UNIT 5

Ecology

CHAPTER

13 Principles of Ecology

KEY CONCEPTS

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How does this bird interact with its ecosystem?

Anhingas live in freshwater marshes and swamps of the southeastern United States. While they are primarily consumers of fish, an anhinga's diet may also include aquatic insects and invertebrates. The anhinga and the fish are just two of the many organisms that interact in this complex wetland ecosystem.

Connecting CONCEPTS

Vertebrates Unlike other water birds, anhingas do not have oil glands to waterproof their feathers. Without the buoyancy of waterproof feathers, anhingas are effective underwater divers and swimmers. Because they cannot fly when their feathers are waterlogged, anhingas are often seen perched above water, drying their wings in the sun.

13.1 Ecologists Study Relationships

KEY CONCEPT Ecology is the study of the relationships among organisms and their environment.

MAIN IDEAS

- Ecologists study environments at different levels of organization.
- Ecological research methods include observation, experimentation, and modeling.

VOCABULARY

ecology, p. 396
community, p. 397
ecosystem, p. 397
biome, p. 397

Review
organism, population

REVIEW AT CLASSZONE.COM

Connect Water birds such as anhingas, along with a variety of other plants and animals, rely on the presence of wetlands for their survival. How might the loss of wetland areas affect these aquatic species? Learning about organisms and how they interact with one another, with other species, and with their environment is what the study of ecology is all about.

MAIN IDEA

Ecologists study environments at different levels of organization.

Over their life cycle, Pacific salmon are the main food source for more than 140 species of wildlife, including grizzly bears, as shown in **FIGURE 13.1.** If they are not eaten, their bodies return vital nutrients back into the river system, some of which are used by plants to grow. In addition to their role in the health of river systems, salmon are also important to the Pacific Northwest's economy. Today, many species of wild Pacific salmon are threatened with extinction due to competition from hatchery fish, blocked river paths, and loss of spawning grounds. As salmon populations decline, how are other species affected? What effect would the loss of salmon have on a local and a global scale? These are the types of questions ecologists are trying to answer.

FIGURE 13.1 Salmon are a primary food source for many species, including grizzly bears. If salmon disappeared, species dependent on them would also suffer.

What Is Ecology?

Ecology is the study of the interactions among living things, and between living things and their surroundings. The word *ecology* comes from the Greek word *oikos,* which means "house." This word origin makes sense if you think of Earth as home and all organisms as members of Earth's household. Ernst Haeckel, a German biologist, coined the term *ecology* in 1866 to encourage biologists to consider the ways organisms interact. Until that time, most scientists studied a plant or an animal as though it existed in isolation—as if it did not affect its surroundings, and its surroundings did not affect it.

Levels of Organization

Ecologists study nature on different levels, from a local to a global scale. These levels, shown in **FIGURE 13.2**, reveal the complex relationships found in nature.

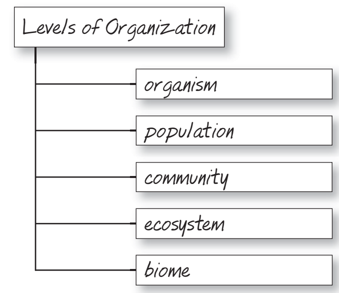
- **Organism** An organism is an individual living thing, such as an alligator.
- **Population** A population is a group of the same species that lives in one area, such as all the alligators that live in a swamp.
- **Community** A **community** is a group of different species that live together in one area, such as groups of alligators, turtles, birds, fish, and plants that live together in the Florida Everglades.
- **Ecosystem** An **ecosystem** includes all of the organisms as well as the climate, soil, water, rocks, and other nonliving things in a given area. Ecosystems can vary in size. An entire ecosystem may live within a decaying log, which in turn may be part of a larger wetland ecosystem.
- **Biome** A **biome** (BY-OHM) is a major regional or global community of organisms. Biomes are usually characterized by the climate conditions and plant communities that thrive there.

Ecologists study relationships within each level of organization and also between levels. For example, researchers may study the relationships within a population of alligators, as well as the relationships between alligators and turtles in a community.

Apply What level of organization describes a flock of pigeons in a park?

TAKING NOTES

Use a diagram to take notes on the levels of organization.



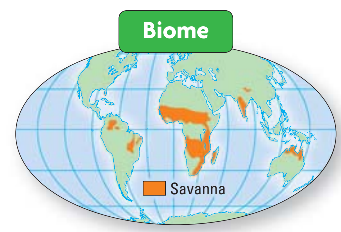
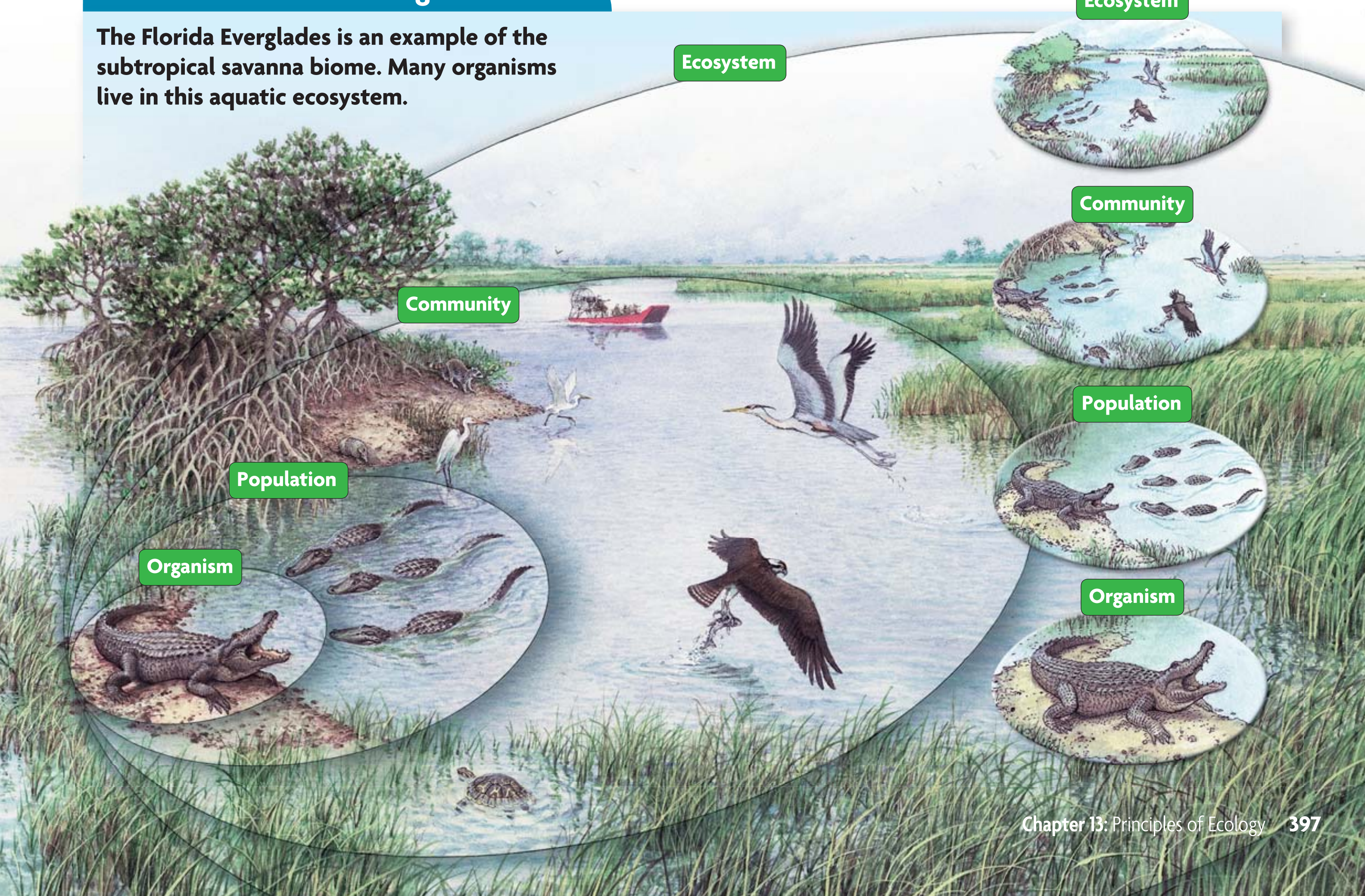


FIGURE 13.2 Levels of Organization

The Florida Everglades is an example of the subtropical savanna biome. Many organisms live in this aquatic ecosystem.



MAIN IDEA

Ecological research methods include observation, experimentation, and modeling.

Scientists rely on a variety of methods and tools to conduct research. Tools can range from a simple tape measure used to find an organism's size to a sophisticated computer system used to create a model of an entire ecosystem.

FIGURE 13.3 Much of the data gathered by ecologists results from long hours of observation in the field. This ecologist is using radio telemetry to track gray wolves.

Observation

Observation is the act of carefully watching something over time. Such observations may occur over short or long periods of time. Long-term studies are a key part of a scientist's toolkit because most environmental changes happen over a long period of time. For example, studies of prairie-dog populations are helping scientists to determine which locations are most appropriate for the reintroduction of the black-footed ferret. The black-footed ferret is an endangered species that relies on the prairie dog as its main food source.

One way that scientists monitor and observe populations is by conducting surveys. Visual surveys may be direct or indirect.

- Direct surveys are used for species that are easy to follow. In these surveys, scientists watch animals either with the naked eye or with tools such as binoculars or scopes.
- Indirect surveys are used for species that are difficult to track. In these surveys, scientists search for other signs of its presence, such as feces or a recent kill.

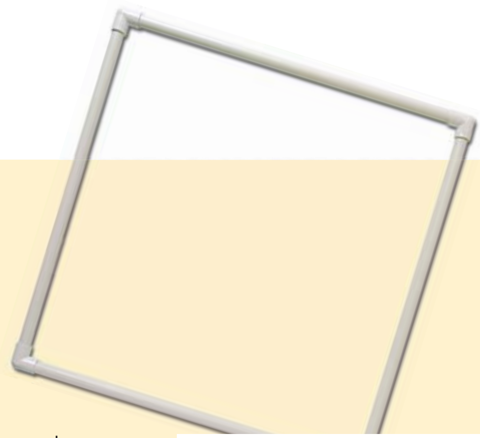
Radio telemetry is another method used by scientists to monitor populations. Scientists fit an animal with a radio collar that emits a signal and then use the signal to track the animal's movement, as shown in **FIGURE 13.3.** This practice is especially useful when studying a species that has a broad range, such as the gray wolf.

In addition to observing the activities of a species, scientists may want to determine its population size. Rather than count every individual organism in a large study area, scientists often sample the population instead. Mark-recapture is a method used by scientists to estimate the population size of mobile organisms. For example, to monitor prairie-dog populations, scientists capture and mark prairie dogs with ear tags and then release them back into the wild. When scientists later repeat the survey, the captured prairie dogs will include both marked and unmarked animals. Scientists calculate the ratio of marked to unmarked animals and use this value to estimate the total population size.

To monitor plant populations, scientists use a method called quadrat sampling. In this method, quadrats, or rectangular frames, are randomly placed on the study site. To determine plant population numbers, scientists identify and count the number of plants within each randomly selected plot. The total number of counted plants is then plugged into a mathematical formula to determine the plant population of the entire study site.

Apply How might a scientist use observation to study a population of mountain goats? Explain your answer.

QUICK LAB **SAMPLING**



Quadrat Sampling

Ecologists often use quadrats—square or rectangular grids—to collect data about population numbers in an ecosystem. In this lab, you will use a quadrat to collect data on three "species."

