19–1 Bacteria

Imagine living all your life as a member of the only family on your street. Then, one morning, you open the front door and discover houses all around you. You see neighbors tending their gardens and children walking to school. Where did all the people come from? What if the answer turned out to be that they had always been there—you just hadn't seen them? In fact, they had lived on your street for years and years before your house was even built. How would your view of the world change? What would it be like to go, almost overnight, from thinking that you and your family were the only folks on the block to just one family in a crowded community? A bit of a shock!

Humans once had just such a shock. Suddenly, the street was very crowded! Thanks to Robert Hooke and Anton van Leeuwenhoek, the invention of the microscope opened our eyes to the hidden, living world around us.

Microscopic life covers nearly every square centimeter of Earth. There are microorganisms of many different sizes and shapes, even in a single drop of pond water. The smallest and most common microorganisms are **prokaryotes**—unicellular organisms that lack a nucleus. For many years, most prokaryotes were called "bacteria." The word *bacteria* is so familiar that we will use it as a common term to describe prokaryotes.

Prokaryotes typically range in size from 1 to 5 micrometers, making them much smaller than most eukaryotic cells, which generally range from 10 to 100 micrometers in diameter. There are exceptions to this, of course. One example is *Epulopiscium fisheloni,* a gigantic prokaryote, shown in **Figure 19–1,** that is about 500 micrometers long.

Guide for Reading

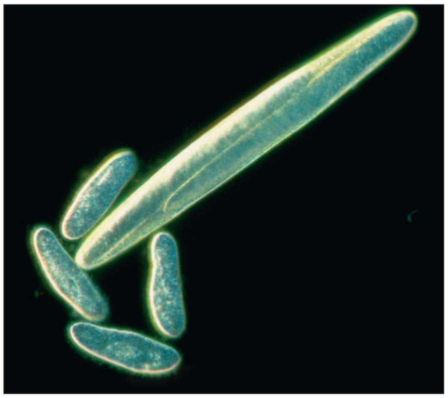
Key Concepts
- How do the two groups of prokaryotes differ?
- What factors are used to identify prokaryotes?
- What is the importance of bacteria?

Vocabulary
prokaryote • bacillus
coccus • spirillum
chemoheterotroph
photoheterotroph
photoautotroph
chemoautotroph
obligate aerobe
obligate anaerobe
facultative anaerobe
binary fission
conjugation • endospore
nitrogen fixation

Reading Strategy: Finding Main Ideas Before you read this section, write down the major headings of the section. Then, as you read the section, list the important information under each heading.

Classifying Prokaryotes

Until fairly recently, all prokaryotes were placed in a single kingdom—Monera. More recently, however, biologists have begun to appreciate that prokaryotes can be divided into two very different groups: the eubacteria (yoo-bak-TEER-ee-uh) and the archaebacteria (ahr-kee-bak-TEER-ee-uh). Each group is now considered to be a separate kingdom. Some biologists think that the split between these two groups is so ancient and so fundamental that they should be called domains, a level of classification even higher than kingdom.



(magnification: 100×)

▶ **Figure 19–1** The large cell in this photograph is *Epulopiscium fisheloni,* one of the largest prokaryotes. Notice its size in relation to the neighboring cells, which are eukaryotic paramecia.

Section 19–1

1 FOCUS

Objectives

19.1.1 ***Explain*** how the two groups of prokaryotes differ.
19.1.2 ***Describe*** the factors that are used to identify prokaryotes.
19.1.3 ***Explain*** why bacteria are vital to maintaining the living world.

Guide for Reading

Vocabulary Preview

Call on students at random to pronounce the Vocabulary terms in the order in which they appear. Correct any mispronunciations.

Reading Strategy

Have students make an outline of the section, using the blue headings as the first level of the outline and the green side headings as the second level. Explain that they should add third and fourth levels to their outlines by finding details in the section that support each of the headings.

