How Ecosystems Work

CHAPTER 5

READING WARM-UP

Before you read this chapter, take a few minutes to answer the following questions in your ***EcoLog.***

1. How is energy transferred from one organism to another?
2. Why should forest rangers let some forest fires burn?

This green frog gets the energy it needs to survive by eating other organisms, such as dragonflies.

SECTION 1

Energy Flow in Ecosystems

Just as a car cannot run without fuel, an organism cannot survive without a constant supply of energy. Where does an organism's energy come from? The answer to that question depends on the organism, but the ultimate source of energy for almost all organisms is the sun.

Objectives

- Describe how energy is transferred from the sun to producers and then to consumers.
- Describe one way in which consumers depend on producers.
- List two types of consumers.
- Explain how energy transfer in a food web is more complex than energy transfer in a food chain.
- Explain why an energy pyramid is a representation of trophic levels.

Key Terms

photosynthesis
producer
consumer
decomposer
cellular respiration
food chain
food web
trophic level

Life Depends on the Sun

Energy from the sun enters an ecosystem when a plant uses sunlight to make sugar molecules by a process called **photosynthesis.** During photosynthesis, plants, algae, and some bacteria capture solar energy. Solar energy drives a series of chemical reactions that require carbon dioxide and water, as shown in **Figure 1.** The result of photosynthesis is the production of sugar molecules known as *carbohydrates*. Carbohydrates are energy-rich molecules which organisms use to carry out daily activities. As organisms consume food and use energy from carbohydrates, the energy travels from one organism to another. Plants, such as the sunflowers in **Figure 2,** produce carbohydrates in their leaves. When an animal eats a plant, some energy is transferred from the plant to the animal. Organisms use this energy to move, grow, and reproduce.

Figure 1 ▶ During photosynthesis, plants use carbon dioxide, water, and solar energy to make carbohydrates and oxygen.

Figure 2 ▶ The cells in the leaves of these sunflowers contain a green chemical called *chlorophyll*. Chlorophyll helps plants trap energy from the sun to produce energy-rich carbohydrates.