PROBLEM What is the population size of each species?

PROCEDURE

1. Obtain a quadrat frame. Measure, calculate, and record the area of the quadrat.
2. Stand at the edge of the area you will sample and randomly throw your quadrat.
3. Move your quadrat so that it does not overlap with any other quadrat. Each different object represents a different species. Count how many individuals of each species are in your quadrat and record your data in a data table. Repeat this procedure three times.
4. Combine your data with that of your classmates. Find the average number of each species for all of the samples. Obtain the area of the sampling plot from your teacher. Calculate how many quadrats would fit in the area of the sampling plot. Multiply this by the average number of each species found in one quadrat to estimate the population of each species.

MATERIALS

- quadrat
- meterstick
- calculator
- objects to count

ANALYZE AND CONCLUDE

1. **Analyze** Compare your population estimate for each species to the actual number that your teacher provides. Is the estimate accurate? Why or why not?
2. **Evaluate** How can you ensure that your estimate of population size will be as accurate as possible?

Experimentation

Scientists may perform experiments in the lab or in the field. There are benefits and drawbacks to each type of experiment. While a lab experiment gives the researcher more control, the artificial setting does not reflect the complex interactions that occur in nature. A field experiment, on the other hand, gives a more accurate picture of how organisms interact in a natural setting. However, in a field study, it is more difficult to determine cause and effect due to the large number of factors at work in nature.

A lab experiment is conducted in a controlled, indoor environment. This isolation helps scientists to focus each experiment on a very specific part of an ecosystem, such as a single organism. For example, to find out how climate change affects the growth rates of plants, scientists can grow plants in a lab and adjust temperature settings. Working in a lab allows scientists to control variables in a way that would not be possible in the field.

A field experiment is performed where the organisms live. Like lab experiments, field experiments also have controls and manipulated variables. For example, to determine how browsing by deer affects plant and small-animal communities, scientists might fence off large study plots to keep out the deer. By monitoring the fenced and unfenced plots over a period of time, scientists can determine whether deer significantly change the areas in which they browse for food.

Contrast **What is the difference between a lab experiment and a field experiment?**

Connecting CONCEPTS

Scientific Method As you learned in **Chapter 1**, all fields of science, including ecology, use the scientific method to investigate and answer scientific questions. Applied ecology uses the principles of ecology along with the scientific method to solve environmental problems.

FIGURE 13.4 Ecologists use data transmitted by GPS receivers worn by elephants to develop computer models of the animals' movements.

Modeling

Sometimes the questions scientists wish to ask cannot be easily answered through observation or experimentation. Instead, scientists use computer and mathematical models to describe and model nature. Scientists can manipulate different model variables to learn about organisms or whole ecosystems in ways that would not be possible in a natural setting.

Although they are used to test hypothetical situations, models are created with the use of real data. For example, in Kenya, scientists are using satellite technology to track the movement of elephants, as shown in **FIGURE 13.4**. These data, in turn, can be used to create a model to study how changes to the ecosystem might affect elephant movement patterns. Before putting the model to use, scientists can test it by inserting actual data values. Such testing allows scientists to make sure that the values predicted by the model are similar to actual observations in the field.

In the United States, scientists developed a computer software program to create a virtual model of the Greater Yellowstone ecosystem. A variety of data were used to create this model, including

- the movements of elk, bison, bear, and wolf populations
- the location of different vegetation, such as meadows and forests
- the amount of snow
- the activities of geysers and other geothermal landforms

The combination of these data together with computer-generated maps creates a virtual ecosystem that scientists can use to model how one variable affects another. This type of modeling program sometimes plays a role in the development of wildlife conservation plans. Computer programs modeled population dynamics with and without the presence of the gray wolf. These programs were used to study how the reintroduction of gray wolves into Yellowstone might affect other species within the park and the surrounding area. By understanding how different organisms and factors within an ecosystem interact, wildlife managers are able to make well-informed decisions.

NSTA SCILINKS scilinks.org
To learn more about ecology, go to scilinks.org.
Keycode: MLB013

Contrast **How does modeling differ from experimentation?**

13.1 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. What are the five different levels of organization studied by ecologists?
2. Describe the three general methods used by ecologists to study organisms.

CRITICAL THINKING

3. **Apply** What ecological research methods would you use to study bird migration? Explain your choices.
4. **Apply** How might an ecologist use modeling to study fire in a forest **ecosystem**? What might be some key variables used to create the model?

Connecting CONCEPTS

5. **Evolution** Ernst Haeckel was greatly influenced by the writings of Charles Darwin. How do the principles of **ecology** relate to understanding how adaptations occur?

DATA ANALYSIS
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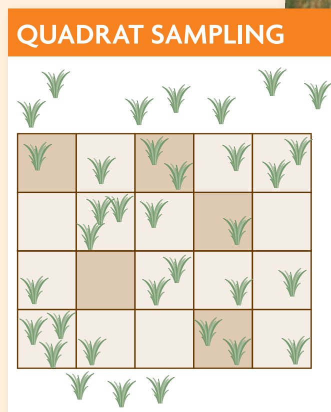
Quadrats and Population Size

One part of studying a population is to record its size. Often, it is possible to count all of the individuals in a population of organisms, such as large mammals or trees. With smaller organisms or more numerous populations, the population must be estimated based on representative samples. A **sample** is a portion of the population that is defined and counted.



Quadrat sampling is most often used to survey plant populations. This method can be used to identify species, calculate species' frequency, and monitor changes in plant communities over time.

EXAMPLE

One method used to estimate populations is to count the number of individuals within a known sample area. To sample plants, quadrats are randomly placed over a large area and the number of individuals of the same species within the quadrat is counted. The number of quadrats sampled depends on the size of the entire area under study. In the example shown here, a scientist used quadrats to estimate the population of shrubs in a field. A simple equation can be used to find the population estimate: $T = NA$

$$T = NA$$

T = Total population estimate

$$N = \frac{\text{Total number of individuals counted}}{\text{Number of quadrats}}$$

$$A = \frac{\text{Total area}}{\text{Area of quadrat}}$$

In the example, each darkly shaded area represents a quadrat. Six shrubs were counted in five quadrats. The area of each quadrat is 1 m^2. The total area of the sampling plot is 200 m^2.

$$T = NA$$

$$T = \frac{6}{5} \cdot \frac{200 \text{ m}^2}{1 \text{ m}^2}$$

$$T = 1.20 \cdot 200 = 240$$

T = 240 individuals = estimated population of shrubs in the field

ESTIMATE A POPULATION FROM A SAMPLE

For each example, calculate the estimated population. Use the formula and show all of your work.

1. **Calculate** A scientist uses a quadrat of 2 m^2 to estimate the population of daisies in a field. She counts 173 individuals in 15 quadrats. The total area of the field is 250 m^2.
2. **Calculate** A scientist uses a 0.25 m^2 quadrat to sample a population of dandelions in a garden that is 500 m^2. The number of dandelions counted in 10 quadrats is 63.

13.2 Biotic and Abiotic Factors

KEY CONCEPT Every ecosystem includes both living and nonliving factors.

MAIN IDEAS

- An ecosystem includes both biotic and abiotic factors.
- Changing one factor in an ecosystem can affect many other factors.

VOCABULARY

biotic, p. 402
abiotic, p. 402
biodiversity, p. 403
keystone species, p. 403

REVIEW AT CLASSZONE.COM

Connect A vegetable garden is a small ecosystem, and its success depends on many factors. You can probably list several without too much thought. You might think of sunlight, fertilizer, or insects to pollinate the plants' flowers. Gardeners usually don't think of themselves as scientists, but they must take into account how these factors affect their plants in order for the plants to flourish.

MAIN IDEA

An ecosystem includes both biotic and abiotic factors.

All ecosystems are made up of living and nonliving components. These parts are referred to as biotic and abiotic factors.

- **Biotic** (by-AHT-ihk) factors are living things, such as plants, animals, fungi, and bacteria. Each organism plays a particular role in the ecosystem. For example, earthworms play a key role in enriching the soil.
- **Abiotic** (AY-by-AHT-ihk) factors are nonliving things such as moisture, temperature, wind, sunlight, and soil. The balance of these factors determines which living things can survive in a particular environment.

In the Caribbean Sea, scientists found that coral reefs located near saltwater marshes have more fish than do reefs farther out at sea. As shown in **FIGURE 13.5**, the key biotic factor is the mangrove trees that live in the marshes. The trees provide food and shelter for newly hatched fish, protecting them from predators. After the fish mature, they swim to the reefs. Abiotic factors that affect the growth of mangrove trees include low levels of oxygen in the mud where they grow and changing levels of salinity, or saltiness, due to daily tidal changes.

FIGURE 13.5 The underwater roots of mangrove trees camouflage young coral-reef fish from predators.

An ecosystem may look similar from one year to the next, with similar numbers of animals and plants. However, an ecosystem is always undergoing some changes. For example, a long period of increased precipitation might allow one plant species to grow better than others. As the plant continues to grow, it may crowd out other plant species, changing the community's composition. Though the total number of plants in the community may remain the same, the species have changed. As these cyclic changes occur, an ecosystem falls into a balance, which is known as approximate equilibrium.

Contrast **What is the difference between biotic and abiotic factors?**

MAIN IDEA

Changing one factor in an ecosystem can affect many other factors.

An ecosystem is a complex web of connected biotic and abiotic factors. You may not always think of yourself as part of the ecosystem, but humans, like other species, rely on the environment for survival. All species are affected by changes to the biotic and abiotic factors in an ecosystem.

Biodiversity

The relationships within an ecosystem are very complicated. If you attached a separate string between a forest tree and each of the living and nonliving things in the ecosystem that influenced it, and did the same for each of those living and nonliving things, the forest would quickly become a huge web of strings. The web would also reveal the biodiversity in the forest. **Biodiversity** (BY-oh-dih-VUR-sih-tee) is the assortment, or variety, of living things in an ecosystem. An area with a high level of biodiversity, such as a rain forest, has a large assortment of different species living near one another. The amount of biodiversity found in an area depends on many factors, including moisture and temperature.

Some areas of the world have an unusually large amount of biodiversity in comparison to other locations. For example, tropical rain forests, which are moist and warm environments, cover less than 7 percent of Earth's ground surface. However, they account for over 50 percent of the planet's plant and animal species. This large amount of biodiversity emphasizes the importance of conserving such areas. Tropical rain forests are one of several areas referred to as hot spots. These hot spots, located across the globe, are areas that are rich in biodiversity, but are threatened by human activities.

Connecting CONCEPTS

Biodiversity The discovery of potential medicines and new species are two reasons why it is important to maintain biodiversity. In **Chapter 16**, you will learn how human activities impact biodiversity and how the loss of biodiversity affects us all.

Keystone Species

The complex relationships in ecosystems mean that a change in a single biotic or abiotic factor—a few broken strings in the web—can have a variety of effects. The change may barely be noticed, or it may have a deep impact. In some cases, the loss of a single species may cause a ripple effect felt across an entire ecosystem. Such an organism is called a keystone species. A **keystone species** is a species that has an unusually large effect on its ecosystem.