2 INSTRUCT

Classifying Prokaryotes

Make Connections

Mathematics Point out that 1 micrometer equals 1/1,000,000 meter, or 1/10,000 centimeter. A typical prokaryote ranges in size from 1 to 5 micrometers. Then, ask students: **How many prokaryotic cells could be lined up across a coin that is 1 centimeter in diameter?** *(2000 to 10,000 cells)* L2

TIME SAVER

SECTION RESOURCES

Print:
- ***Laboratory Manual B,*** Chapter 19 Lab
- ***Teaching Resources,*** Section Review 19–1, Chapter 19 Exploration
- ***Reading and Study Workbook A,*** Section 19–1
- ***Adapted Reading and Study Workbook B,*** Section 19–1
- ***Lesson Plans,*** Section 19–1

Technology:
- ***iText,*** Section 19–1
- ***Transparencies Plus,*** Section 19–1

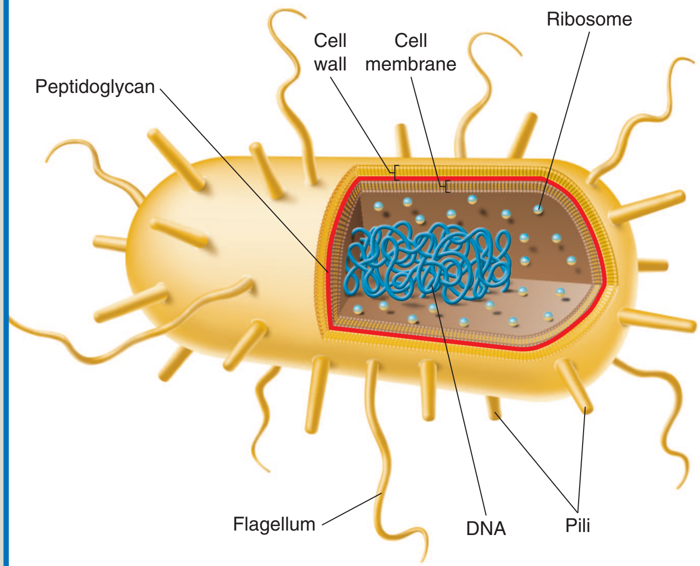
19–1 (continued)

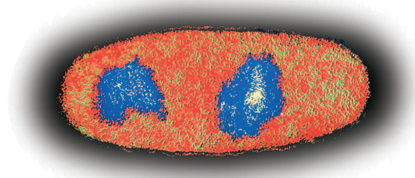
Use Visuals

Figure 19–2 To reinforce for students the difference between prokaryotic cells and eukaryotic cells, have them make a labeled drawing of each kind of cell. For the typical prokaryotic cell, they can use the illustration in Figure 19–2 as a model. For the typical eukaryotic cell, have them turn back to Figure 7–6 on page 175 and use the animal cell as a model. L1 L2

Build Science Skills

Using Models Have students gather a variety of craft materials from school and home to make models of bacteria. These materials might include yarn, sandpaper, textured fabrics, and pipe cleaners. As a resource for this model, students may use any of the photos or illustrations of bacteria in this chapter or in another textbook or one of the drawings they made in observing bacteria with a microscope. L2





(magnification: 32,300×)

Figure 19–2 A bacterium such as *E. coli* has the basic structure typical of most prokaryotes: cell wall, cell membrane, and cytoplasm. Some prokaryotes have flagella that they use for movement. The pili are involved in cell-to-cell contact. **The cell walls of eubacteria contain peptidoglycan.**

Eubacteria The larger of the two kingdoms of prokaryotes is the eubacteria. Eubacteria include a wide range of organisms with different lifestyles. The variety is so great, in fact, that biologists do not agree on exactly how many phyla are needed to classify this group. Eubacteria live almost everywhere. They live in fresh water, salt water, on land, and on and within the human body. **Figure 19–2** shows a diagram of *Escherichia coli,* a typical eubacterium that lives in human intestines.

