Chapter 4

Ecosystems

Organisms in ecosystems interact with each other. This small fish has an unusual predator—a spider. This fishing spider from French Guiana waits at the surface of the water for its prey.

Some species of fishing spiders can walk on the water's surface, aided by fine hairs on the legs which trap air and act as buoys.

Preview

Why It Matters

An ecosystem is a community of organisms that interact with one another and their physical environment. Humans are part of ecosystems and are dependent on healthy ecosystems. However, humans can disrupt ecosystems, and the disruption may harm the organisms of the ecosystems and humans themselves.

Section 1

What Is an Ecosystem?

Key Ideas	Key Terms	Why It Matters
❯ What are the parts of an ecosystem? ❯ How does an ecosystem respond to change? ❯ What two key factors of climate determine a biome? ❯ What are the three major groups of terrestrial biomes? ❯ What are the four kinds of aquatic ecosystems?	**community** **ecosystem** **habitat** **biodiversity** **succession** **climate** **biome**	Ecosystems are important units of the natural world. Humans are part of ecosystems and depend on ecosystems for food and many products. Without healthy ecosystems, humans would be in trouble!

When you walk through a forest, you see many different organisms. There are trees, birds, ants, mushrooms, and much more. You may not see many of these organisms interact. But all organisms, including humans, that live together are interdependent.

Ecosystems

A species never lives alone. A group of various species that live in the same place and interact with one another is called a **community.** The group, along with the living and nonliving environment, make up an **ecosystem.** ❯ **An ecosystem includes a community of organisms and their physical environment.**

Community of Organisms A community of organisms is a web of relationships. One relationship is that of a predator eating its prey. For example, some fish eat spiders, as **Figure 1** shows. Some species help each other. For example, some bacteria fix nitrogen into a form that plants can use to grow. Relationships between organisms are examples of biotic factors that affect an ecosystem. *Biotic* describes living factors in an ecosystem. Biotic factors also include once-living things, such as dead organisms and the waste of organisms.

community a group of various species that live in the same habitat and interact with each other

ecosystem a community of organisms and their abiotic environment

Figure 1 In this relationship, the fish is the predator, and the spider is the prey. ❯ **Give another example of a relationship between two species in a community.**

Hands-On

QuickLab

30 min

Biodiversity Evaluation

By making simple observations, you can draw some conclusions about biodiversity in an ecosystem.

Procedure

CAUTION: Follow your teacher's instructions about handling organisms. Prepare a list of biotic and abiotic factors to observe around your home or in a nearby park, and record your observations.

Analysis

1. **Identify** the habitat and community that you observed.
2. **Calculate** the number of individual organisms and the number of different species that you saw.
3. **Rank** the importance of biotic factors within the ecosystem that you observed.
4. **Infer** what the relationships are between biotic factors and abiotic factors in the observed ecosystem.

habitat a place where an organism usually lives

biodiversity the variety of organisms in a given area, the genetic variation within a population, the variety of species in a community, or the variety of communities in an ecosystem

succession the replacement of one type of community by another at a single location over a period of time

Physical Factors The physical or nonliving factors of an environment are called *abiotic factors*. Examples of abiotic factors are oxygen, water, rocks, sand, sunlight, temperature, and climate. These physical factors shape organisms. For example, plants and animals in deserts are small because deserts do not have enough water to support large organisms. Water supply also affects the amount and variety of species that an ecosystem can support. A crop of corn will have a higher yield in a wetter habitat than in a drier habitat. A **habitat** is the place where an organism lives.

Biodiversity Suppose you counted the various species in a pine forest. Then, you counted the number of species in a tropical rain forest. Do you think the number of species in each ecosystem would be the same? No, a tropical rain forest has many more species than a pine forest does. The variety of organisms in a given area is called **biodiversity.**

Physical factors can have a big influence on biodiversity. In places that have very high or very low temperatures, biodiversity is often lower. Limited water and food also cause lower biodiversity. The biodiversity of habitats and ecosystems varies greatly. The vast expanse of the open ocean has very low biodiversity. In contrast, rain forests and coral reefs have very high biodiversity. When ecosystems have high biodiversity, they are often more able to resist damage. Damage to ecosystems can be caused by severe weather events or human activities. Systems with low biodiversity can be severely damaged easily. When biodiversity decreases in any ecosystem, that ecosystem is not as healthy as it could be.

Reading Check *List three examples of physical parts of an ecosystem. (See the Appendix for answers to Reading Checks.)*

Succession

When we observe at an ecosystem, it may look like an unchanging feature of the landscape. However, all ecosystems change. As an ecosystem changes, the kinds of species that the ecosystem supports change. The replacement of one kind of community by another at a single place over a period of time is called **succession.**

Change in an Ecosystem When a volcano forms a new island or a fire burns the vegetation of an area, new opportunities are made for organisms. The first organisms to appear in a newly made habitat are called *pioneer species*. Pioneer species are often small, fast-growing plants that reproduce quickly. They change the habitat in such a way that other species can live in the ecosystem. For example, pioneer plants will break down volcanic rock on a new island to help form soil. Other new plant species can then grow in the soil. Often, the new species will replace the pioneer species. For example, grasses and weeds may cover a new volcanic island at first. Shrubs and trees often outcompete and replace the grass. Then, the grassland turns into a forest. **Figure 2** shows an example of succession in response to the receding of a glacier.

Equilibrium If a major change strikes a community, many of the organisms may be wiped out. But the ecosystem reacts to the change. **An ecosystem responds to change in such a way that the ecosystem is restored to equilibrium.** When a tree falls down in a rain forest, for example, the newly vacant patch proceeds through succession until the patch returns to its original state. Sometimes, the ecosystem will find an equilibrium in which different species dominate after a change. In the grasslands of Africa, for example, weather conditions can lead to succession. When there is a lot of rain in the grasslands, one species of grass dominates the savanna. But when conditions are drier, a drought-resistant species of grass will dominate.