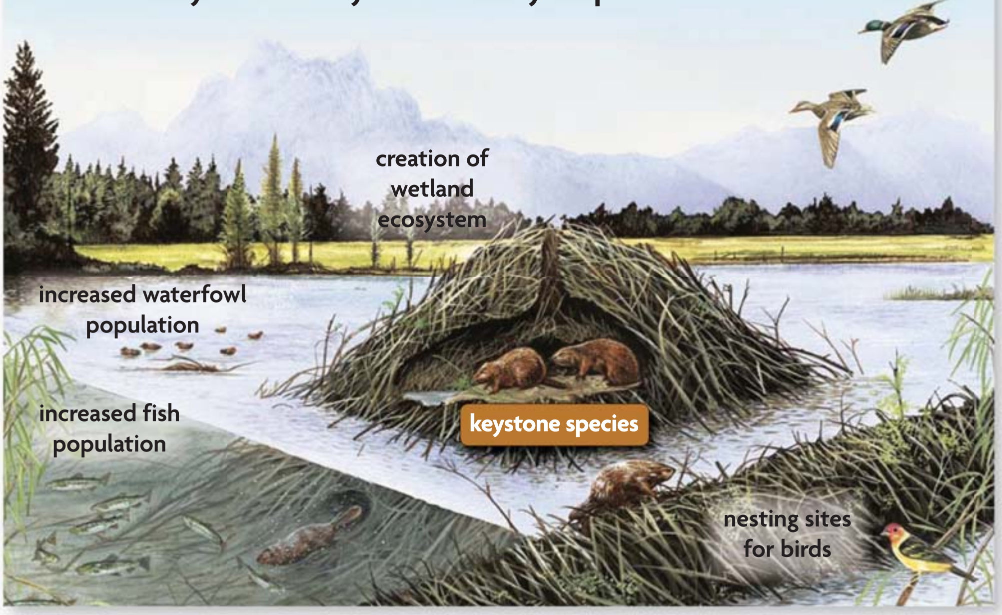
One example of a keystone species is the beaver. By felling trees to construct dams, beavers change free-flowing stream habitats into ponds, wetlands, and meadows. This modification leads to a cascade of changes within their ecosystem.

VISUAL VOCAB

Like a keystone that holds up an arch, a **keystone species** holds together a dynamic ecosystem.

FIGURE 13.6 Keystone Species

Beavers are a keystone species. By constructing dams, beavers create an ecosystem used by a wide variety of species.



As **FIGURE 13.6** shows, beavers cause changes that create an ecosystem used by a variety of different species, leading to an overall increase in biodiversity.

- A greater number and wider variety of fish are able to live in the still waters of the pond.
- The fish attract fish-eating birds, such as herons and kingfishers.
- Insects inhabit the pond and the dead trees along the shore, attracting insect-eating birds, such as great-crested flycatchers, that nest in the tree cavities.
- Waterfowl nest among the shrubs and grasses along the pond's edge.
- Animals that prey on birds or their eggs are also attracted to the pond.

Keystone species form and maintain a complex web of life. Whatever happens to that species affects all the other species connected to it.

Connect Explain why the Pacific salmon, introduced in Section 13.1, could be considered a keystone species.

13.2 ASSESSMENT

ONLINE QUIZ
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REVIEWING MAIN IDEAS

1. Select an ecosystem that is familiar to you and describe the **biotic** and **abiotic** factors that exist there.
2. How would the removal of a **keystone species** affect an ecosystem's **biodiversity**?

CRITICAL THINKING

3. **Predict** Explain how a change in an abiotic factor such as sunlight would affect biodiversity.
4. **Analyze** Humans are sometimes described as being a keystone species. Does this label fit? Why or why not?

Connecting CONCEPTS

5. **Evolution** What role might an abiotic factor such as temperature play in the evolution of a species?

MATERIALS

- 4 radish seedlings
- 4 cups
- ruler
- cheesecloth
- sand
- gravel
- potting soil
- household-plant liquid fertilizer
- plastic wrap in a variety of colors
- graduated cylinder

PROCESS SKILLS

- **Designing Experiments**
- **Collecting Data**

Abiotic Factors and Plant Growth

Many factors affect plant growth. Is it possible to test some in a laboratory setting? In this investigation you will choose an abiotic factor and attempt to test how (or if) it affects the growth of radish seedlings.

PROBLEM How do abiotic factors affect plant growth?

PROCEDURE

1. Choose an abiotic factor to test on the growth of radish seedlings. Possible factors include amount of sunlight, amount of water, soil type, light color available to plants, or amount of fertilizer.
2. Determine a way to vary the factor you have chosen. Be sure to include at least three different settings of your variable and to keep all other factors constant. Write out a procedure for your investigation.
3. Obtain 4 plants. Label one "Control" and the remaining three "A," "B," and "C."
4. Measure the height of your control and variable plants over a period of seven days. Use the same method to repeat measurements each day. Be sure to keep plants watered.
5. Record all data you generate in a well-organized data table.

ANALYZE AND CONCLUDE

1. **Operational Definitions** On the basis of your procedure, how are you defining plant growth?
2. **Identify Variables** What are your independent and dependent variables? What are your constants? What is your control?
3. **Graph Data** Make a bar graph to present the data you obtained on plant growth.
4. **Conclude** By studying your data, what can you conclude about how (or if) your variable affects the growth of radish seedlings?
5. **Conclude** Is your experiment a failure if your variable did not apparently affect the growth? Explain.
6. **Experimental Design** What possible sources of error may have occurred in your experiment? Why might they have occurred?

EXTEND YOUR INVESTIGATION

How would you design an experiment to determine whether a specific biotic factor influences plant growth?

13.3 Energy in Ecosystems

KEY CONCEPT Life in an ecosystem requires a source of energy.

MAIN IDEAS

- Producers provide energy for other organisms in an ecosystem.
- Almost all producers obtain energy from sunlight.

VOCABULARY

producer, p. 406
autotroph, p. 406
consumer, p. 406
heterotroph, p. 406
chemosynthesis, p. 407

Review
photosynthesis

REVIEW AT CLASSZONE.COM

Connect In the previous section, you learned that every ecosystem includes biotic and abiotic factors. Another important part of an ecosystem is the flow of energy. This energy is needed to fuel life processes, such as breathing and growing. Where does this energy come from, and what role does it play within an ecosystem?

MAIN IDEA

Producers provide energy for other organisms in an ecosystem.

All organisms must have a source of energy in order to survive. However, not all organisms obtain their energy by eating other organisms.

- **Producers** are organisms that get their energy from nonliving resources, meaning they make their own food. Their distribution is shown in **FIGURE 13.7.** Producers are also called **autotrophs** (AW-tuh-TRAHFS). In the word *autotroph,* the suffix *-troph* comes from a Greek word meaning "nourishment." The prefix *auto-* means "self."
- **Consumers** are organisms that get their energy by eating other living or once-living resources, such as plants and animals. Consumers are also called **heterotrophs** (HEHT-uhr-uh-TRAHFS). In the word *heterotroph,* the prefix *hetero-* means "different."

All ecosystems depend on producers, because they provide the basis for the ecosystem's energy. Even animals that eat only meat rely on producers. One such species is the gray wolf. Gray wolves are consumers that eat elk and moose. Elk and moose are consumers that eat plants, such as grasses and shrubs. Plants are producers that make their own food. If the grasses and shrubs disappeared, the elk and moose would either have to find some other producer to eat or they would starve. The wolves would also be affected because they eat elk and moose. Although the wolves do not eat plants, their lives are tied to the grasses and shrubs that feed their prey. Likewise, all consumers are connected in some way to producers.

Most producers need sunlight to make food. These producers depend directly on the sun as their source of energy. For this reason, all the consumers connected to these producers depend indirectly on the sun for their energy.

Predict **How would a long-term drought affect producers and consumers?**

BIOLOGY
Visit ClassZone.com to view satellite evidence of producers.

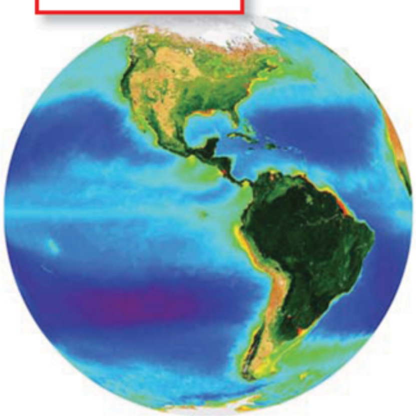

FIGURE 13.7 This satellite image uses chlorophyll abundance to show the distribution of producers in the Western Hemisphere. Dark green areas are heavily forested, while yellow areas have limited vegetation.

MAIN IDEA

Almost all producers obtain energy from sunlight.

Most producers on Earth use sunlight as their energy source. Photosynthesis is the two-stage process that green plants, cyanobacteria, and some protists use to produce energy. Chemical reactions form carbohydrates from carbon dioxide and water. Oxygen is released as a waste product.

Photosynthesis in plants begins when energy from the sun hits chloroplasts and is absorbed by chlorophyll. In the first stage of photosynthesis, energy from sunlight is converted to chemical energy. In the second stage, this chemical energy is used to change carbon dioxide into carbohydrates, such as glucose. Plants use these carbohydrates as an energy source to fuel cellular respiration.

Not all producers depend on sunlight for their energy. Scientists were stunned in 1977 when they first visited deep-sea vents on the bottom of the ocean. There they found thriving ecosystems in places where super-heated water shoots up from the ocean floor. Studies showed that tiny prokaryotes were making their own food from minerals in the water. They had no need for sunlight. **Chemosynthesis** (KEE-moh-SIHN-thih-sihs) is the process by which an organism forms carbohydrates using chemicals, rather than light, as an energy source. A series of reactions changes the chemicals into a usable energy form. Different reactions occur depending on which chemicals are present.

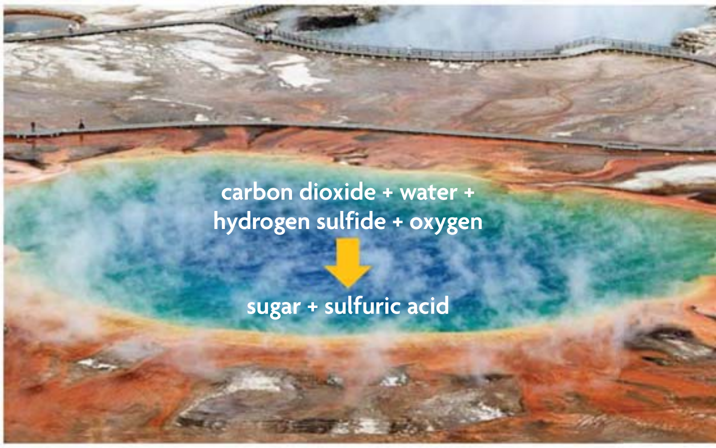

FIGURE 13.8 Chemosynthetic bacteria thrive in many of Yellowstone National Park's hydrothermal pools.

In addition to deep-sea vents, chemosynthetic organisms are also found in sulfur-rich salt marsh flats and in hydrothermal pools, such as those in Yellowstone National Park, shown in **FIGURE 13.8.** In this case, chemical energy is used to change carbon dioxide (CO_2), water (H_2O), hydrogen sulfide (H_2S), and oxygen (O_2) into an energy-rich sugar molecule. Sulfuric acid (H_2SO_4) is released as a waste product.

Contrast How do photosynthesis and chemosynthesis differ?

13.3 ASSESSMENT

ONLINE QUIZ
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REVIEWING MAIN IDEAS

1. How does the stability of an ecosystem depend on its **producers**?
2. What are the two processes used by producers to obtain energy?

CRITICAL THINKING

3. **Hypothesize** Few producers live deep below a lake's surface. Suggest an explanation for this pattern.
4. **Infer** Could producers survive without **consumers**? Explain why or why not.

Connecting CONCEPTS

5. **History of Life** How might chemosynthetic organisms help scientists to understand how life developed on Earth?

