▶ **Figure 19–6** **Bacteria help to break down the nutrients in this tree, allowing other organisms to use the nutrients.** In this way, bacteria help maintain equilibrium in the environment.

Importance of Bacteria

You probably remember the principal actors in the last film you saw. You might even recall some of the supporting actors. Have you ever thought that there would be no film at all without the hundreds of workers who are never seen on screen? Bacteria are just like those unseen workers. **Bacteria are vital to maintaining the living world. Some are producers that capture energy by photosynthesis. Others are decomposers that break down the nutrients in dead matter and the atmosphere. Still other bacteria have human uses.**

Decomposers Every living thing depends directly or indirectly on a supply of raw materials. If these materials were lost when an organism died, life could not continue. Before long, plants would drain the soil of minerals and die, and animals that depend on plants for food would starve. As decomposers, bacteria help the ecosystem recycle nutrients, therefore maintaining equilibrium in the environment. When a tree dies, such as the one in **Figure 19–6**, armies of bacteria attack and digest the dead tissue, breaking it down into simpler materials, which are released into the soil. Other organisms, including insects and fungi, also play important roles in breaking down dead matter.

Bacteria also help in sewage treatment. Sewage contains human waste, discarded food, and chemical waste. Bacteria break down complex compounds in the sewage into simpler ones. This process produces purified water, nitrogen and carbon dioxide gases, and leftover products that can be used as fertilizers.

Nitrogen Fixers Plants and animals depend on bacteria for nitrogen. You may recall that plants need nitrogen to make amino acids, the building blocks of proteins. Nitrogen gas (N_2) makes up approximately 80 percent of Earth's atmosphere.

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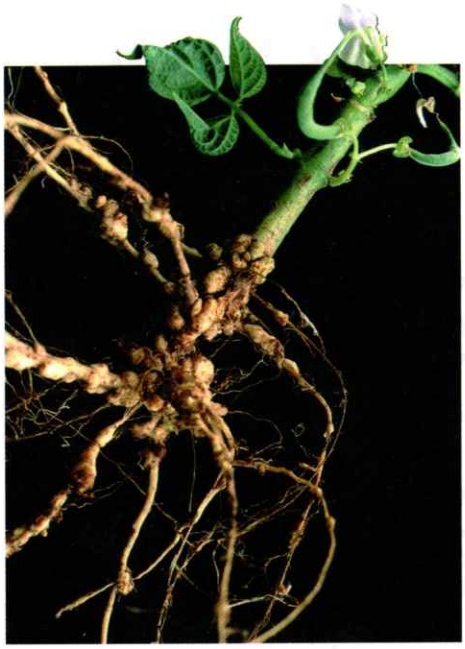
However, plants cannot use nitrogen gas directly. Nitrogen must first be changed chemically to ammonia (NH_3) or other nitrogen compounds. Expensive synthetic fertilizers contain these nitrogen compounds, but certain bacteria in the soil produce them naturally. The process of converting nitrogen gas into a form plants can use is known as **nitrogen fixation.** Nitrogen fixation allows nitrogen atoms to continually cycle through the biosphere.

Many plants have symbiotic relationships with nitrogen-fixing bacteria. For example, soybeans and other legumes host the bacterium *Rhizobium*. *Rhizobium* grows in nodules, or knobs, on the roots of the soybean plant, as shown in **Figure 19–7.** The plant provides a source of nutrients for *Rhizobium*, which converts nitrogen in the air into ammonia, helping the plant. Thus, soybeans have their own fertilizer factories in their roots!



▲ **Figure 19–7** The knoblike structures on the roots of this soybean plant are called nodules. Within these nodules are populations of the nitrogen-fixing bacteria *Rhizobium*.
Applying Concepts ***What is the name of the relationship between* Rhizobium *and soybean plants?***

Human Uses of Bacteria Many of the remarkable properties of bacteria provide us with products we depend on every day. For example, bacteria are used in the production of a wide variety of foods and beverages. Bacteria can also be used in industry. One type of bacteria can digest petroleum, making it very helpful in cleaning up small oil spills. Some bacteria remove waste products and poisons from water. Others can even help to mine minerals from the ground. Still others are used to synthesize drugs and chemicals through the techniques of genetic engineering.

Our intestines are inhabited by large numbers of bacteria, including *E. coli*. The term *coli* was derived from the fact that these bacteria were discovered in the human colon, or large intestine. In the intestines, the bacteria are provided with a warm and safe home, plenty of food, and free transportation. These bacteria also make a number of vitamins that the body cannot produce by itself. So both we and the bacteria benefit from this symbiotic relationship.

Biologists continue to discover new uses for bacteria. For example, biotechnology companies have begun to realize that bacteria adapted to extreme environments may be a rich source of heat-stable enzymes. These enzymes can be used in medicine, food production, and industrial chemistry.

19–1 Section Assessment

1. **Key Concept** Describe the characteristics of the two kingdoms of prokaryotes.
2. **Key Concept** What factors can be used to identify prokaryotes?
3. **Key Concept** Give one example of how bacteria maintain equilibrium in the environment.
4. Identify the parts of a prokaryote.
5. What are some ways that prokaryotes obtain energy?
6. **Critical Thinking Inferring** Why might an infection by Gram-negative bacteria be more difficult to treat than a Gram-positive bacterial infection?