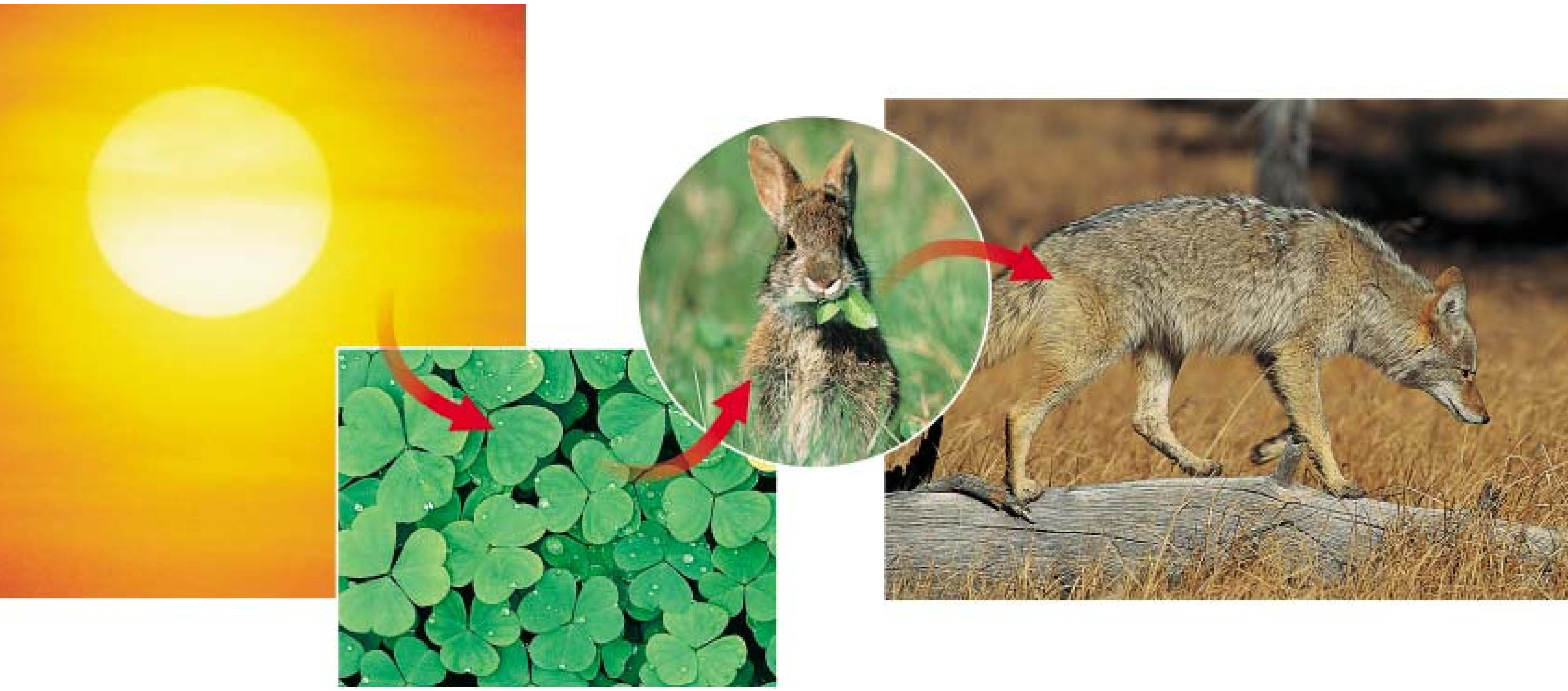


Figure 3 ▶ Transfer of Energy Almost all organisms depend on the sun for energy. Plants like the clover shown above get energy from the sun. Animals like the rabbit and coyote get their energy by eating other organisms.

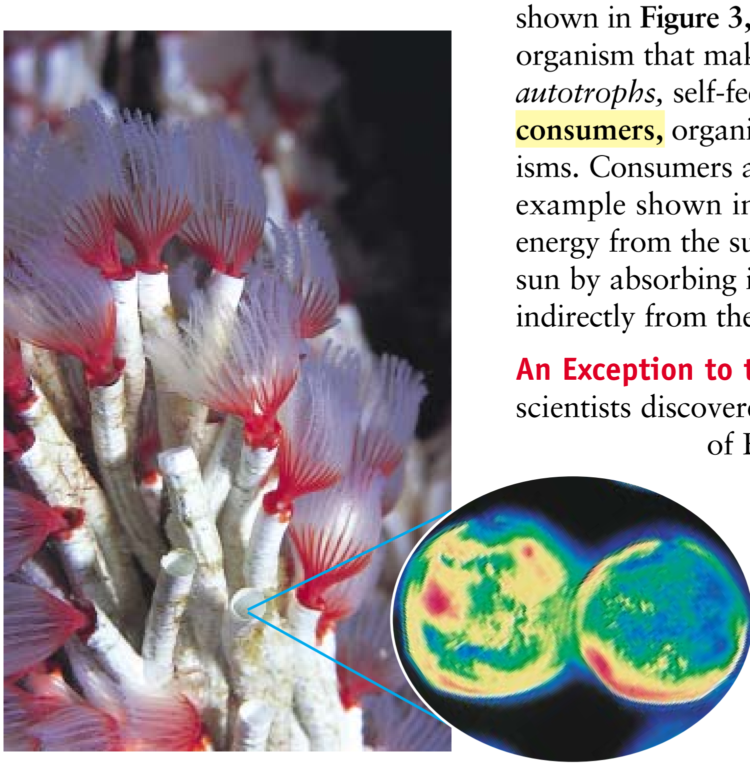


Figure 4 ▶ The tube worms (above) depend on bacteria that live inside them to survive. The bacteria (right) use energy from hydrogen sulfide to make their own food.

From Producers to Consumers When a rabbit eats a clover plant, the rabbit gets energy from the carbohydrates the clover plant made through photosynthesis. If a coyote eats the rabbit, some of the energy is transferred from the rabbit to the coyote. In the example shown in **Figure 3,** the clover is the producer. A **producer** is an organism that makes its own food. Producers are also called *autotrophs,* self-feeders. Both the rabbit and the coyote are **consumers,** organisms that get their energy by eating other organisms. Consumers are also called *heterotrophs,* other-feeders. In the example shown in **Figure 3,** the clover, rabbit, and coyote get their energy from the sun. Some producers get energy directly from the sun by absorbing it through their leaves. Consumers get energy indirectly from the sun by eating producers or other consumers.