13.4 Food Chains and Food Webs

KEY CONCEPT Food chains and food webs model the flow of energy in an ecosystem.

MAIN IDEAS

- A food chain is a model that shows a sequence of feeding relationships.
- A food web shows a complex network of feeding relationships.

VOCABULARY

food chain, p. 408
herbivore, p. 409
carnivore, p. 409
omnivore, p. 409
detritivore, p. 409
decomposer, p. 409
specialist, p. 409
generalist, p. 409
trophic level, p. 409
food web, p. 411

REVIEW AT CLASSZONE.COM

Connect As we have seen, energy flows through an ecosystem in one direction—from producers to consumers. However, since an ecosystem can have hundreds or even thousands of different species, determining the relationship between species can be quite tricky. Food chains and food webs are used to model these relationships.

MAIN IDEA

A food chain is a model that shows a sequence of feeding relationships.

The simplest way to look at energy flow in an ecosystem is through a food chain. A **food chain** is a sequence that links species by their feeding relationships. Rather than describe every potential relationship, this model chain only follows the connection between one producer and a single chain of consumers within an ecosystem. For example, in a desert ecosystem, a desert cottontail eats grass. The food chain is, therefore, grass–desert cottontail. If another consumer such as a Harris's hawk eats a desert cottontail, the food chain gets longer: grass–desert cottontail–Harris's hawk, as shown in **FIGURE 13.9**.

FIGURE 13.9 Food Chain

Energy flows through a food chain.

GRAMA GRASS | DESERT COTTONTAIL | HARRIS'S HAWK

Grama grass, a producer, obtains its energy through photosynthesis.

The desert cottontail, a consumer, obtains its energy by eating the seeds of plants, such as grama grass.

The Harris's hawk, a consumer, obtains its energy by eating other animals, such as desert cottontails.

Types of Consumers

As you read in Section 13.3, consumers are organisms that eat other organisms. All consumers, however, are not alike.

- **Herbivores,** such as desert cottontails, are organisms that eat only plants.
- **Carnivores** are organisms that eat only animals. Harris's hawks are carnivores that eat desert cottontails.
- **Omnivores** are organisms that eat both plants and animals. Kangaroo rats are omnivores that eat both seeds and insects.
- **Detritivores** (dih-TRY-tuh-VOHRZ) are organisms that eat detritus, or dead organic matter. A millipede is a detritivore that feeds on particles of detritus on the ground.
- **Decomposers** are detritivores that break down organic matter into simpler compounds. Fungi, for example, are decomposers. Decomposers are important to the stability of an ecosystem because they return vital nutrients back into the environment.

VOCABULARY

Most words for consumers come from Latin words.

- *Vorāre* means "to swallow or devour."
- *Herba* means "vegetation."
- *Carnus* means "flesh."
- *Omnis* means "all."
- *Dētrere* means "to wear away."

Food chains are especially helpful in describing feeding relationships among extremely selective eaters, known as specialists. A **specialist** is a consumer that primarily eats one specific organism or feeds on a very small number of organisms.

FIGURE 13.10 Florida snail kites are specialists that rely on apple snails as their primary food source.

Specialists are very sensitive to changes in the availability of prey. For example, the Florida snail kite, shown in **FIGURE 13.10**, is a specialist that depends on the apple snail as its main source of food. In the early 1900s, apple snails became less common in Florida as a result of land development. Florida snail kite populations declined suddenly, and in 1967, the bird was listed as an endangered species. Currently, the snails and the birds continue to survive in lower numbers in protected areas, such as the Everglades.

Most species do not rely on a single source of food. These species are called generalists. **Generalists** are consumers that have a varying diet. For example, the diet of a gray wolf may include a number of animals, including elk, moose, white-tailed deer, beavers, and even mice.

Trophic Levels

Trophic levels are the levels of nourishment in a food chain. For example, the producer–herbivore–carnivore chain has three trophic levels. Carnivores are at the highest trophic level. Herbivores are at the second trophic level. Producers are at the first, or bottom, trophic level. Energy flows up the food chain from the lowest trophic level to the highest.

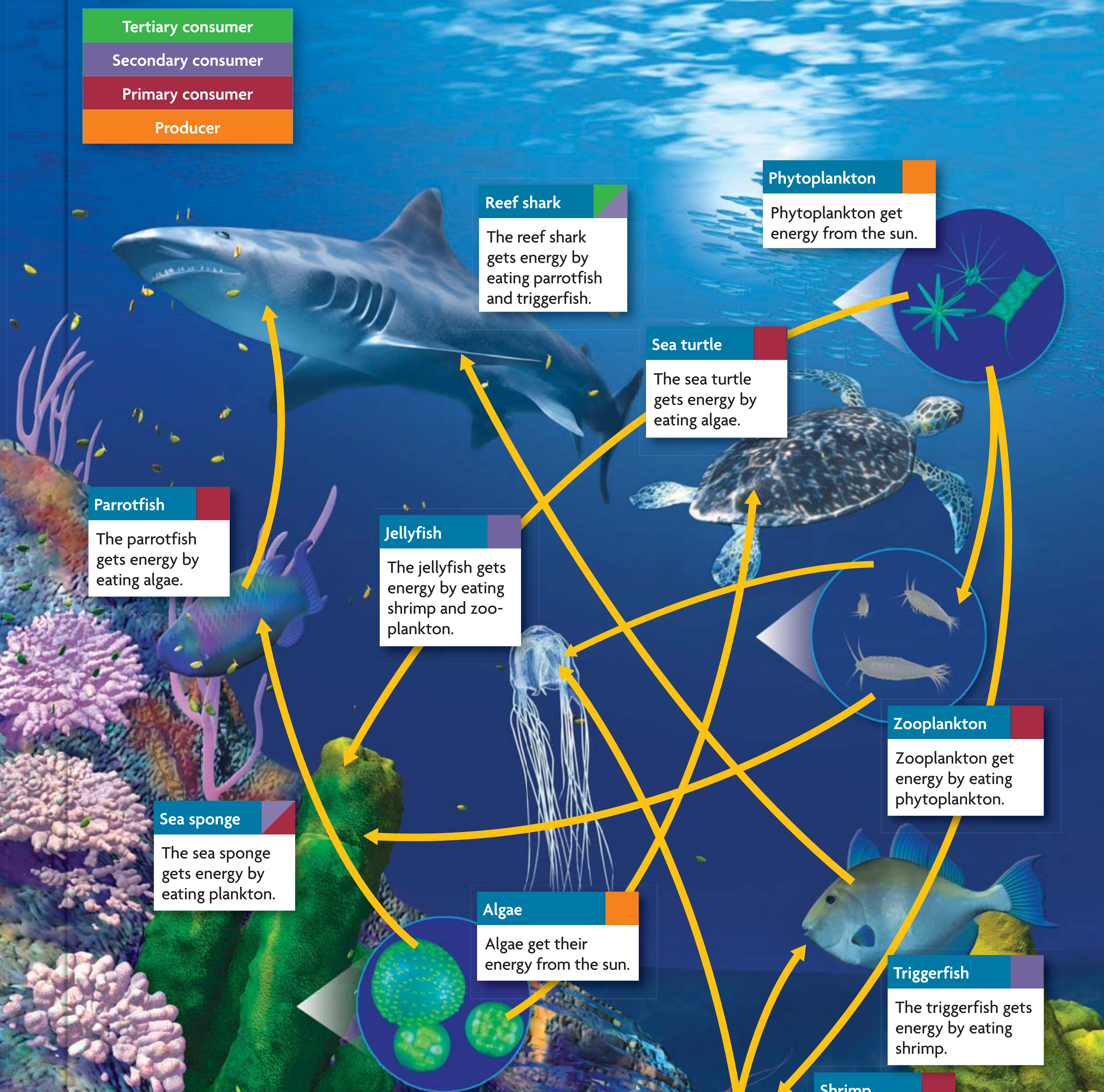
- Primary consumers are herbivores because they are the first consumer above the producer trophic level.
- Secondary consumers are carnivores that eat herbivores.
- Tertiary consumers are carnivores that eat secondary consumers.

Omnivores, such as humans that eat both plants and animals, may be listed at different trophic levels in different food chains. When a person eats a salad, the trophic levels in the food chain are producer–omnivore. When a person eats a steak, the trophic levels are producer–herbivore–omnivore.

Connect **What is the connection between food chains and trophic levels?**

FIGURE 13.11 Food Web

A **food web** shows the network of feeding relationships between trophic levels within an ecosystem. The food web in a coral reef can be quite complex because many organisms feed on a variety of other species.



CRITICAL VIEWING Which organism, if removed, would impact the food web the most? Explain your answer.

MAIN IDEA

A food web shows a complex network of feeding relationships.

Generalists may be involved in many food chains, depending on which links are in the chain. Each of the organisms in those links, in turn, may be part of many other food chains. As a result, scientists use food webs to describe these interconnections. A **food web** is a model that shows the complex network of feeding relationships and the flow of energy within and sometimes beyond an ecosystem. At each link in a food web, some energy is stored within an organism, and some energy is dissipated into the environment.

Coral reefs are often referred to as rain forests of the sea, due to the abundance and diversity of species found there. The complex connections in a coral reef ecosystem, illustrated in **FIGURE 13.11**, are created by the feeding relationships within the food web.

The stability of any food web depends on the presence of producers, as they form the base of the food web. In the case of a marine ecosystem such as a coral reef, algae and phytoplankton are two of the producers that play this important role.

An organism may have multiple feeding relationships within a food web. For example, reef sharks are generalists that eat several different food items. When a reef shark eats a parrotfish, it is a secondary consumer, because a parrotfish is a primary consumer that eats algae. However, a reef shark is a tertiary consumer when it eats a triggerfish. This difference in trophic levels occurs because a triggerfish is a secondary consumer that feeds on shrimp. The shrimp, in turn, is a primary consumer that eats phytoplankton. Food webs like this one emphasize both the complicated nature of feeding relationships and the flow of energy within an ecosystem.

Analyze How might the introduction of a new predator affect the flow of energy through a food web?

Connecting **CONCEPTS**

Marine Ecosystems Coral reefs are ecosystems that are rich in diversity. In **Chapter 15** you will learn about the complex relationships found in these underwater ecosystems.

13.4 ASSESSMENT

ONLINE QUIZ
ClassZone.com

REVIEWING MAIN IDEAS

1. Why are **food chains** especially useful for describing the relationships of **specialists**?
2. What happens to energy as it flows through a **food web**?

CRITICAL THINKING

3. **Compare and Contrast** Only a small percentage of all consumers are specialists. What danger does a specialist face that a **generalist** does not?
4. **Predict** How might the stability of an ecosystem be affected if all of the **decomposers** were suddenly removed?

Connecting CONCEPTS

5. **Pollution** How might an oil spill in the ocean affect an aquatic food web? What might happen to the food web on land located near the spill? Explain your answers.

13.5 Cycling of Matter

KEY CONCEPT Matter cycles in and out of an ecosystem.

MAIN IDEAS

- Water cycles through the environment.
- Elements essential for life also cycle through ecosystems.

VOCABULARY

hydrologic cycle, p. 412
biogeochemical cycle, p. 413
nitrogen fixation, p. 415

REVIEW AT CLASSZONE.COM

Connect Since life in most ecosystems requires a constant inflow of energy from the sun, Earth is an open system in terms of energy. However, in terms of matter, such as oxygen and carbon, Earth is a closed system. Today's Earth has roughly the same amount of carbon as it had billions of years ago, meaning that the same carbon atoms that make up your body may once have been part of a tree, or gases spewed by a volcano, or even part of a dinosaur.