Reading Check ***Why are pioneer species helpful to other species?***

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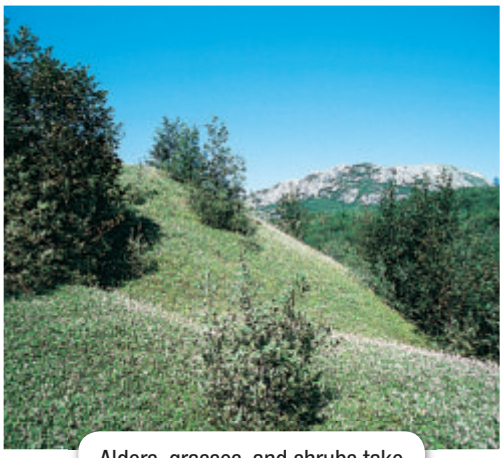
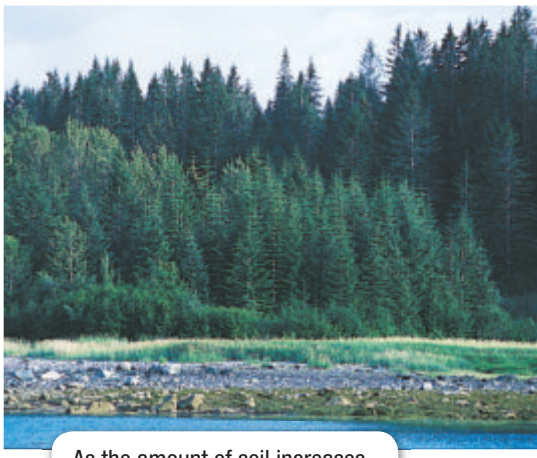
Topic: Biodiversity
Code: HX80151

Pioneer species quickly modify the land recently exposed after a glacier has receded.

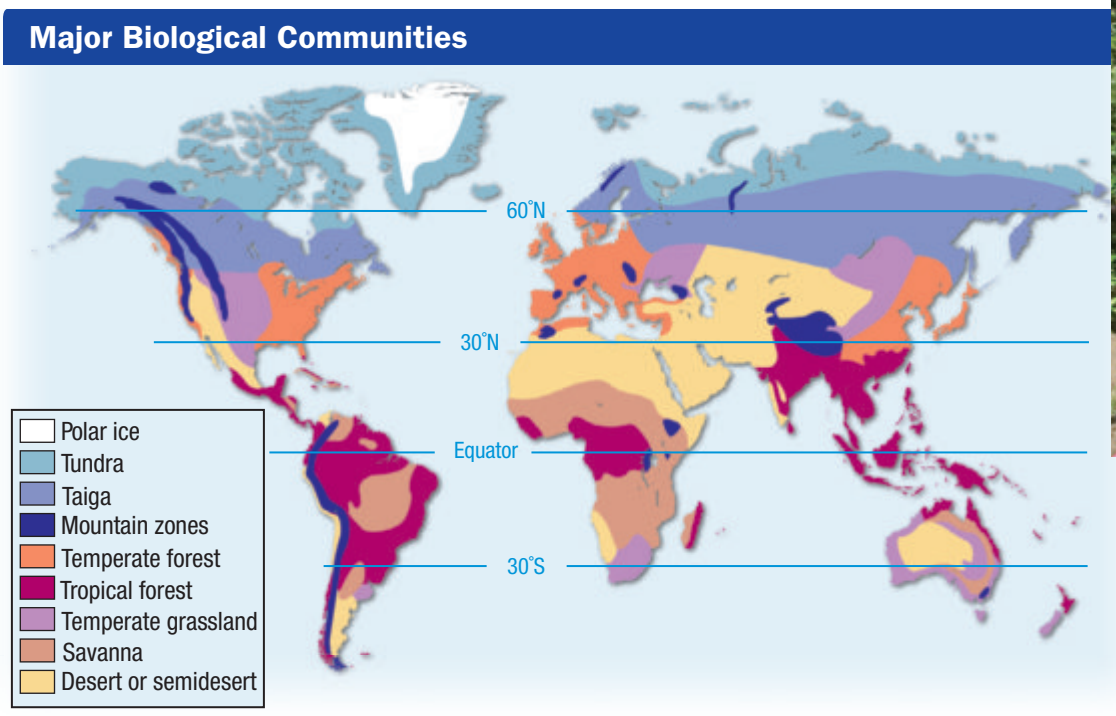


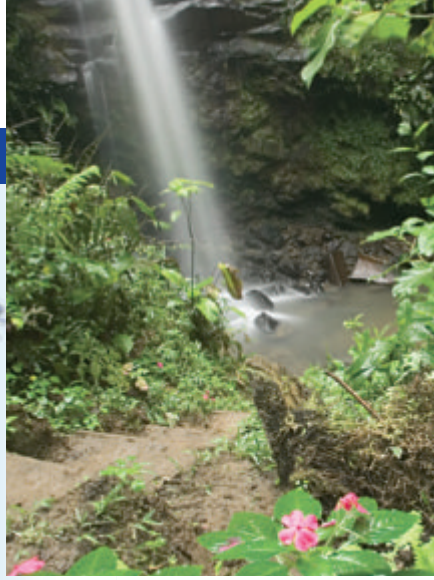
Alders, grasses, and shrubs take over from the pioneer plants and help form more soil.



As the amount of soil increases, spruce and hemlock trees become plentiful.

Figure 2 At Glacier Bay in Alaska, a receding glacier makes succession possible.





Tropical biome: rain forest

Figure 3 Biomes cover most of Earth's land surface. Because mountainous areas do not belong to any one biome, they are given their own designation. Polar ice covers Greenland and Antarctica, which is not shown in the map. **Identify the biome that you live in.**

Major Biological Communities

If you drive across the United States, you notice a change in the kinds of plants and animals. The kinds of species that live in a particular place are determined partly by climate. **Climate** is the average weather conditions in an area over a long period of time. At places near the North Pole, you may see polar bears. Polar bears have thick, white fur and insulating fat that keep them warm on the frozen tundra. The same adaptations that help polar bears in the tundra would hurt polar bears in a tropical forest. Polar bears must live in a biome to which they are adapted. A **biome** is a large region characterized by a specific kind of climate and certain kinds of plant and animal communities.