An Exception to the Rule: Deep-Ocean Ecosystems In 1977, scientists discovered areas on the bottom of the ocean off the coast of Ecuador that were teeming with life, even though sunlight did not reach the bottom of the ocean. The scientists found large communities of worms, clams, crabs, mussels, and barnacles living near thermal vents in the ocean floor. These deep-ocean communities exist in total darkness, where photosynthesis cannot occur. So where do these organisms get their energy? Bacteria, such as those pictured in **Figure 4,** live in some of these organisms and use hydrogen sulfide to make their own food. Hydrogen sulfide is present in the hot water that escapes from the cracks in the ocean floor. Therefore, the bacteria are producers that can make food without sunlight. These bacteria are eaten by the other underwater organisms and thus support a thriving ecosystem.

What Eats What

Table 1 below classifies organisms by the source of their energy. Consumers that eat only producers are called *herbivores*, or plant eaters. Rabbits are herbivores and so are cows, sheep, deer, grasshoppers, and many other animals. Consumers, such as lions and hawks, that eat only other consumers are called *carnivores*, or flesh eaters. You already know that humans are consumers, but what kind of consumers are we? Because most humans eat both plants and animals, we are called *omnivores*, or eaters of all. Bears, pigs, and cockroaches are other examples of omnivores. Some consumers get their food by breaking down dead organisms and are called **decomposers.** Bacteria and fungi are examples of decomposers. The decomposers allow the nutrients in the rotting material to return to the soil, water, and air.

MATHPRACTICE

A Meal Fit for a Grizzly Bear Grizzly bears are omnivores that can eat up to 15 percent of their body weight per day when eating salmon and up to 33 percent of their body weight when eating fruits and other vegetation. How many pounds of salmon can a 200 lb grizzly bear eat in one day? How many pounds of fruits and other vegetation can the same bear eat in one day?

Table 1 ▼

What Eats What in an Ecosystem		
	Energy source	**Examples**
Producer	makes its own food through photosynthesis or chemical sources	grasses, ferns, cactuses, flowering plants, trees, algae, and some bacteria
Consumer	gets energy by eating producers or other consumers	mice, starfish, elephants, turtles, humans, and ants
Types of Consumers in an Ecosystem		
	Energy source	**Examples**
Herbivore	producers	cows, sheep, deer, and grasshoppers
Carnivore	other consumers	lions, hawks, snakes, spiders, sharks, alligators, and whales
Omnivore	both producers and consumers	bears, pigs, gorillas, rats, raccoons, cockroaches, some insects, and humans
Decomposer	breaks down dead organisms in an ecosystem and returns nutrients to soil, water, and air	fungi and bacteria

Figure 5 ▶ Bears, such as the grizzly bear below, are omnivores. Grizzly bears eat other consumers, such as salmon, but they also eat various plants.

Connection to Chemistry

Chemical Equations Chemical reactions are represented by chemical equations. A chemical equation is a shorthand description of a chemical reaction using chemical formulas and symbols. The starting materials in a reaction are called *reactants*, and the substances formed from a reaction are called *products*. The number of atoms of each element in the reactants equals the number of atoms of those elements in the products to make a balanced equation.

Cellular Respiration: Burning the Fuel

So far, you have learned how organisms get energy. But how do they use the energy they get? To understand the process, use yourself as an example. Suppose you have just eaten a large meal. The food you ate contains a lot of energy. Your body gets the energy out of the food by using the oxygen you breathe to break down the food. By breaking down the food, your body obtains the energy stored in the food.

The process of breaking down food to yield energy is called **cellular respiration,** which occurs inside the cells of most organisms. This process is different from *respiration,* which is another name for breathing. During cellular respiration, cells absorb oxygen and use it to release energy from food. As you can see in **Figure 6,** the chemical equation for cellular respiration is essentially the reverse of the equation for photosynthesis. During cellular respiration, sugar and oxygen combine to yield carbon dioxide, water, and, most importantly, energy.

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

Figure 6 ▶ Through cellular respiration, cells use glucose and oxygen to produce carbon dioxide, water, and energy.

CASE STUDY

DDT in an Aquatic Food Chain

In the 1950s and 1960s, something strange was happening in the estuaries near Long Island Sound, near New York and Connecticut. Birds of prey, such as ospreys and eagles, that fed on fish in the estuaries had high concentrations of the pesticide DDT in their bodies. But when the water in the estuary was tested, it had low concentrations of DDT.