MAIN IDEA

Water cycles through the environment.

Matter changes form, but it does not disappear. It can be used over and over again in a continuous cycle. If you crush a rock, for example, it does not vanish. Instead, it turns into sand and other bits of minerals. Although matter may change form over time, the total amount of matter remains the same.

As you learned earlier, a major part of life on Earth is water, which has a cycle of its own. The **hydrologic cycle** (HY-druh-LAHJ-ihk), also known as the water cycle, is the circular pathway of water on Earth from the atmosphere, to the surface, below ground, and back. Part of that pathway involves humans and other organisms, which all have bodies made mostly of water.

As shown in **FIGURE 13.12**, precipitation, such as rain or snow, falls to Earth. Some of this precipitation seeps into the ground, some drops into ponds, streams, lakes, or other waterways, and some forms puddles or other temporary pools. Depending on the type of soil and rocks surrounding it and also on its location, groundwater may empty directly into oceans. Sometimes water flows first into lakes, swamps, or wetlands, but these—along with rivers, streams, and other freshwater sources—also feed into oceans.

In addition, some droplets of water quickly reenter the atmosphere through evaporation. Since oceans cover over 70 percent of Earth's surface, about 85 percent of Earth's evaporation occurs between the oceans and the atmosphere. On land, water vapor is released by plants during transpiration, which is evaporation that occurs between plant leaves and the atmosphere. The cycle is completed as water vapor in the atmosphere condenses and forms clouds, returning water to the surface once again in the form of precipitation.

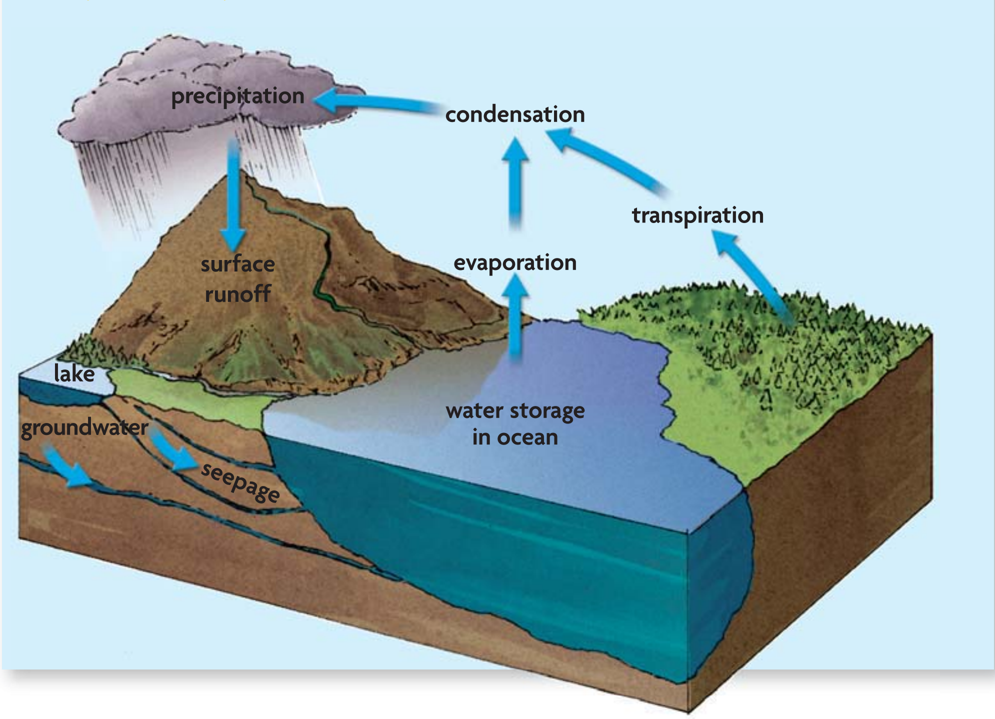
Analyze If the total amount of water on Earth does not change, why are there concerns about global freshwater shortages?

***Connecting* CONCEPTS**

Properties of Water The presence of water is necessary for life on Earth. All organisms depend on the simple structure of the water molecule. As you learned in **Chapter 2**, water has several unique properties. Water's high specific heat helps keep cells at the right temperature to carry out life processes.

FIGURE 13.12 Hydrologic Cycle

The hydrologic cycle is the circular pathway of water on Earth.



MAIN IDEA

Elements essential for life also cycle through ecosystems.

Many elements are essential to the structure and function of organisms. Elements are basic chemical substances, such as the oxygen and hydrogen found in the chemical compound of water. Additional elements important to life include carbon, nitrogen, phosphorus, and sulfur. As you learned in Chapter 2, oxygen, carbon, nitrogen, and hydrogen make up 96 percent of the mass of the human body. This is just one reason why the cycling of these elements is so important. All of these elements cycle through ecosystems, just as water does.

A **biogeochemical cycle** (BY-oh-JEE-oh-KEHM-ih-kuhl) is the movement of a particular chemical through the biological and geological, or living and nonliving, parts of an ecosystem. Just as water changes from solid form (ice or snow) to liquid form (rain) or gaseous form (water vapor), other substances may also change state as they move through their cycles.

The Oxygen Cycle

Plants, animals, and most other organisms need oxygen for cellular respiration. As shown in **FIGURE 13.13,** plants release oxygen as a waste product during photosynthesis. In turn, humans and other organisms take in this oxygen and release it as carbon dioxide through respiration. Oxygen is also indirectly transferred through an ecosystem by the cycling of other nutrients, including carbon, nitrogen, and phosphorus.

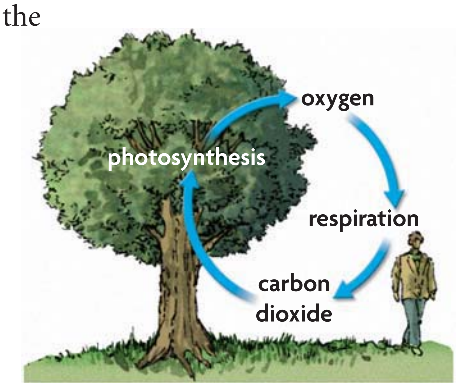
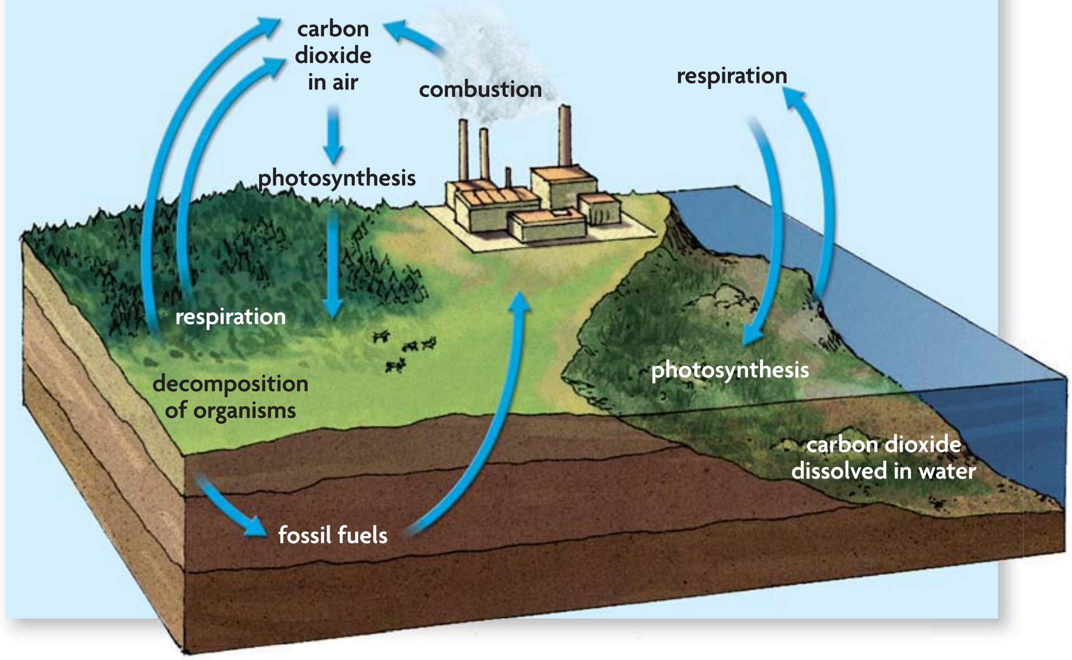


FIGURE 13.13 In the oxygen cycle, oxygen flows into the atmosphere as a byproduct of photosynthesis. Organisms take in this oxygen and release it as carbon dioxide through respiration.

Apply Explain how deforestation might affect the oxygen cycle.

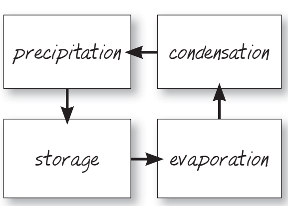
FIGURE 13.14 Carbon Cycle

Photosynthesis and respiration account for much of the transformation and movement of carbon.



TAKING NOTES

For each cycle, draw and label a simple diagram in your notes.



The Carbon Cycle

Carbon is the building block of life—it is key to the structure of all organisms on our planet. It is an essential component of carbohydrates, proteins, fats, and all the other organic molecules that make up your body. Carbon continually flows from the environment to living organisms and back again in the carbon cycle, shown in **FIGURE 13.14**.

Carbon exists in the abiotic world in several forms. Carbon can be found in solid, liquid, and gaseous states. Sources of carbon include

- carbon dioxide (CO_2) gas in the atmosphere
- bicarbonate (HCO_3^-) dissolved in water
- fossil fuels, which are underground deposits of oil, natural gas, and coal
- carbonate rocks, such as limestone
- dead organic matter, such as humus, in the soil

The simplest transfer of carbon occurs between plants and animals. Plants use energy from the sun to convert carbon dioxide from the air into organic material that becomes a part of the plant's structure. The carbon then moves through the biotic world as one organism eats another.

Carbon is returned to the atmosphere as carbon dioxide by respiration or through the decomposition of dead organisms. The burning of fossil fuels and wood, as well as emissions from factories and automobiles, adds to carbon dioxide in the atmosphere. Another source of atmospheric carbon is methane, which is emitted from wetlands, landfills, and livestock.

Not all carbon molecules move freely through the cycle. Areas that store carbon over a long period of time are called carbon sinks. One example is forest land, where large amounts of carbon are stored in the cellulose of wood.

The Nitrogen Cycle

About 78 percent of Earth's atmosphere is made of nitrogen gas. However, most organisms can use nitrogen only in the form of ions such as ammonium (NH_4^+) or nitrate (NO_3^-). As shown in **FIGURE 13.15,** much of the nitrogen cycle takes place underground.