Eubacteria are usually surrounded by a cell wall that protects the cell from injury and determines its shape. The cell walls of eubacteria contain peptidoglycan, a carbohydrate. Inside the cell wall is a cell membrane that surrounds the cytoplasm. Some eubacteria have a second membrane, outside the cell membrane, that makes them especially resistant to damage.

Archaebacteria Under a microscope, archaebacteria look very similar to eubacteria. They are equally small, lack nuclei, have cell walls, but chemically archaebacteria are quite different. **Archaebacteria lack the peptidoglycan of eubacteria and also have different membrane lipids. Also, the DNA sequences of key archaebacterial genes are more like those of eukaryotes than those of eubacteria.** Based on this and other data, scientists reason that archaebacteria may be the ancestors of eukaryotes.

Many archaebacteria live in extremely harsh environments. One group of archaebacteria is the methanogens, prokaryotes that produce methane gas. Methanogens live in oxygen-free environments, such as thick mud and the digestive tracts of animals. Other archaebacteria live in extremely salty environments, such as Utah's Great Salt Lake, or in hot springs where temperatures approach the boiling point of water.

CHECKPOINT *Where do archaebacteria live?*

Differentiated Instruction — Solutions for All Learners

Inclusion/Special Needs
Explain to students who have trouble understanding distinctions among prokaryotes that the section divides these organisms in several ways, and each way of division doesn't necessarily have anything to do with the other ways. For instance, cocci bacteria can be aerobic or anaerobic. L1

Less Proficient Readers
To help students understand the text under the heading Releasing Energy on page 474, have them turn back to Chapter 9 to review the processes of fermentation and cellular respiration. L1 L2

English Language Learners
For learners of English, read aloud the definitions in the text for *obligate* and *facultative*. Then, review the pronunciations of all the new terms in the subsection Metabolic Diversity. Encourage students to add these terms to their personal science glossaries. L1 L2

Identifying Prokaryotes

Because prokaryotes are so small, it may seem difficult to tell one type of prokaryote from another. **Prokaryotes are identified by characteristics such as shape, the chemical nature of their cell walls, the way they move, and the way they obtain energy.**

Shapes Look at the different shapes of the prokaryotes shown in **Figure 19–3.** Rod-shaped prokaryotes are called **bacilli** (buh-SIL-eye; singular: bacillus). Spherical prokaryotes are called **cocci** (KAHK-sy; singular: coccus). Spiral and corkscrew-shaped prokaryotes are called **spirilla** (spy-RIL-uh; singular: spirillum).

Cell Walls Two different types of cell walls are found in eubacteria. A method called Gram staining is used to tell them apart. The Gram stain consists of two dyes—one violet (the primary stain) and the other red (the counterstain). The violet stain, applied first, stains peptidoglycan cell walls. This is followed by an alcohol treatment that tends to wash out the stain. Gram-positive bacteria have thick peptidoglycan walls that retain the dark color of the violet stain even after the alcohol wash. Gram-negative bacteria have much thinner walls inside an outer lipid layer. Alcohol dissolves the lipid and removes the dye from the walls of these bacteria. The counterstain then makes these bacteria appear pink or light red.

Movement You can also identify prokaryotes by whether they move and how they move. Some prokaryotes do not move at all. Others are propelled by flagella, whiplike structures used for movement. Other prokaryotes lash, snake, or spiral forward. Still others glide slowly along a layer of slimelike material they secrete.

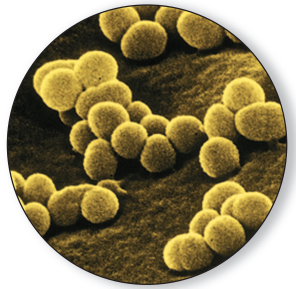
Metabolic Diversity

No characteristic of prokaryotes illustrates their diversity better than the ways in which they obtain energy. Depending on their source of energy and whether or not they use oxygen for cellular respiration, prokaryotes can be divided into two main groups. Most prokaryotes are heterotrophs, meaning that they get their energy by consuming organic molecules made by other organisms. Other prokaryotes are autotrophs and make their own food from inorganic molecules.