What accounted for the high levels of DDT in the birds? Poisons that dissolve in fat, such as DDT, can become more concentrated as they move up a food chain in a process called *biological magnification.* When the pesticide enters the water, algae and bacteria take in the poison. When fish eat the algae and bacteria, the poison dissolves into the fat of the fish rather than diffusing back into the water. Each time a bird feeds on a fish, the bird accumulates more DDT in its fatty tissues. In some estuaries on Long Island Sound, DDT concentrations in fatty tissues of organisms were magnified almost 10 million times from the bottom to the

▶ A high concentration of DDT decreases the thickness and the strength of eggshells of many birds of prey.

You use a part of the energy you obtained through cellular respiration to carry out your daily activities. Every time you walk, breathe, read a book, think, or play a sport, you use energy. The energy you obtain is also used to make more body tissues and to fight diseases so that you grow and stay healthy. Excess energy you obtain is stored as fat or sugar. All living things use cellular respiration to get the energy they need from food molecules. Even organisms that make their own food through photosynthesis use cellular respiration to obtain energy from the carbohydrates they produce.

Energy Transfer

Each time one organism eats another organism, a transfer of energy occurs. We can trace the transfer of energy as it travels through an ecosystem by studying food chains, food webs, and trophic levels. Food chains, food webs, and trophic levels can tell us how energy is transferred as well as how much energy is transferred between organisms in an ecosystem. Studying the paths of energy between organisms can also tell us which organisms in an ecosystem depend on other organisms to survive.

Connection to Biology

Calories from Food The substances your body needs to survive and grow come from food. Carbohydrates, proteins, and fats are major sources of energy for the body. The energy content of food can be found by burning a dry food sample in a special calorimeter. Both carbohydrates and proteins provide 4 Calories (Cal) of energy per gram, while fats provide 9 Cal of energy per gram.

▶ Poisons such as DDT have the greatest affect on organisms at the top of food chains. For example, the osprey shown here would have a greater concentration of DDT in its body than the perch it's about to eat.

top of the food chain. Large concentrations of DDT may kill an organism, weaken its immune system, cause deformities, or impair its ability to reproduce. DDT can also weaken the shells of bird eggs. When eggs break too soon, bird embryos die. Therefore, the effects of these chemicals cause a tremendous drop in the population of carnivorous bird species.

The U.S. government recognized DDT as an environmental contaminant and in 1972 banned its sale except in emergencies. The aquatic food chains immediately started to recover, and the populations of ospreys and eagles started to grow.

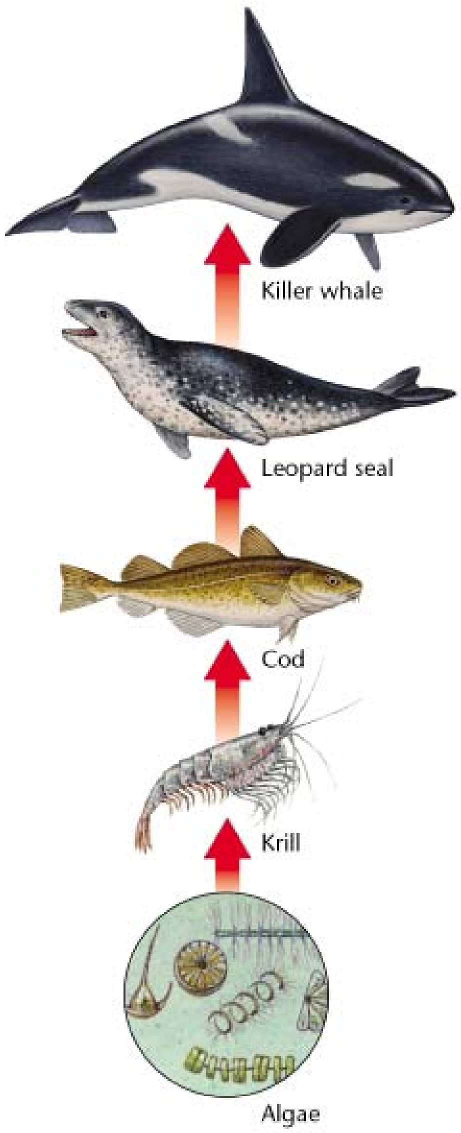
Food chains are still not free of DDT. DDT is still legal in some countries, where it is used in large quantities to eliminate mosquitoes that carry the disease malaria. As a result, migratory birds may be exposed to DDT while wintering in locations outside the United States.