Two key factors of climate that determine biomes are temperature and precipitation. Most organisms are adapted to live within a particular range of temperatures and cannot survive at temperatures too far above or below that range. Precipitation also determines the kinds of species that are found in a biome. In biomes where precipitation is low, for example, the vegetation is made up mostly of plants that need little water, such as cactuses.

ACADEMIC VOCABULARY

range a scale or series between limits

climate the average weather conditions in an area over a long period of time

biome a large region characterized by a specific type of climate and certain types of plant and animal communities

Terrestrial Biomes

There are many different biomes on land. **Earth's major terrestrial biomes can be grouped by latitude into tropical, temperate biomes, and high-latitude.** As **Figure 3** shows, tropical biomes are generally near the equator. For the most part, temperate biomes are between 30° and 60° latitude. High-latitude biomes are at latitudes 60° and higher. Latitude affects the amount of solar energy that a biome receives and thus affects a biome's temperature range.

Temperate biome: temperate grasslands

Polar biome: taiga

Tropical Biomes Because they are located at low latitudes near the equator, all tropical biomes are warm. However, each tropical biome receives a different amount of rain. *Tropical rain forests* receive large amounts of rain and are warm all year. They have the greatest biodiversity of any land biome. At least half of Earth's species of land organisms live in tropical rain forests. *Savannas* are tropical grasslands. They get less rain than tropical rain forests do. Savannas also have long dry seasons and shorter wet seasons. The most well-known savannas are in eastern Africa, where zebras, giraffes, lions, and elephants roam the grasslands. *Tropical deserts* get very little rain. Because the deserts have less water, they have fewer plants and animals than other biomes do.

Temperate Biomes Biomes at mid-latitudes have a wide range of temperatures throughout the year. *Temperate grasslands* have moderate precipitation and cooler temperatures than savannas do. Temperate grasslands are often highly productive when used for agriculture. Herds of grazing animals, like bison, used to live on the temperate grasslands of North America. *Temperate forests* grow in mild climates that receive plenty of rain. Trees of the temperate deciduous forests shed their leaves in the fall because of the cold winters. Trees of temperate evergreen forests do not lose their leaves or needles during the winter. Temperate forests are home to deer, bears, beavers, and raccoons. Like tropical deserts, *temperate deserts* receive little precipitation. However, unlike tropical deserts, temperate deserts have a wide temperature range throughout the year.

High-Latitude Biomes Biomes at high latitudes have cold temperatures. Coniferous forests in cold, wet climates are called *taiga*. Winters are long and cold. Most of the precipitation falls in the summer. Moose, wolves, and bears live in the taiga. The *tundra* gets very little rain, so plants are short. Much of the water in the soil is not available because the water is frozen for most of the year. Foxes, lemmings, owls, and caribous live in the tundra.

› **Reading Check** ***In what latitudes are savannas found?***

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Topic: Biomes
Code: HX80158

Figure 4 A bayou, such as this one in Louisiana, is an example of a wetland. The coral reef is an example of a marine ecosystem.

Aquatic Ecosystems

The diverse regions in the world's bodies of water are not usually called *biomes*. They are often called *aquatic ecosystems*. **› Aquatic ecosystems are organized into freshwater ecosystems, wetlands, estuaries, and marine ecosystems.**

Freshwater ecosystems are located in bodies of fresh water, such as lakes, ponds, and rivers. These ecosystems have a variety of plants, fish, arthropods, mollusks, and other invertebrates.

Wetlands provide a link between the land and fully aquatic habitats. Water-loving plants dominate wetlands. This ecosystem supports many species of birds, fishes, and plants, as shown in **Figure 4.** Wetlands are important because they moderate flooding and clean the water that flows through them.

An *estuary* is an area where fresh water from a river mixes with salt water from an ocean. Estuaries are productive ecosystems because they constantly receive fresh nutrients from the river and the ocean.

Marine ecosystems are found in the salty waters of the oceans. Kelp forests, seagrass communities, and coral reefs are found near land. The open ocean, far from land, has plankton and large predators, such as dolphins, whales, and sharks.

› Reading Check ***Which aquatic ecosystems have salt water?***

READING TOOLBOX

Word Families Use a dictionary to find the meanings of the words *aquatic* and *ecosystem*. Then, use the definitions to write your own definition of *aquatic ecosystem*.

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Topic: Estuaries
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Section 1 Review

› KEY IDEAS

1. **Describe** the difference between an ecosystem and a community.
2. **Explain** how an ecosystem responds to change.
3. **Identify** the three major groups of terrestrial biomes.
4. **Describe** the four types of aquatic ecosystems.
5. **Identify** two factors of climate that determine a biome.

CRITICAL THINKING

6. **Relating Concepts** If two areas on separate continents have similar climates, do they have similar communities? Explain your answer.

WRITING FOR SCIENCE

7. **Essay** Identify a biome in which the plants are short and require little water and the animals are small. Then, write a one page description of this biome.

Section 2

Energy Flow in Ecosystems

Key Ideas	Key Terms	Why It Matters
❯ How does energy flow through an ecosystem? ❯ What happens to energy as it is transferred between trophic levels in a community?	producer consumer decomposer trophic level energy pyramid	The way in which energy flows through an ecosystem is critical to the ecosystem's productivity and ability to support its species. By understanding this flow of energy, we can learn how to develop food more efficiently.

Everything that organisms do requires energy. Running, breathing, and even sleeping require energy. Every species must somehow get food for energy. A zebra grazes on savanna grass. A lion chases down the zebra and eats it. The lion eventually dies and is eaten by scavengers. The rest of the carcass is decomposed by bacteria and other microbes. At each step in this process, energy flows through the ecosystem.

Trophic Levels

An organism eating another organism is the most obvious interaction in a community. This interaction transfers energy through an ecosystem. The way in which energy flows through an ecosystem determines how many species and individuals live in the ecosystem.