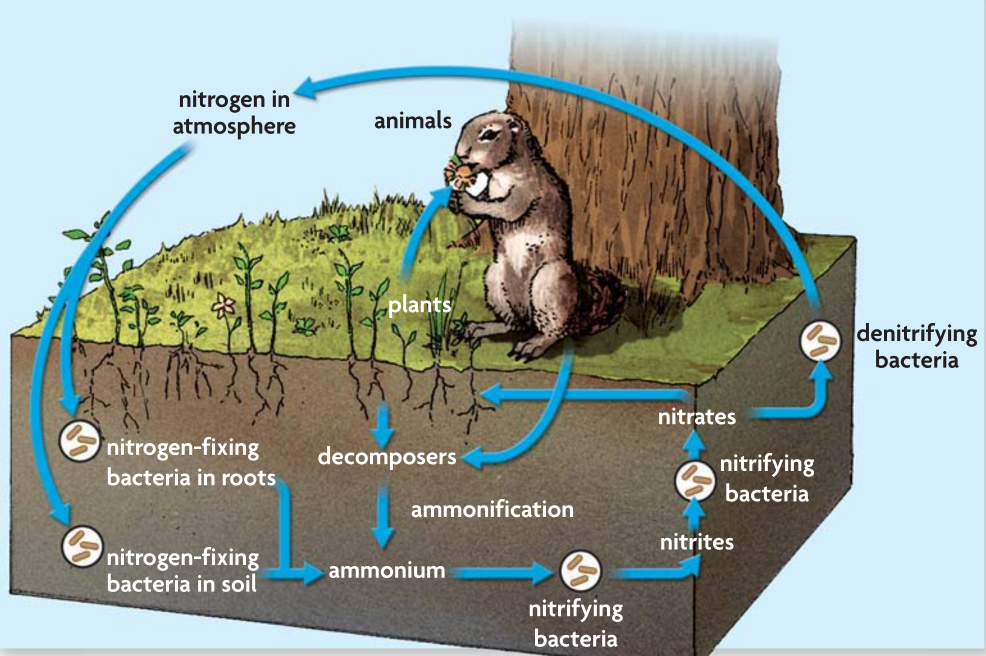
Certain types of bacteria convert gaseous nitrogen into ammonia (NH_3) through a process called **nitrogen fixation.** A few types of cyanobacteria fix nitrogen in aquatic ecosystems. On land, some nitrogen-fixing bacteria live in small outgrowths, called nodules, on the roots of plants such as beans and peas. Other nitrogen-fixing bacteria live freely in the soil. The ammonia released by these bacteria is transformed into ammonium by the addition of hydrogen ions found in acidic soil. Some ammonium is taken up by plants, but most is used by nitrifying bacteria as an energy source. Through the process called nitrification, these bacteria change ammonium into nitrate.

Nitrates released by soil bacteria are taken up by plants, which convert them into organic compounds such as amino acids and proteins. Nitrogen continues along the cycle as animals eat plant or animal matter. When decomposers break down animal excretions or dead animal and plant matter, nitrogen is returned to the soil as ammonium, in a process called ammonification.

Denitrifying bacteria use nitrate as an oxygen source, releasing nitrogen gas into the atmosphere as a waste product. Some nitrogen also enters the soil as a result of atmospheric fixation by lightning. Lightning's energy breaks apart nitrogen molecules in the atmosphere. Nitrogen recombines with oxygen in the air, forming nitrogen oxide. The combination of nitrogen oxide with rainwater forms nitrates, which are absorbed by the soil.

FIGURE 13.15 Nitrogen Cycle

Much of the nitrogen cycle occurs underground, where bacteria transform ammonium into nitrates, which are used by plants to make amino acids.

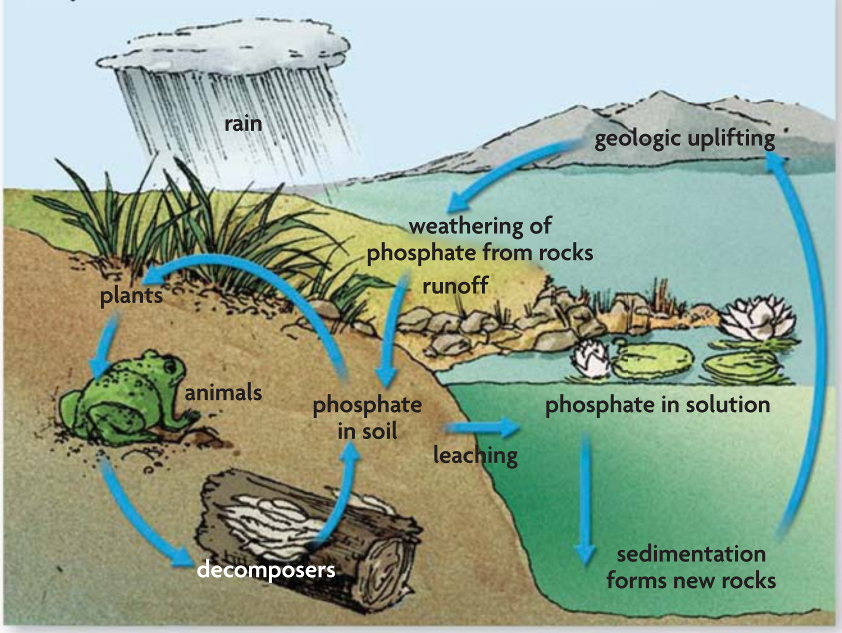


The Phosphorus Cycle

Unlike the other cycles, the phosphorus cycle does not include an atmospheric portion. Instead, most of the cycle takes place at and below ground level, as shown in **FIGURE 13.16.**

FIGURE 13.16 Phosphorus Cycle

The phosphorus cycle occurs on a local, rather than global, scale. Its cycle is limited to water, soil, and ocean sediment.



The phosphorus cycle begins when phosphate is released by the weathering of rocks. Plants and some fungi found near plant roots are able to take up phosphate. Phosphorus moves from producers to consumers through the food web. When the producers and consumers die, decomposers break down the organisms. This process releases phosphorus back into the soil or water for use by producers. Some phosphorus may leach into groundwater from the soil. This groundwater may flow into a lake or other body of water, where the phosphorus becomes locked in sediments at the bottom. Over many thousands of years, these sediments eventually become rock again, and the cycle starts again as phosphate is released by the weathering of these newly formed rocks.

Mining and agricultural runoff also add to the overall amount of phosphorus in the environment. The excessive flow of phosphorus into an aquatic ecosystem from sewage and agricultural runoff can cause significant problems. Phosphorus is a limiting factor for the growth of plants. Large amounts of phosphorus within an aquatic environment can lead to algal blooms. These blooms crowd out other plant species and negatively impact wildlife populations as well.

Summarize **Choose one of the biogeochemical cycles, and list the key processes involved in the cycling of the element.**

13.5 ASSESSMENT

ONLINE QUIZ
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REVIEWING MAIN IDEAS

1. How does the **hydrologic cycle** move water through the environment?
2. What are four elements that cycle through ecosystems, and why are they important?

CRITICAL THINKING

3. **Apply** Why might farmers plant legumes such as peas to improve the nitrogen levels in their soil?
4. **Synthesize** Explain the importance of decomposers to the overall **biogeochemical cycle.**

Connecting CONCEPTS

5. **Evolution** How might Earth's biogeochemical cycles help scientists to understand the early history of life on Earth?

13.6 Pyramid Models

KEY CONCEPT Pyramids model the distribution of energy and matter in an ecosystem.

MAIN IDEAS

- An energy pyramid shows the distribution of energy among trophic levels.
- Other pyramid models illustrate an ecosystem's biomass and distribution of organisms.

VOCABULARY

biomass, p. 417
energy pyramid, p. 418

REVIEW AT CLASSZONE.COM

Connect You have seen that ecosystems have a structure, with large numbers of producers supporting several levels of consumers. Ecologists often model this structure as a pyramid, in terms of both matter and energy. The pyramids can represent the general flow of energy through an ecosystem, from producers to consumers. They can also represent the mass or numbers of organisms at each trophic level.

MAIN IDEA

An energy pyramid shows the distribution of energy among trophic levels.

Ecosystems get their energy from sunlight. Sunlight provides the energy for photosynthesis, and that energy flows up the food chain. However, along the way, some of the energy is dissipated, or lost. Producers use energy from sunlight to make food. Herbivores eat the plants, but burn some energy in the process. This energy is given off as heat, and the heat escapes into space. Carnivores then eat the herbivores, but again lose energy as heat. In other words, each level in the food chain contains much less energy than the level below it. Fortunately, the Sun pumps new energy into the system and allows life to continue.

Loss of Available Energy

Each meal that you consume is packed with energy in the form of proteins, fats, and carbohydrates. Your body uses this energy for many purposes such as movement and growth. The majority of the food you consume is used to keep your body at its normal temperature. Your body is very inefficient at converting what you consume into useful energy, so there will always be some material that is not used. Unused material is simply excreted as waste.

Energy in an ecosystem works in much the same way, only on a larger scale. **Biomass** is a measure of the total dry mass of organisms in a given area. When a consumer incorporates the biomass of a producer into its own biomass, a great deal of energy is lost in the process as heat and waste. The conversion of biomass from a producer into biomass of the consumer is inefficient.

Consider the simple producer-to-consumer food chain of grass–prairie dog. Photosynthesis traps energy as carbohydrates, which can be thought of as a high-quality form of energy. A hungry prairie dog then eats the grass.

***Connecting* CONCEPTS**

Cellular Respiration As you learned in **Chapter 4**, the processes of cellular respiration use ATP to maintain your body's functions. While the chemical reactions of metabolism are relatively efficient, there will always be some loss of available energy.

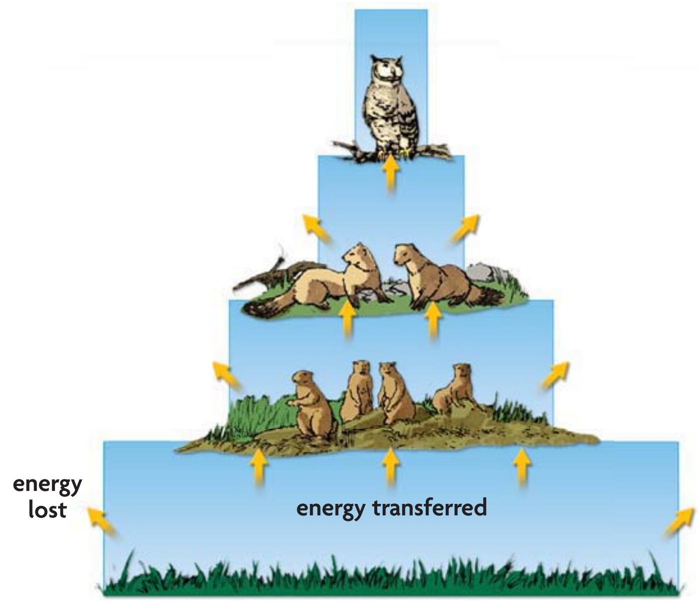


FIGURE 13.17 An energy pyramid illustrates the energy flow between trophic levels in an ecosystem. Between each tier, up to 90 percent of the energy is lost as heat into the atmosphere.

Some of the energy is used by the animal to grow. The remaining energy may be used to fuel cellular respiration or remains undigested. The dissipation, or loss, of energy between trophic levels may be as much as 90 percent, meaning that only 10 percent of the available energy is left to transfer from one trophic level to another.

Energy Pyramids

Because energy is lost at each stage of a food chain, the longer the chain is, the more energy is lost overall. The total energy used by producers far exceeds the energy used by the consumers they support. This concept can be illustrated with an energy pyramid. An **energy pyramid** is a diagram that compares energy used by producers, primary consumers, and other trophic levels. The pyramid, therefore, illustrates how available energy is distributed among trophic levels in an ecosystem. The unit of measurement used to describe the amount of energy at each trophic level in an energy pyramid is the kilocalorie (kcal).