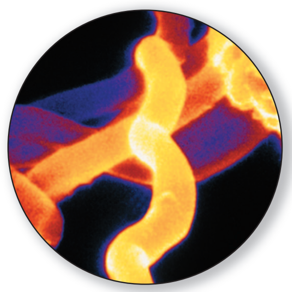
Heterotrophs Most heterotrophic prokaryotes must take in organic molecules for both energy and a supply of carbon. These prokaryotes are called **chemoheterotrophs** (kee-moh-HET-ur-oh-trohfs). Most animals, including humans, are chemoheterotrophs. A smaller group of heterotrophic prokaryotes are called **photoheterotrophs** (foh-toh-HET-ur-oh-trohfs). These organisms are photosynthetic, using sunlight for energy, but they also need to take in organic compounds as a carbon source.

Figure 19–3 **Prokaryotes can be identified by their shapes.** Prokaryotes usually have one of three basic shapes: rods (bacilli), spheres (cocci), or spirals (spirilla).

Bacilli
(magnification: 3738×)



Cocci
(magnification: 30,000×)



Spirilla
(magnification: about 7000×)

BIO INSIGHTS **FACTS AND FIGURES**

Prokaryotes in a cow's gut
The kingdom Archaebacteria includes exotic prokaryotes that live in such extreme environments as deep ocean vents and hot sulfur springs. Archaebacteria also include common prokaryotes that live in the digestive tracts of all animals, especially in the rumina of cows and other grazing beasts. These prokaryotes, called methanogens, use hydrogen and carbon to produce methane (CH_4), and most of the methane in the atmosphere is the result of this process. In the atmosphere, the methane reacts with oxygen to produce CO_2. If it were not for methanogens, Earth would be a much different place. Carbon would pile up in huge deposits in the ground, and oxygen would make up a much greater percentage of the atmosphere.

Identifying Prokaryotes

Demonstration

Collect some common items that can be used to model the three basic shapes of bacteria as you discuss the shapes with students. For example, you can represent cocci with marbles, beads, spheres of modeling clay, or malted milk balls. You can represent bacilli with unsharpened pencils, pieces of chalk, or short dowels. You can represent spirilla with springs or pipe cleaners that have been shaped into spirals by wrapping them around a pencil. L1 L2

Build Science Skills

Observing Set up at least one learning station with a microscope and a number of prepared slides showing various species of bacteria, each labeled with the species name. Provide opportunities for students to use the station during class periods. To guide students as they make their observations, prepare a study sheet containing the following instructions to use with each slide:

- What is the scientific name of this bacterium?
- What magnification did you use to see the bacterium clearly?
- How would you classify this bacterium according to cell shape? L2 L3

Metabolic Diversity

Build Science Skills

Applying Concepts After students have read about chemoautotrophs, ask: **Suppose you leave a jar of mayonnaise on the counter with the top off for a day, make a sandwich with the mayonnaise, and get sick. With what you know about chemoautotrophs, what do you think caused your illness?** *(Chemoautotrophic bacteria began eating the mayonnaise, multiplied, and released toxins. The toxins in the mayonnaise caused the illness.)* L2

Answer to . . .

CHECKPOINT *Many archaebacteria live in harsh environments, including thick mud, animal digestive tracts, salt lakes, and hot springs.*

19–1 (continued)

Use Visuals

Figure 19–4 Ask students: **What kind of prokaryotes might you find near an ocean vent?** *(Chemoautotrophs)* **How do chemoautotrophs obtain the energy they need to carry out life processes?** *(They get energy from chemical reactions involving ammonia, hydrogen sulfide, nitrites, sulfur, or iron.)* **From what chemical do chemoautotrophs obtain energy near ocean vents?** *(From hydrogen sulfide gas that flows from the vents)* L2

Build Science Skills

Forming Operational Definitions Help students differentiate among the different groups of prokaryotes by reviewing the word parts that make up the terms used to describe these organisms. On the board, write the following:

- *auto* = "self"
- *chemo* = "chemical"
- *photo* = "light"
- *hetero* = "other"
- *troph* = "nourishment"

Then, have students write definitions for the terms using these equivalencies.