The primary source of energy for an ecosystem is the sun. Photosynthetic organisms, such as plants and algae, change light energy from the sun into energy that they can use to grow. These photosynthetic organisms are **producers,** the basic food source for an ecosystem. **Consumers** are organisms that eat other organisms instead of producing their own food. **Decomposers,** such as bacteria and fungi, are organisms that break down the remains of animals.

❯ **In an ecosystem, energy flows from the sun to producers to consumers to decomposers.** Each step in the transfer of energy through an ecosystem is called a **trophic level.** **Figure 5** shows the trophic levels through which energy passes to a blue jay.

❯ **Reading Check** *Where do consumers get their energy?*

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Topic: Food Webs
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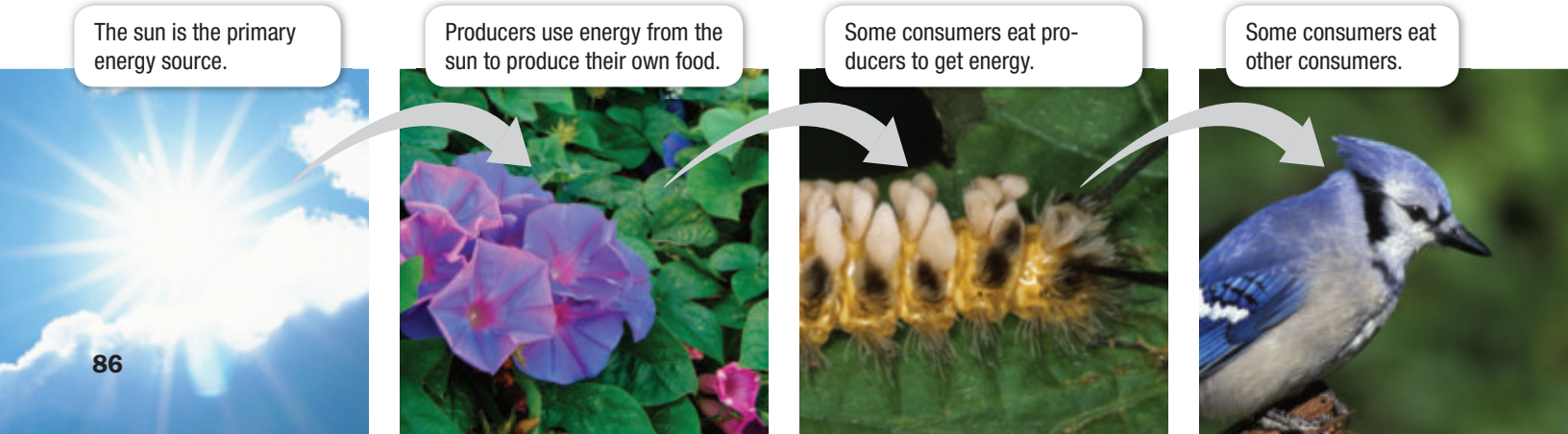


Figure 5 Each step in the transfer of energy through an ecosystem is called a *trophic level*.

Food Chains In ecosystems, energy flows from one trophic level to the next, forming a *food chain.* The first trophic level of ecosystems is made up of producers. Plants, algae, and some bacteria use the energy in sunlight to build energy-rich carbohydrates. The second trophic level of a food chain is made up of *herbivores,* which eat producers. Cows are an example of an herbivore. The third trophic level includes animals that eat herbivores. Any animal that eats another animal is a *carnivore*. Some carnivores are on the third trophic level because they eat herbivores. For example, small birds eat caterpillars, which feed on plant leaves. Other carnivores are on the fourth trophic level or an even higher trophic level because they eat other carnivores. For example, hawks eat small birds. *Omnivores,* such as bears, are animals that are both herbivores and carnivores.

Food Web In most ecosystems, energy does not follow a simple food chain. Energy flow is much more complicated. Ecosystems almost always have many more species than a single food chain has. In addition, most organisms eat more than one kind of food. For example, hawks eat fish, small birds, and rabbits. Rabbits are food not only for hawks but also for wolves, mountain lions, and many other carnivores. This complicated, interconnected group of food chains, such as the group in **Figure 6,** is called a *food web*.

producer a photosynthetic or chemosynthetic autotroph that serves as the basic food source in an ecosystem

consumer an organism that eats other organisms or organic matter instead of producing its own nutrients or obtaining nutrients from inorganic sources

decomposer an organism that feeds by breaking down organic matter from dead organisms

trophic level one of the steps in a food chain or food pyramid

Figure 6 A food web shows a more complete picture of the feeding relationships in an ecosystem. The arrows show the direction in which energy travels. **› In the diagram, identify the animals that receive energy from the rabbit.**

Figure 7 This girl is eating producers, which form the base of an energy pyramid.

Loss of Energy

When a zebra eats 20 lb of grass, the zebra does not gain 20 lb. A lot of the energy that was stored in the grass is lost. Where did the energy go? **Energy is stored at each link in a food web. But some energy that is used dissipates as heat into the environment and is not recycled.**

The Ten Percent Rule When a zebra eats grass, some of the energy in the grass is stored in the zebra. The energy may be stored as fat or as tissue. However, most of the energy does not stay in the zebra. As the zebra uses energy from the grass to run and grow, the energy is changed into heat energy. Then, the heat energy is dispersed into the environment. Thus, the zebra does not keep 90% of the energy that it gets from the grass. Only about 10% of the energy in the grass becomes part of the zebra's body. This amount of stored energy is all that is available to organisms at the next trophic level that consume the zebra. For example, a 100 kg lion needs 1,000 kg of zebras. And combined, the zebras need 10,000 kg of plants!

By understanding energy flow between trophic levels, we can learn how to feed more people. If people eat big fish that are in the third trophic level, it takes 1,000 kg of producers to build 1 kg of human. If people eat cows that are in the second trophic level, 100 kg of producers are needed for 1 kg of human. If people, such as the girl in **Figure 7,** eat producers—such as vegetables, fruits, and grains—only 10 kg of producers are needed to produce 1 kg of human.