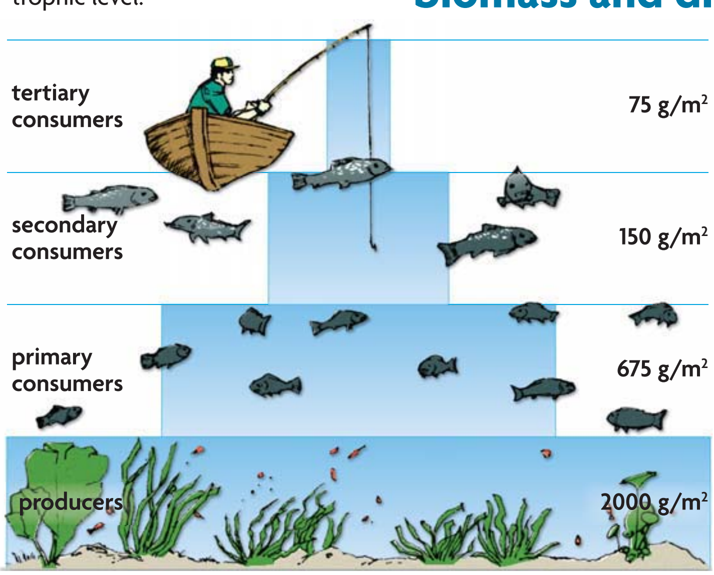
A typical energy pyramid has a very large section at the base for the producers, and sections that become progressively smaller above. For example, in a prairie ecosystem, as illustrated in **FIGURE 13.17**, energy flows from grass at the producer level, to prairie dogs at the primary consumer level, to black-footed ferrets at the secondary consumer level, to a great horned owl at the tertiary consumer level.

Connect **Draw an energy pyramid for the desert food chain introduced in Section 13.4. Use arrows to illustrate the flow of energy.**

MAIN IDEA

Other pyramid models illustrate an ecosystem's biomass and distribution of organisms.

FIGURE 13.18 The biomass pyramid depicts the total dry mass of organisms found at each trophic level.



A biomass pyramid is a diagram that compares the biomass of different trophic levels within an ecosystem. Unlike an energy pyramid, which represents energy use, a biomass pyramid provides a picture of the mass of producers needed to support primary consumers, the mass of primary consumers required to support secondary consumers, and so on.

In a pond ecosystem, such as the one illustrated in **FIGURE 13.18**, a biomass pyramid shows that the total dry mass (given in grams per square meter, or g/m^2) of algae within the pond is far greater than the dry mass of fish. This example illustrates yet again the important role producers play in maintaining a stable ecosystem.

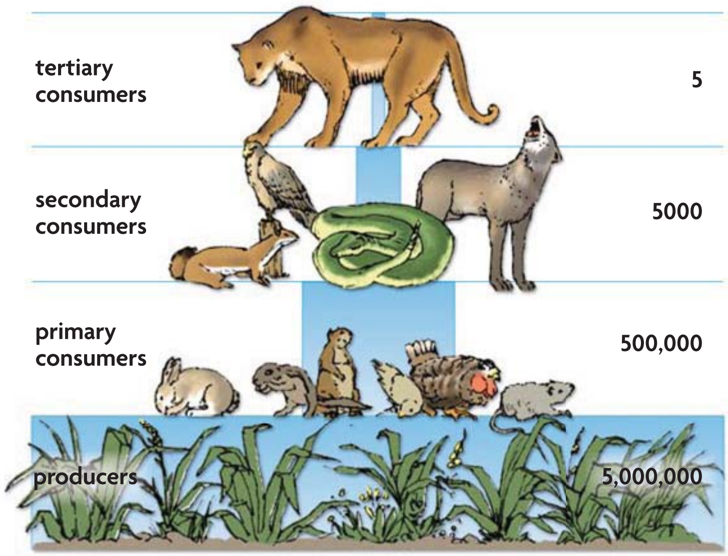


FIGURE 13.19 In a pyramid of numbers, each tier represents the actual number of individual organisms present in each trophic level.

A pyramid of numbers shows the numbers of individual organisms at each trophic level in an ecosystem. For example, a pyramid of numbers depicting a mountainous habitat, as shown in **FIGURE 13.19**, might include organisms such as grasses, snowshoe hares, gophers, coyotes, snakes, and mountain lions. This type of pyramid is particularly effective in showing the vast number of producers required to support even a few top level consumers.

In certain situations, both biomass pyramids and pyramids of numbers may occur in an inverted, or upside down, formation. Consider, for example, a pyramid of numbers based on a single tree. This single tree would be greatly outnumbered by the primary and secondary consumers, such as insects and birds, that live within it. In this case, the upper tiers of the pyramid of numbers would be much larger than the bottom tier representing the single tree.

Apply If a scientist wanted to compare the exact number of organisms at each trophic level within a desert ecosystem, which pyramid model would he or she use?

13.6 ASSESSMENT

ONLINE QUIZ
ClassZone.com

REVIEWING MAIN IDEAS

1. How does an **energy pyramid** help to describe energy flow in a food web?
2. What is the difference between a **biomass** pyramid and a pyramid of numbers?

CRITICAL THINKING

3. **Apply** How would you draw a pyramid of numbers for a dog with fleas? What shape would the pyramid take?
4. **Calculate** If each level in a food chain typically loses 90 percent of the energy it takes in, and the producer level uses 1000 kcal of energy, how much of that energy is left after the third trophic level?

Connecting CONCEPTS

5. **Nutrition** Why is an herbivorous diet more energy efficient than a carnivorous diet? Explain your answer.

Use these inquiry-based labs and online activities to deepen your understanding of ecological principles.

INVESTIGATION

Random Sampling

In this activity, you will use random sampling to calculate the number of big bluestems, a typical tall-grass species, found in a restored prairie.

SKILL Sampling

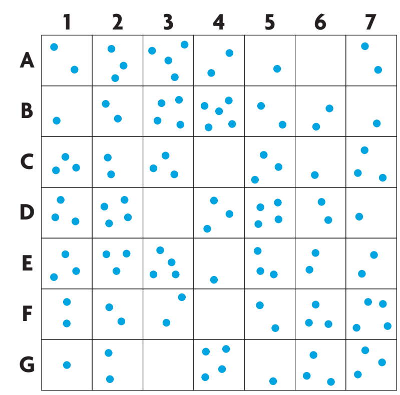
PROBLEM How many big bluestems are in the field?

MATERIALS

- ruler
- scissors
- paper
- 2 containers
- Calculation datasheet
- calculator

PROCEDURE

1. Cut 14 equal-sized paper squares.
2. Letter seven of the squares A through G. Number seven of the squares 1 through 7. Place the lettered squares and numbered squares in separate containers.
3. In your notebook, draw a data table like the one below. Include 12 rows in your table.
4. The pictured grid is your study plot. It is part of a larger grassland. The study plot measures 7 meters on each side, and each grid segment measures 1 meter by 1 meter. A single big bluestem plant is represented by each dot.



5. Determine which segment you will count by taking one square from each container without looking. Locate the letter-number combination on the grid and count the number of big bluestem plants. Record this number in your data table. Place each square back in its container.
6. Repeat step 5 until you have collected data for 12 different grid segments. Do not count the same segment twice.

CALCULATE Complete the calculation datasheet to estimate the population size.

TABLE 1. RANDOM SAMPLE DATA

Grid Letter	Grid Number	No. of Big Bluestems in Grid Segment

ANALYZE AND CONCLUDE

1. **Experimental Design** Why were paper squares used to determine which grid segment to count? Why didn't you just choose ten grid segments on your own?
2. **Evaluate** How could you change the procedure to reduce your percent error?
3. **Analyze** What are the advantages of using random sampling to estimate population size? What are the disadvantages?

INVESTIGATION

Build a Terrarium

In this activity, you will construct a miniature self-sustaining ecosystem and monitor its stability.

SKILL **Modeling**

PROBLEM How does an ecosystem change or maintain its equilibrium over time?

MATERIALS

- glass jar with lid
- gravel
- potting soil
- large sealable plastic bags
- water
- measuring cup
- ruler
- small plants
- light source

PROCEDURE

1. Cover the bottom of the jar with a layer of gravel about 2 centimeters deep.
2. Place 2 cups of potting soil and 1/2 cup of water in the plastic bag. Seal the bag and mix well until the soil is moist.
3. Add the moistened soil into the jar over the gravel layer.
4. Select and plant the small plants in the soil. Cover the jar with the lid and tighten it shut.
5. Observe and record changes in your terrarium over time.

ANALYZE AND CONCLUDE

1. **Operational Definitions** What criteria did you use to select the size and number of plants for your terrarium?
2. **Identify Variables** What are the key variables involved in maintaining your ecosystem?
3. **Observe** How did your terrarium ecosystem change over time?
4. **Conclude** Was your terrarium a success? Explain.

Online BIOLOGY
CLASSZONE.COM

VIRTUAL LAB

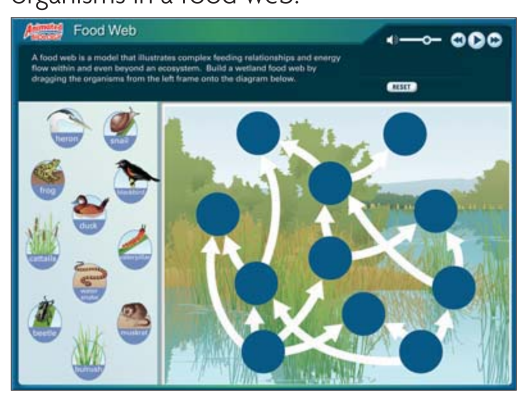
Estimating Population Size

How does a scientist count a mobile population? In this interactive lab, capture, mark, then recapture individual animals to estimate the size of a sample population.

ANIMATED BIOLOGY

Build a Food Web

Build a food web. Use your knowledge of producers and consumers to place a set of organisms in a food web.



WEBQUEST

A sea otter is playful, fun to watch, and very critical to its ecosystem. In this WebQuest, you will explore its role as a keystone species within the aquatic environment of the California coast. Learn what happened after sea otters were almost wiped out. Finally, think of ways you can protect sea otter populations and the ecosystems in which they live.

CHAPTER 13

Interactive Review @ CLASSZONE.COM

KEY CONCEPTS | Vocabulary Games | Concept Maps | Animated Biology | Online Quiz

13.1 Ecologists Study Relationships

Ecology is the study of the relationships among organisms and their environment. Ecologists study environments at different levels of organization. Ecologists use methods such as observation, experimentation, and modeling to study ecological principles.

13.2 Biotic and Abiotic Factors

Every ecosystem includes both living and nonliving factors. Changing one factor in an ecosystem can affect many other factors. The removal of a keystone species may lead to changes in an ecosystem's biodiversity.

13.3 Energy in Ecosystems

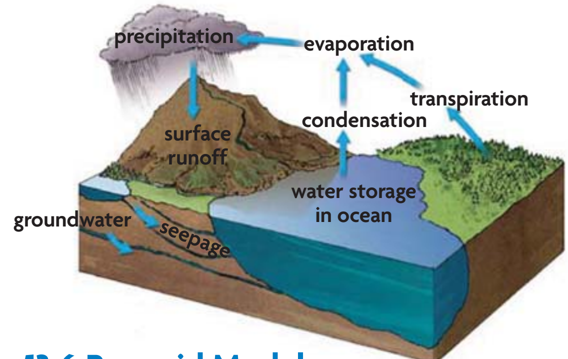
Life in an ecosystem requires a source of energy. Producers provide energy for other organisms in an ecosystem. Most producers obtain their energy from sunlight through photosynthesis. Other producers obtain their energy through a process called chemosynthesis.

13.4 Food Chains and Food Webs

Food chains and food webs model the flow of energy in an ecosystem. A food chain is a simple model that shows a sequence of feeding relationships. A food web provides a more complex picture of the network of feeding relationships among organisms in an ecosystem.

