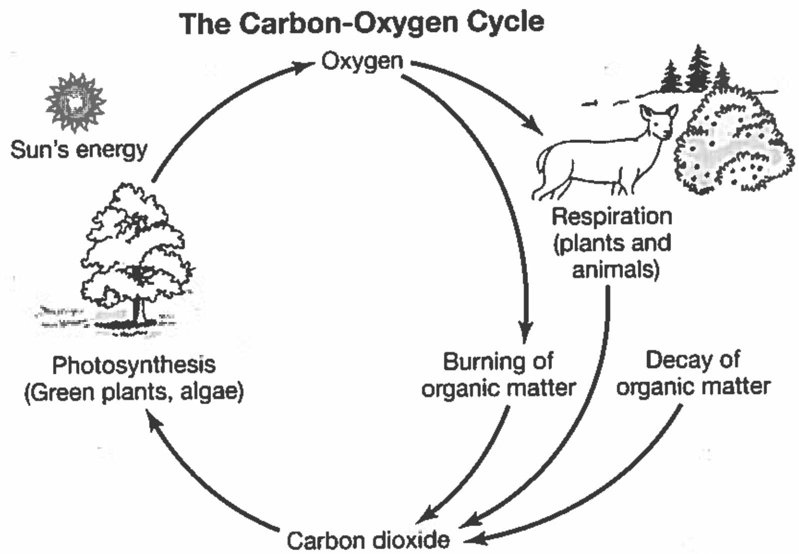
ⓐ wide, flat leaves

ⓑ thinner branches

ⓒ shorter stem

ⓓ thick roots

11. The diagram shows parts of the carbon-oxygen cycle.



Which BEST explains why these elements must be cycled in an ecosystem?

ⓐ to provide a constant supply of water in the environment

ⓑ because new atoms of these elements cannot be created

ⓒ to prevent the buildup of dead organisms

ⓓ because elements cannot change form

12. Human activity accidentally introduces an insect species into a new habitat. The introduced insects feed on trees and have no natural predators in their new habitat. What is the MOST LIKELY way this will impact the environment?

ⓐ The populations of trees will grow.

ⓑ The introduced insects will not thrive.

ⓒ The population of introduced insects will grow.

ⓓ Predators will evolve to feed on the insects.