Reading Check ***When energy is transferred from one trophic level to another, where does 90% of the energy go?***

Math Skills Energy Pyramid

This energy pyramid shows the trophic levels in a marine ecosystem. You can use the pyramid to help you understand how energy is transferred from one trophic level to another.

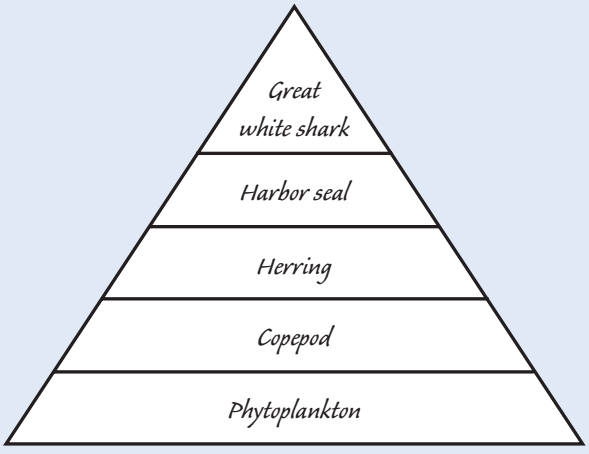
The base of a pyramid is the producer, which contains the most energy. Phytoplankton is the base of this pyramid. As energy is transferred from one trophic level to the next trophic level, 90% of the energy is lost. Only 10% of the energy is available to the next trophic level.

If the phytoplankton level has 10,000 units of energy, the amount of energy stored in the copepod level can be calculated as follows:

10,000 units of energy × 10% = 1,000 units of energy

The amount of energy stored in the herring level can be calculated as follows:

1,000 units of energy × 10% = 100 units of energy



Assume an energy loss of 90% from trophic level to trophic level.

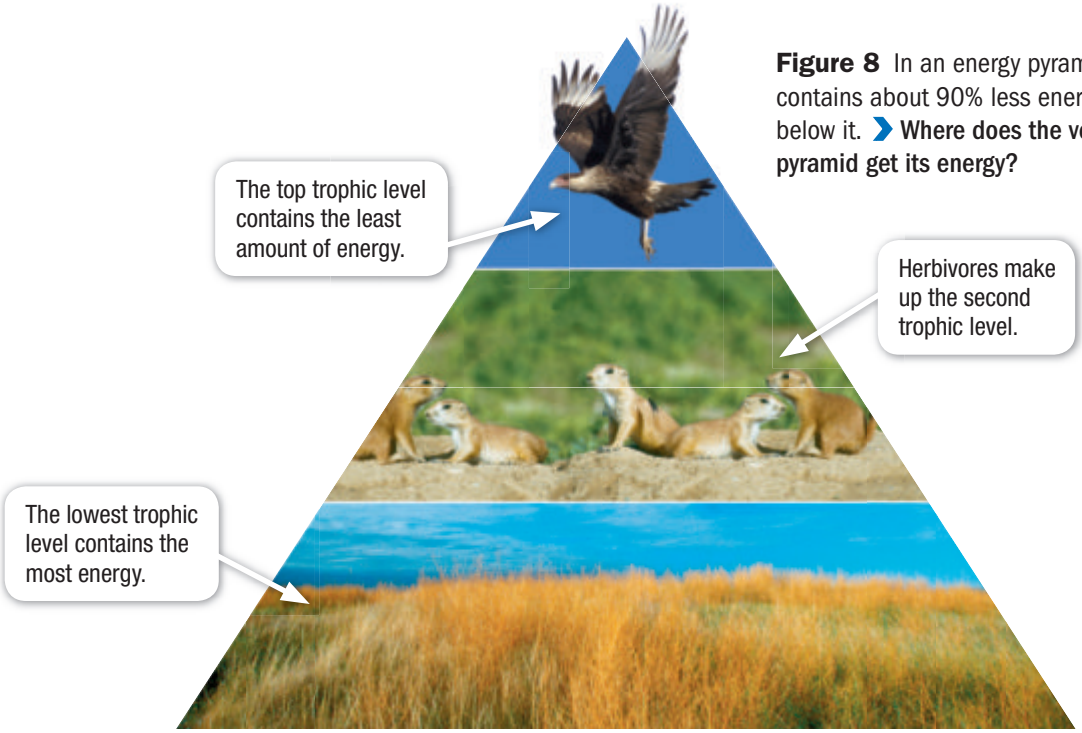


Figure 8 In an energy pyramid, each level contains about 90% less energy than the level below it. **Where does the vegetation in this pyramid get its energy?**

Energy Pyramid A triangular diagram that shows an ecosystem's loss of energy, which results as energy passes through the ecosystem's food chain, is called an **energy pyramid.** An energy pyramid is shown in **Figure 8.** Each layer in the energy pyramid represents one trophic level. Producers form the pyramid's base, which is the lowest trophic level. The lowest level has the most energy in the pyramid. Herbivores have less energy and make up the second level. Carnivores that feed on herbivores make up the higher level. The energy stored by the organisms at each trophic level is about one-tenth the energy stored by the organisms in the level below. So, the diagram takes the shape of a pyramid.

Big predators, such as lions, are rare compared to herbivores. Big predators are rare because a lot more energy is required to support a single predator than a single herbivore. Many ecosystems do not have enough energy to support a large population of predators.

energy pyramid a triangular diagram that shows an ecosystem's loss of energy, which results as energy passes through the ecosystem's food chain

READING TOOLBOX

Word Problem If the prairie dog level in a food pyramid contains 35,000 units of energy, how much of that energy can be stored in the eagle level of the food pyramid?

Section 2 Review

KEY IDEAS

1. **Describe** how energy flows in an ecosystem.
2. **Explain** why only 10% of energy is transferred from one trophic level to the next.
3. **Describe** the difference between a herbivore, a carnivore, and an omnivore.

CRITICAL THINKING

4. **Justifying Conclusions** What limits the length of food chains in an ecosystem?
5. **Evaluating an Argument** Explain why scientists believe that most animals would become extinct if all plants died.
6. **Analyzing Data** Which trophic level contains more energy: a trophic level of herbivores or a trophic level of carnivores? Why?