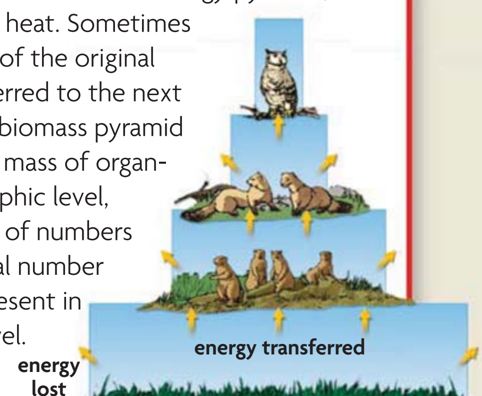
13.5 Cycling of Matter

Matter cycles in and out of an ecosystem. The hydrologic cycle is the circular pathway of water through the environment. Elements essential for life on Earth, such as oxygen, carbon, nitrogen, and phosphorus, also cycle through ecosystems.



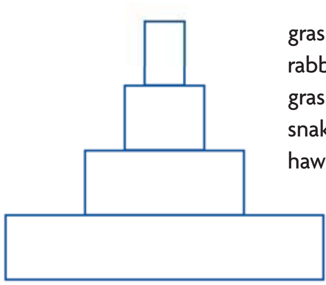
13.6 Pyramid Models

Pyramids model the distribution of energy and matter in an ecosystem. An energy pyramid shows the distribution of energy in a food chain. Energy flows upward from producers to consumers. Between each tier of the energy pyramid, energy is lost as heat. Sometimes only 10 percent of the original energy is transferred to the next trophic level. A biomass pyramid shows the total mass of organisms at each trophic level, while a pyramid of numbers shows the actual number of organisms present in each trophic level.



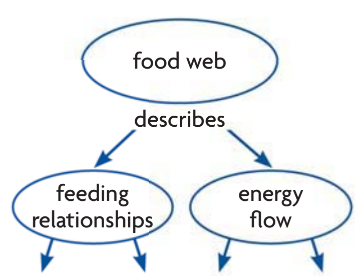
Synthesize Your Notes

Energy Pyramid Add labels and organisms that belong in each trophic level to this energy pyramid.



grass	producer
rabbit	primary consumer
grasshopper	secondary consumer
snake	tertiary consumer
hawk	

Concept Map Use a concept map to summarize what you know about food webs.



Chapter Assessment

Chapter Vocabulary

13.1 ecology, p. 396
community, p. 397
ecosystem, p. 397
biome, p. 397

13.2 biotic, p. 402
abiotic, p. 402
biodiversity, p. 403
keystone species, p. 403

13.3 producer, p. 406
autotroph, p. 406
consumer, p. 406
heterotroph, p. 406
chemosynthesis, p. 407

13.4 food chain, p. 408
herbivore, p. 409
carnivore, p. 409
omnivore, p. 409
detritivore, p. 409
decomposer, p. 409
specialist, p. 409
generalist, p. 409
trophic level, p. 409
food web, p. 411

13.5 hydrologic cycle, p. 412
biogeochemical cycle, p. 413
nitrogen fixation, p. 415

13.6 biomass, p. 417
energy pyramid, p. 418

Reviewing Vocabulary

Find an Opposite

Pair each of the words listed below with a different vocabulary term that has an opposing definition. Then, write one sentence describing a difference.

1. abiotic factor
2. producer
3. heterotroph
4. carnivore
5. specialist

Greek and Latin Word Origins

Use the definitions of the word parts to answer the following questions.

Part	Meaning
bio-	life
eco-	home
syn-	together, joined
vore	eat

6. Explain why the root *vore* is used in the appropriate vocabulary terms.

7. Six vocabulary terms include the prefix *bio-*. Describe how they are all related.

8. Use the meaning of *eco-* to write your own definition of *ecosystem.*

9. *Photo-* means “light,” and *chemo-* means “chemical.” Explain why *photosynthesis* and *chemosynthesis* both include the prefix *syn-*.

Reviewing MAIN IDEAS

10. How can an individual organism simultaneously be part of a population, community, ecosystem, and biome?

11. What are the major differences between observation, experimentation, and modeling? **IE.1.g**

12. List some biotic and abiotic factors you would expect to find in a city park. **6.5.e**

13. What is a keystone species and how might the removal of it affect the stability of and biodiversity within its ecosystem? **6.a**

14. What would happen to a forest ecosystem if a fire killed most of its producers? **6.e, 6.5.c**

15. Describe one similarity and one difference between photosynthesis and chemosynthesis. **1.f**

16. An acorn is eaten by a squirrel, which is eaten by an owl. What model best describes this simple relationship, and how does it show energy flow?

17. How is a food web related to energy flow within an ecosystem? **6.f, 6.5.b**

18. Describe the main processes involved in the hydrologic cycle. **6.d**

19. Give an example of one biogeochemical cycle and explain how it is important to living things. **6.d**

20. How does an energy pyramid show the flow of energy in an ecosystem? **6.f**

21. A biomass pyramid and a pyramid of numbers are two ways of modeling the flow of matter in an ecosystem. What is the main difference between the two?

Critical Thinking

22. Apply At what level of organization would a scientist study the interaction between seals and polar bears in the Arctic? Explain your answer.

23. Apply Explain which biotic factors used by the beaver are related to its role as a keystone species.

24. Evaluate Scientists used to say that all living things depend on the sun. Explain why this statement is no longer valid.

25. Analyze How might a drought affect a grassland food web? Which trophic level would the drought affect the most? Explain your answer.

26. Synthesize Humans have changed many ecosystems on Earth. Compare different types of consumers, and predict which types would be more likely to adapt to these changes and which would not. Explain your answers.

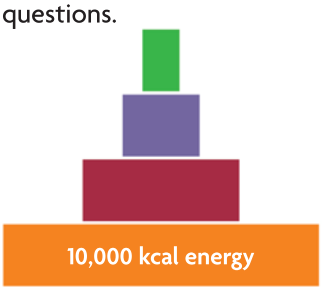
27. Synthesize Use the information you learned about carbon-based molecules to explain a human's need to participate in the biogeochemical cycles.

28. Connect What role do decomposers play in the nitrogen cycle?

29. Predict In a pyramid of numbers, the highest organism has the smallest number of individuals in a community. What might happen if this organism increased its numbers significantly? Explain the effect this increase would have on the other members of the community.

Interpreting Visuals

Use the energy pyramid below to answer the following questions.



30. Apply Use the energy pyramid to describe the flow of energy within an ecosystem. Identify which tier represents producers, primary consumers, and so on.

31. Calculate If 90 percent of the energy is lost as heat between trophic levels, approximately how much energy is available to the secondary consumers in this energy pyramid? Show your calculations.

Analyzing Data

Use the equation $T = N \times A$ to estimate the population size in questions 32–33. Show all of your work.

32. Calculate A scientist wants to estimate the population of mushrooms on a forest floor with an area of 300 m^2. Each quadrat is 2 m^2. She counts 13 mushrooms in 20 quadrats. What is the population of mushrooms in the forest?

33. Calculate A scientist uses quadrats to sample the population of strawberry cactus plants in a section of the Chihuahuan desert that is 150 m^2. He counts 5 cacti in 10 quadrats. Each quadrat is 2 m^2. What is the population of strawberry cacti in the desert?

34. Analyze What are the advantages and disadvantages of using random sampling to obtain an estimate of the population size?

35. Evaluate A scientist uses quadrats to determine the population size of lupines in a field 500 m^2 in size. She uses ten 1 m^2 quadrats. Is this an adequate sample size? Explain your answer.

36. Apply Scientists often use tables of random numbers to determine where to place quadrats on their study site. Why might they do this? Why can't they choose where to place the quadrats?

37. Apply A scientist wants to determine the population size of whiptail lizards within a 15-acre area. What sampling method should she use? How can she ensure that she obtains an accurate estimate of the lizard population? Explain your answer.

Connecting CONCEPTS

38. Write About Your Own Ecosystem Imagine you built a large greenhouse in your home to create your own ecosystem. What types of organisms would you include? How would you ensure that the biogeochemical cycles were in place? Describe in detail an ecosystem you would like to have in your home. Be sure to include the biotic and abiotic factors in your explanation of how the ecosystem would sustain itself.

39. Make a Food Web Read the description of anhingas on page 395 and draw a partial food web of a freshwater marsh ecosystem. Include producers and consumers in your web.

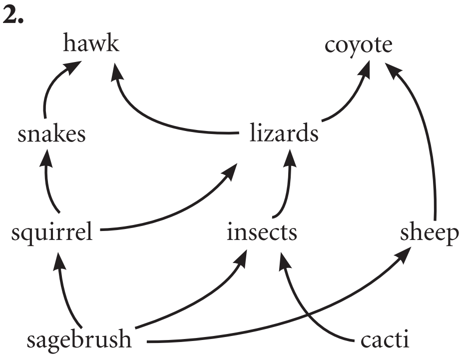
REVIEW AT CLASSZONE.COM

Test Practice
For more test practice, go to ClassZone.com.

1. A scientist wants to measure the size of a cactus population in a desert valley. What method should she use?

A mark-recapture sampling
B quadrat sampling
C computer modeling
D radio telemetry

2.



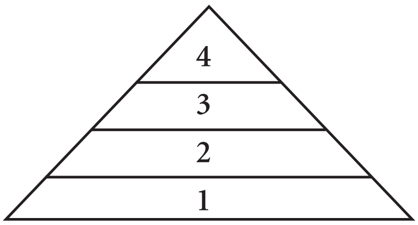
This food web shows the relationships between organisms in an ecosystem. Which type of organism *not* shown in this food web is important to the stability of the ecosystem?

A producer
B consumer
C herbivore
D decomposer

3. Several different plant species grew in an empty lot. The city council decided to turn the lot into a park, so they had the ground torn up and planted with grass to create a playing field. The ecological factor that was most likely affected by the change was the lot's

A biomass.
B temperature.
C biodiversity.
D hydrologic cycle.

4.



In which direction does energy flow through this energy pyramid?

A 4, 3, 2, 1
B 1, 2, 3, 4
C 2, 1, 3, 4
D 3, 4, 2, 1

THINK THROUGH THE QUESTION

Remember that an energy pyramid shows the amount of energy in each trophic level, with producers at the bottom of the pyramid, and consumers at the top.

5. Which of the following groups is most important for bringing energy into an ecosystem?

A consumers
B producers
C decomposers
D generalists

6. In the carbon cycle, through what process does carbon move from an abiotic resource into organic matter?

A immigration
B combustion
C respiration
D photosynthesis

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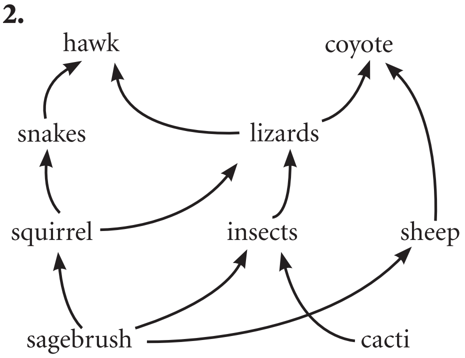

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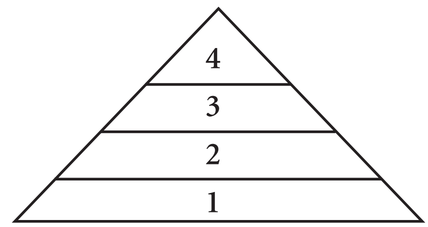

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