CRITICAL THINKING

1. Analyzing Processes DDT does not dissolve readily in water. If it did, how would the accumulation of the pesticide in organisms be affected?

2. Evaluating Information Even though DDT is harmful to the environment, why is it still used in some countries?

Figure 7 ▶ Energy is transferred from one organism to another in a food chain, such as the one shown below. Algae are the producers in this ocean food chain.



Food Chains and Food Webs A **food chain** is a sequence in which energy is transferred from one organism to the next as each organism eats another organism. **Figure 7** shows a typical food chain in an ocean ecosystem. Algae are eaten by krill, which are eaten by cod. The cod are eaten by leopard seals, which are eaten by killer whales.

Energy flow in an ecosystem is much more complicated than energy flow in a simple food chain. Ecosystems almost always contain many more species than a single food chain contains. In addition, most organisms, including humans, eat more than one kind of food. So a food web, such as the one shown in **Figure 8,** includes more organisms and multiple food chains linked together. A **food web** shows many feeding relationships that are possible in an ecosystem. Notice that the food chain is just one strand in the larger food web.

Trophic Levels Each step in the transfer of energy through a food chain or food web in an ecosystem is known as a **trophic level.** In **Figure 8,** the algae are in the bottom trophic level, the krill are in the next level, and so on. Each time energy is transferred from one organism to another, some of the energy is lost as heat and less energy is available to organisms at the next trophic level. Some of this energy is lost during cellular respiration. Organisms use much of the remaining energy to carry out the functions of living, such as producing new cells, regulating body temperature, and moving

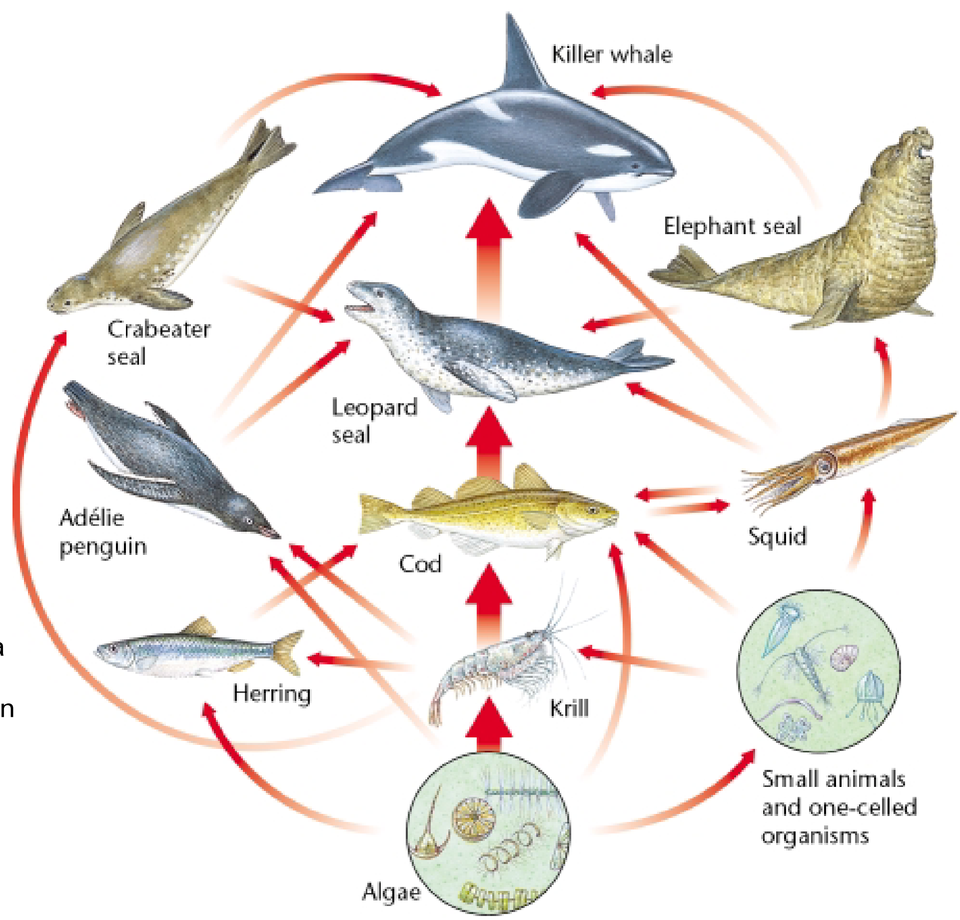
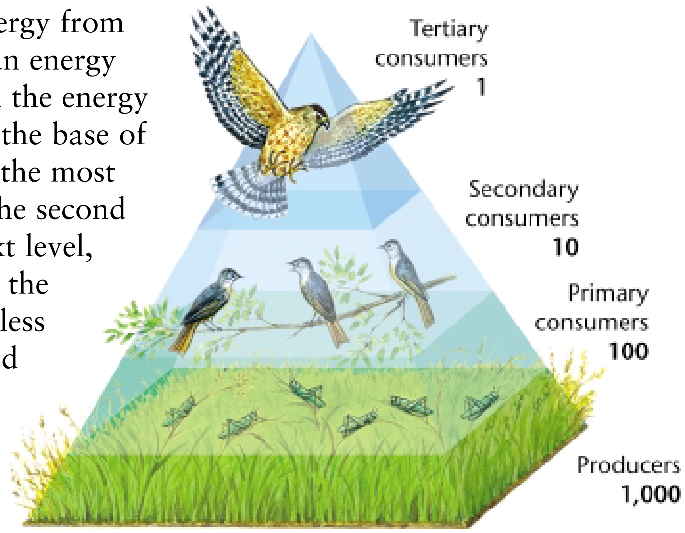