USING SCIENCE GRAPHICS

7. **Creating Diagrams** Draw a diagram of a food web that has four trophic levels and at least one species that is an omnivore. Be sure to label producers, consumers, omnivores, and top predators. Label each trophic level.

Section 3

Cycling of Matter

Key Ideas	Key Terms	Why It Matters
❯ What is the water cycle? ❯ Why are plants and animals important for carbon and oxygen in an ecosystem? ❯ Why must nitrogen cycle through an ecosystem? ❯ Why must phosphorus cycle through an ecosystem?	carbon cycle respiration nitrogen cycle phosphorus cycle	Water, carbon, phosphorus, and nitrogen are critical resources for organisms, including humans. Natural cycles of these resources are important to ecosystems, but humans can disrupt these cycles.

Water, carbon, oxygen, nitrogen, and phosphorus are five of the most important substances for life. An ecosystem must be able to cycle these kinds of matter in order to support life.

Water Cycle

Life could not exist without the *water cycle.* ❯ **The water cycle continuously moves water between the atmosphere, the land, and the oceans.** As **Figure 9** shows, water vapor *condenses* and falls to Earth's surface as *precipitation*. Some of this water *percolates* into the soil and becomes groundwater. Other water runs across the surface of Earth into rivers, lakes, and oceans. Then, the water is heated by the sun and reenters the atmosphere by *evaporation*. Water also evaporates from trees and plants in a process called *transpiration*.

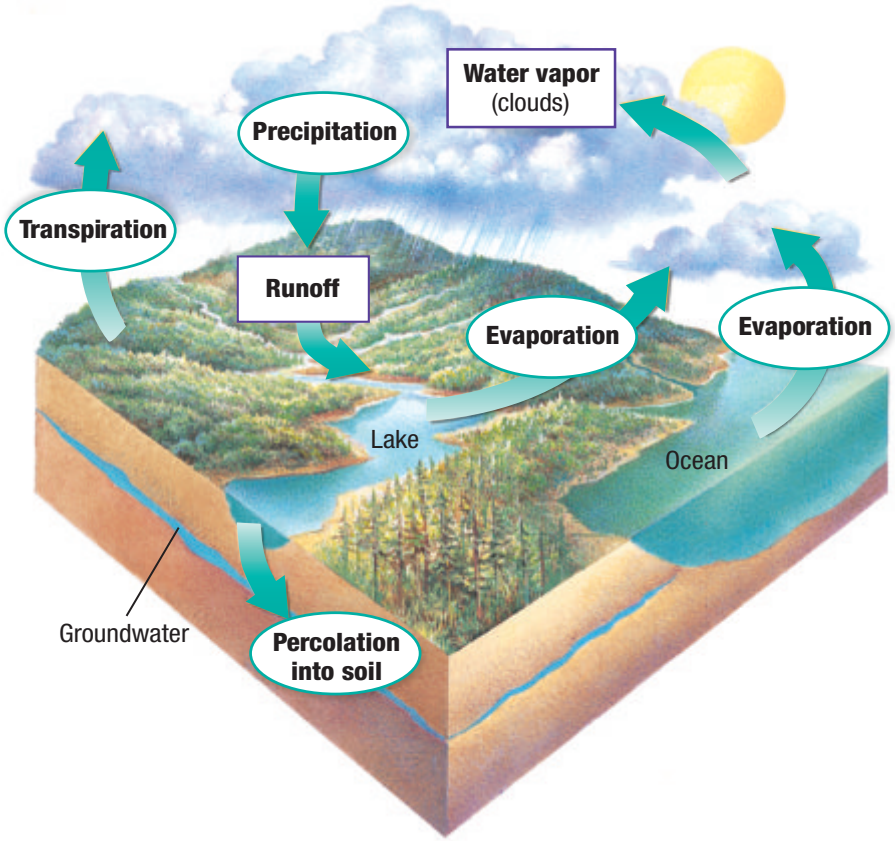


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Figure 9 Water cycles through ecosystems by the processes of transpiration, evaporation, condensation, precipitation and percolation.

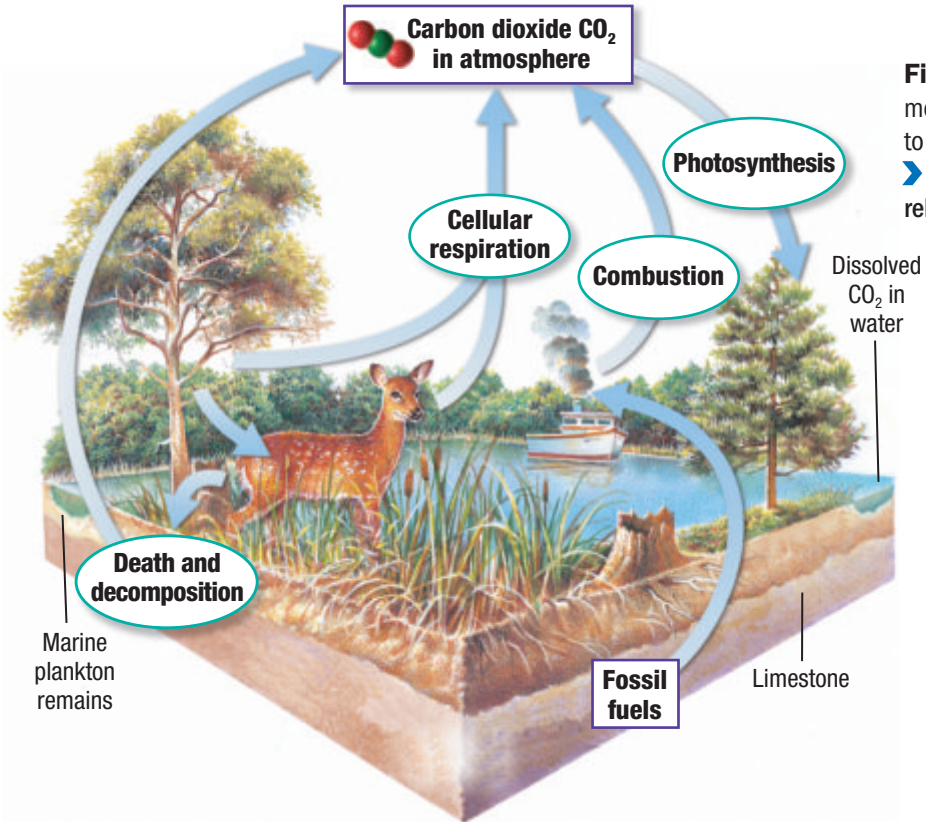

Figure 10 In the carbon cycle, carbon moves from organisms to the atmosphere, to the soil, and to other living things.
How is the carbon in fossil fuels released into the atmosphere?