- *autotroph*, an organism that gets "nourishment from itself"
- *photoautotroph*, an organism that gets "nourishment from itself using light"
- *chemoautotroph*, an organism that gets "nourishment from itself using chemicals"
- *heterotroph*, an organism that gets "nourishment from others"
- *photoheterotroph*, an organism that gets "nourishment from others and from using light" L1 L2

▲ **Figure 19–4** Ocean vents, such as this one, are often home to a variety of organisms, including tube worms and other exotic organisms. **Applying Concepts** *Would photoautotrophs survive in this environment? Why or why not?*

Autotrophs Other groups of prokaryotes are autotrophs. Some autotrophs, the **photoautotrophs** (foh-toh-AW-toh-trohfs), use light energy to convert carbon dioxide and water to carbon compounds and oxygen in a process similar to that used by green plants. As you might expect, these organisms are found where light is plentiful, such as near the surfaces of lakes, streams, and oceans. One group, the cyanobacteria (sy-uh-noh-bak-TEER-ee-uh), contains a bluish pigment and chlorophyll *a*, the key pigment in photosynthesis. Cyanobacteria are found throughout the world—in fresh water, salt water, and even on land. In fact, cyanobacteria are often the very first species to recolonize the site of a natural disaster such as a volcanic eruption.

Other prokaryotes can perform chemosynthesis and are called **chemoautotrophs** (kee-moh-AW-toh-trohfs). Like photoautotrophs, chemoautotrophs make organic carbon molecules from carbon dioxide. Unlike photoautotrophs, however, they do not require light as a source of energy. Instead, they use energy directly from chemical reactions involving ammonia, hydrogen sulfide, nitrites, sulfur, or iron. Some chemoautotrophs live deep in the darkness of the ocean. They obtain energy from hydrogen sulfide gas that flows from hydrothermal vents on the ocean floor, such as the one shown in **Figure 19–4.**

CHECKPOINT *What are the two groups of autotrophs found in prokaryotes?*

Releasing Energy Like all organisms, bacteria need a constant supply of energy. This energy is released by the processes of cellular respiration or fermentation or both. Organisms that require a constant supply of oxygen in order to live are called **obligate aerobes.** (*Obligate* means that the organisms are obliged, or required, by their life processes to live only in that particular way.) *Mycobacterium tuberculosis,* the bacterium that causes tuberculosis, is an obligate aerobe.

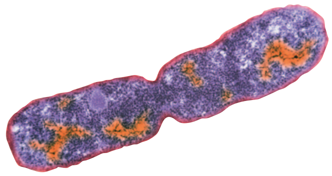
Some bacteria, however, do not require oxygen and, in fact, may be killed by it! These bacteria are called **obligate anaerobes,** and they must live in the absence of oxygen. *Clostridium botulinum* is an obligate anaerobe found in soil. Because of its ability to grow without oxygen, it can grow in canned food that has not been properly sterilized.

A third group of bacteria can survive with or without oxygen and are known as **facultative anaerobes.** (*Facultative* means that the organisms are able to function in different ways, depending on their environment.) Facultative anaerobes do not require oxygen, but neither are they killed by its presence. Their ability to switch between the processes of cellular respiration and fermentation means that facultative anaerobes are able to live just about anywhere. *E. coli* is a facultative anaerobe that lives anaerobically in the large intestine and aerobically in sewage or contaminated water.