Figure 8 ▶ This food web shows how the largest organisms, such as a killer whale, depend on the smallest organisms, such as algae, in an ocean ecosystem.

around. About 90 percent of the energy at each trophic level is used in these ways. The remaining 10 percent of the energy becomes part of the organism's body and is stored in its molecules. This 10 percent that is stored is all that is available to the next trophic level when one organism consumes another organism.

Energy Pyramids One way to visualize the loss of energy from one trophic level to the next trophic level is to draw an energy pyramid like the one shown in **Figure 9.** Each layer in the energy pyramid represents one trophic level. Producers form the base of the pyramid, the lowest trophic level, which contains the most energy. Herbivores contain less energy and make up the second level. Carnivores that feed on herbivores form the next level, and carnivores that feed on other carnivores make up the top level. Organisms in the upper trophic levels store less energy than both herbivores and producers. A pyramid is a good way to illustrate trophic levels because the pyramid becomes smaller toward the top, where less energy is available.

Figure 9 ▶ This energy pyramid shows how energy is lost from one trophic level to the next. The grass at the bottom level stores 1,000 times more energy than the hawk at the top level.



How Energy Loss Affects an Ecosystem The decreased amount of energy at each trophic level affects the organization of an ecosystem. First, the energy loss is usually due to a smaller number of organisms at the higher trophic levels. For example, zebras and other herbivores outnumber lions on the African savanna by about 1,000 to 1. In this example, there simply are not enough herbivores to support more carnivores.

Second, the loss of energy from trophic level to trophic level limits the number of trophic levels in an ecosystem. Ecosystems rarely have more than four or five trophic levels because the ecosystem does not have enough energy left to support higher levels. For example, a lion typically needs up to 250 km^2 of land to hunt for food. Therefore, an animal that feeds on lions would have to expend a lot of energy to harvest the small amount of energy available at the top trophic level. The organisms that do feed on organisms at the top trophic level are usually small, such as parasitic worms and fleas that require a very small amount of energy.

internet connect

www.scilinks.org
Topic: Food Chains, Food Webs, and Trophic Levels
SciLinks code: HE4043

SCILINKS. Maintained by the National Science Teachers Association

SECTION 1 Review

1. **Describe** how energy is transferred from one organism to another.
2. **Describe** the role that producers play in an ecosystem.
3. **Explain** the difference between an herbivore and an omnivore.
4. **Compare** energy transfer in a food chain to energy transfer in a food web.

CRITICAL THINKING

5. **Interpreting Graphics** Look at Figure 8. What feeding relationships does the crabeater seal have?
6. **Inferring Relationships** Read the paragraph under the heading, "Trophic Levels" in this section. Could more people be supported by 20 acres of land if they ate only plants instead of both plants and animals? Explain your answer. READING SKILLS