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Topic: Carbon Cycle
Code: HX80216

Carbon and Oxygen Cycles

Carbon and oxygen are critical for life on Earth, and their cycles are tied closely together. The **carbon cycle** is the continuous movement of carbon from the nonliving environment into living things and back. The carbon cycle is shown in **Figure 10.**

Animals, plants, and other photosynthesizing organisms play an important role in cycling carbon and oxygen through an ecosystem. Plants use the carbon dioxide, CO_2, in air to build organic molecules during the process of photosynthesis. During photosynthesis, oxygen is released into the surroundings. Many organisms, such as animals, use this oxygen to help break down organic molecules, which releases energy and CO_2. Then, plants can use the CO_2 in photosynthesis. The process of exchanging oxygen and CO_2 between organisms and their surroundings is called **respiration.**

Carbon is also released into the atmosphere in the process of combustion. *Combustion* is the burning of a substance. All living things are made of carbon. When living things or once-living things are burned, they release carbon into the atmosphere. For example, the burning of trees releases carbon into the atmosphere as CO_2. Fossil fuels are formed from the remains of dead plants and animals. Thus, the burning of fossil fuels releases CO_2 into the atmosphere. Humans burn fossil fuels to generate electricity and to power vehicles. Examples of fossil fuels that humans burn are oil and coal.

Reading Check ***How does respiration play a role in cycling carbon and oxygen through an ecosystem?***

carbon cycle the movement of carbon from the nonliving environment into living things and back

respiration the exchange of oxygen and carbon dioxide between living cells and their environment

READING TOOLBOX

Word Families Explain how the carbon cycle and the oxygen cycle are similar. Explain how they are different.

nitrogen cycle the cycling of nitrogen between organisms, soil, water, and the atmosphere

phosphorus cycle the cyclic movement of phosphorus in different chemical forms from the environment to organisms and then back to the environment

Nitrogen Cycle

All organisms, including you, need nitrogen. **Nitrogen must be cycled through an ecosystem so that the nitrogen is available for organisms to make proteins.** The **nitrogen cycle** is the process in which nitrogen circulates among the air, soil, water, and organisms in an ecosystem. The nitrogen cycle is shown in **Figure 11.**

The atmosphere is about 78% nitrogen gas, N_2. But most organisms cannot use nitrogen gas. It must be changed into a different form. A few bacteria have enzymes that can break down N_2. These bacteria supply the nitrogen that all other organisms need. The bacteria split N_2 and then bind nitrogen atoms to hydrogen to form ammonia, NH_3. The process of combining nitrogen with hydrogen to form ammonia is called *nitrogen fixation*. Nitrogen may be fixed by lightning. But more nitrogen is fixed by bacteria. Nitrogen-fixing bacteria live in the soil and on the roots of some plants. Nitrogen is also fixed when humans burn fuels in vehicles and industrial plants.

Plants get nitrogen by assimilation. *Assimilation* is the process in which plants absorb nitrogen. When an animal eats a plant, nitrogen compounds become part of the animal's body. During *ammonification,* nitrogen from animal waste or decaying bodies is returned to the soil by bacteria. Ammonia is then converted to nitrite and then nitrate by the process of *nitrification.* Finally, in *denitrification,* nitrate is changed to nitrogen gas, N_2, which returns to the atmosphere.