Thinking Visually

Making a Venn Diagram
Create a Venn diagram that illustrates the similarities and differences between eubacteria and archaebacteria. *Hint*: Before you start, you may want to list the similarities and differences.

Ecology of Algae

Algae are a major food source for life in the oceans. Algae have even been called the "grasses" of the seas, because they make up much of the base of the food chain upon which sea animals "graze." The enormous brown kelp forests off the coasts of North America are home to many animal species.

Algae produce much of Earth's oxygen through photosynthesis. Scientists calculate that about half of all the photosynthesis that occurs on Earth is performed by algae. This fact alone makes algae one of the most important groups of organisms on the entire planet.

Over the years, people have learned to use algae—and the chemicals produced by algae—in many different ways. Many species of algae are rich in vitamin C and iron. Chemicals in algae are used to treat stomach ulcers, high blood pressure, arthritis, and other health problems.

Have you ever eaten algae? Almost certainly, your answer should be yes. In Japan, the red alga *Porphyra* is grown on special marine farms. Dried *Porphyra*—called *nori* in Japanese—is dark green and paper-thin. Nori is used to wrap portions of rice, fish, and vegetables to make sushi, as shown in **Figure 20–19.** You say you've never had sushi? Well, you've probably eaten ice cream, salad dressing, pudding, or a candy bar. Other products from algae are used in pancake syrups and eggnog.

Industry has even more uses for algae. Chemicals from algae are used to make plastics, waxes, transistors, deodorants, paints, lubricants, and even artificial wood. Algae even have an important use in scientific laboratories. The compound agar, derived from certain seaweeds, thickens the nutrient mixtures scientists use to grow bacteria and other microorganisms.

▲ **Figure 20–19** People have found many different uses for algae. The red alga *Porphyra* is used as a wrapper in Japanese sushi rolls. Ice cream often contains algin, a thickener made from brown algae. **Predicting** ***How would your life be different without products made from algae?***

20–4 Section Assessment

1. **Key Concept** Describe the main features of the major phyla of multicellular algae.
2. **Key Concept** What is alternation of generations?
3. How are multicellular algae important at a global level?
4. Why can red algae live in deeper water than green algae?
5. **Critical Thinking Comparing and Contrasting** Choose a green alga and illustrate its life cycle. Identify which parts are haploid and which are diploid. Show where meiosis and mitosis occur. Illustrate which part of the life cycle involves sexual reproduction and which involves asexual reproduction.

Thinking Visually

Organizing Information

Make a poster illustrating three types of multicellular algae. Your poster should have detailed drawings or photographs of each group. Each illustration should show the correct classification and list two written characteristics of each group.

21–3 Ecology of Fungi

Fungi have been around since life first moved onto land. In fact, the oldest known fossils of fungi, shown in **Figure 21–11**, were formed about 460 million years ago. At that time, the largest land plants were small organisms similar to mosses. Paleontologists think that fungi helped early plants to obtain nutrients from the ground. Their early appearance suggests that fungi may have been essential to plants' successful colonization of the land, one of the key events in the history of life.

Over time, fungi have become an important part of virtually all ecosystems, adapting to conditions in every corner of Earth. Because most fungi live their lives out of our sight, people often overlook them. But without fungi, the world would be a very different place.

Guide for Reading

Key Concepts

- What is the main role of fungi in natural ecosystems?
- What problems do parasitic fungi cause?
- What kinds of symbiotic relationships do fungi form with other organisms?

Vocabulary

saprobe
lichen
mycorrhiza

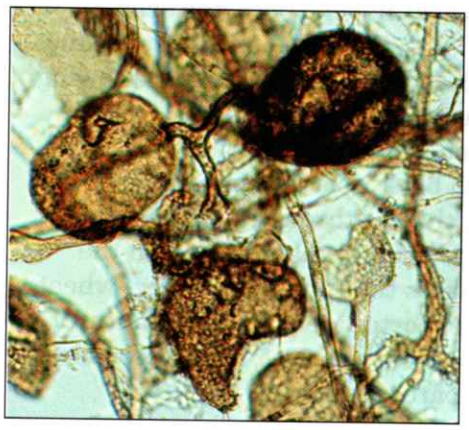
Reading Strategy: Using Prior Knowledge

Before you read this section, write down all the different ways that you think fungi interact in the environment. As you read, add to or revise your list as necessary.

All Fungi Are Heterotrophs

As heterotrophs, fungi cannot manufacture their own food. Instead, they must rely on other organisms for their energy. Unlike animals, fungi cannot move to capture food, but their mycelia can grow very rapidly into the tissues and cells of plants and other organisms. Many fungi are **saprobes,** organisms that obtain food from decaying organic matter. Others are parasites, which harm other organisms while living directly on or within them. Still other fungi are symbionts that live in close and mutually beneficial association with other species.

Although most fungi feed on decaying matter, a few feed by capturing live animals. *Pleurotus ostreatus* is a carnivorous fungus that lives on the sides of trees. As roundworms crawl into the fungus to feed, they are exposed to a fungal chemical that makes them become sluggish. As the worms slow to a stop, fungal hyphae penetrate their bodies, trapping them in place and then digesting them.



(magnification: 280×)

(magnification: 560×)

Figure 21–11 These microscopic images show fossils of the earliest known fungi, zygomycetes that lived about 460 million years ago. An overview of fossilized hyphae with spores is shown on the left. The close-up of hyphae growing out of a spore is shown on the right. **Observing** *Can you identify structures similar to those of modern molds?*