ACADEMIC VOCABULARY

convert to change from one form to another

Reading Check ***Explain the role of bacteria in the nitrogen cycle.***

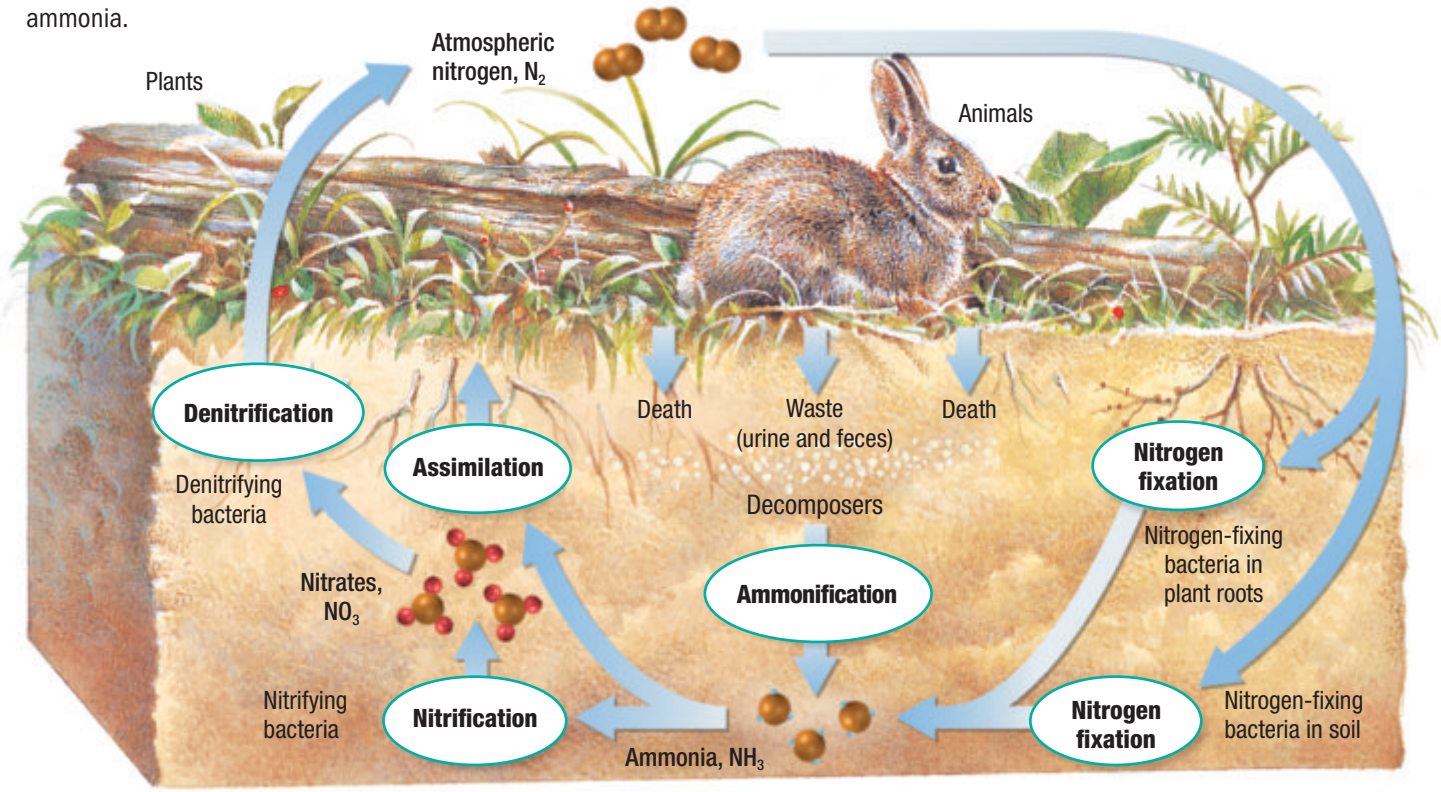

Figure 11 Bacteria carry out many of the important steps in the nitrogen cycle, including the conversion of atmospheric nitrogen into a usable form, such as ammonia.

Hands-On

QuickLab

15 min

The Carbon Cycle

You are part of the carbon cycle. Every time that you exhale, you release CO_2 into the atmosphere. But the CO_2 does not stay as CO_2 for very long.

Procedure

1. Pour **100 mL of water** into a **250 mL beaker.** Add **several drops of bromthymol blue** to the water. Add enough drops to make the solution dark blue.
2. **CAUTION: Be sure not to inhale or ingest the solution.** Exhale through a **straw** into the solution until the CO_2 in your breath turns the solution yellow.
3. Pour the yellow solution into a **large test tube** that contains a **sprig of Elodea.**
4. Use a **stopper** to seal the test tube. Then, place the test tube in a sunny location.
5. Observe the solution in the test tube after 15 min.

Analysis

1. CRITICAL THINKING **Inferring Conclusions** What do you think happened to the carbon dioxide that you exhaled into the solution?
2. CRITICAL THINKING **Analyzing Methods** How do plants, such as the *Elodea,* affect the carbon cycle?

Phosphorus Cycle

Like water, carbon, oxygen, and nitrogen, phosphorus must be cycled in order for an ecosystem to support life. The **phosphorus cycle** is the movement of phosphorus in different chemical forms from the surroundings to organisms and then back to the surroundings. Phosphorus is often found in soil and rock as calcium phosphate, which dissolves in water to form phosphate. The roots of plants absorb phosphate. Humans and animals that eat the plants reuse the organic phosphorus. When the humans and animals die, phosphorus is returned to the soil.

Reading Check *How is phosphorus passed from soil to plants?*

Section 3 **Review**

KEY IDEAS

1. **Explain** how carbon and oxygen are cycled through an ecosystem.
2. **Describe** why nitrogen must cycle through an ecosystem.
3. **Explain** why it is important that phosphorus be cycled through an ecosystem.
4. **Summarize** the steps of the water cycle.

CRITICAL THINKING

5. **Making Connections** Explain why the oxygen and carbon cycles are tied so closely together.
6. **Predicting Outcomes** Describe what would happen if matter could not cycle through ecosystems.
7. **Analyzing Processes** Defend the argument that nutrients can cycle but energy cannot.

METHODS OF SCIENCE

8. **Designing an Experiment** Design an experiment in which you would determine whether nitrogen-fixing bacteria really help plants grow faster.

Chapter 4 Summary

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SUPER SUMMARY
Keyword: HX8ECOS

Key Ideas	Key Terms

1 What Is an Ecosystem?

- An ecosystem is a community of organisms and their abiotic environment.
- An ecosystem responds to change in such a way that the ecosystem is restored to equilibrium.
- Two key factors of climate that determine biomes are temperature and precipitation.
- Earth's major terrestrial biomes can be grouped by latitude into tropical, temperate biomes, and high-latitude.
- Aquatic ecosystems are organized into freshwater ecosystems, wetlands, estuaries, and marine ecosystems.

community (79)
ecosystem (79)
habitat (80)
biodiversity (80)
succession (81)
climate (82)
biome (82)

2 Energy Flow in Ecosystems

- In an ecosystem, energy flows from the sun to producers to consumers to decomposers.
- Energy is stored at each link in a food web, but some energy that is used dissipates as heat into the environment and is not recycled.

producer (86)
consumer (86)
decomposer (86)
trophic level (86)
energy pyramid (89)

3 Cycling of Matter

- The water cycle is the continuous movement of water between the atmosphere, the land, and the oceans.
- Animals, plants, and other photosynthesizing organisms play an important role in cycling carbon and oxygen through an ecosystem.
- Nitrogen must be cycled through an ecosystem so that the nitrogen is available for organisms to make proteins.
- Like water, carbon, oxygen, and nitrogen, phosphorus must be cycled in order for an ecosystem to support life.

carbon cycle (91)
respiration (91)
nitrogen cycle (92)
phosphorus cycle (93)