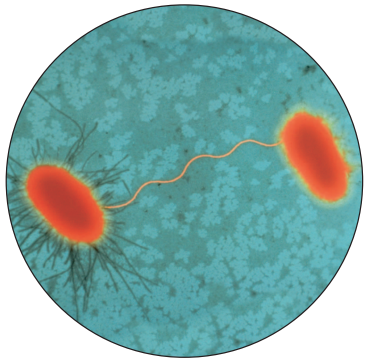
BIO INSIGHTS — FACTS AND FIGURES

Anaerobes get energy

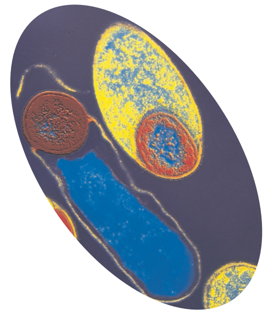
There are four main ways that anaerobes obtain energy. In fermentation, which is performed by many bacteria as well as by fungi such as yeasts, an energy-rich molecule such as glucose is split, releasing energy. In nitrate reduction, which occurs in a number of bacteria that are facultative anaerobes, the oxygen in the nitrate ion is used to oxidize an organic compound and so obtain energy. In carbonate reduction, which is carried out by methanogens, the oxygen in carbon dioxide or carbonate is used to oxidize hydrogen produced by other microorganisms and so obtain energy. In sulfate reduction, the oxygen in the sulfate ion is used to oxidize organic matter or hydrogen and so obtain energy. One of the products of this reaction under acidic conditions is hydrogen sulfide (H_2S), a foul-smelling gas that is poisonous to most living things.



Binary Fission
(magnification: 26,500×)



Conjugation
(magnification: 7000×)



Spore Formation
(magnification: 7800×)

Growth and Reproduction

When conditions are favorable, bacteria can grow and divide at astonishing rates. Some divide as often as every 20 minutes! If unlimited space and food were available to a single bacterium and if all of its offspring divided every 20 minutes, in just 48 hours they would reach a mass approximately 4000 times the mass of Earth! Fortunately, this does not happen. In nature, growth is held in check by the availability of food and the production of waste products.

Binary Fission When a bacterium has grown so that it has nearly doubled in size, it replicates its DNA and divides in half, producing two identical "daughter" cells, as in **Figure 19–5** (left). This type of reproduction is known as **binary fission.** Because binary fission does not involve the exchange or recombination of genetic information, it is an asexual form of reproduction.

Conjugation Many bacteria are also able to exchange genetic information by a process called conjugation. During **conjugation,** a hollow bridge forms between two bacterial cells, as shown in **Figure 19–5** (center), and genes move from one cell to the other. This transfer of genetic information increases genetic diversity in populations of bacteria.

Spore Formation When growth conditions become unfavorable, many bacteria form structures called spores, the objects that appear red in **Figure 19–5** (right). One type of spore, called an **endospore,** is formed when a bacterium produces a thick internal wall that encloses its DNA and a portion of its cytoplasm. Spores can remain dormant for months or even years while waiting for more favorable growth conditions. When conditions improve, the endospore will germinate and the bacterium will begin to grow again. The ability to form spores makes it possible for some bacteria to survive harsh conditions—such as extreme heat, dryness, or lack of nutrients—that might otherwise kill them.

Figure 19–5 Most prokaryotes reproduce by binary fission, producing two identical "daughter" cells. Some prokaryotes take part in conjugation, in which genetic information is transferred from one cell to another by way of a hollow bridge. Other prokaryotes produce endospores, which allow them to withstand harsh conditions. **Comparing and Contrasting** ***Compare the process of conjugation to binary fission.***

Growth and Reproduction

Use Visuals

Figure 19–5 Focus students' attention on the photo of conjugation, and have a student read aloud the text explanation of the process. Then, ask: **Since two bacterial cells are involved in conjugation, should this be considered a form of sexual reproduction?** *(No. Although genes move from one cell to the other, no daughter cells are produced.)* L1 L2

Demonstration

To show that bacteria can survive through such harsh conditions as freezing temperatures, place a small amount of soil into a plastic container. Cover the container and place it in a freezer overnight. The next day, sprinkle some soil onto a petri dish of agar. On another dish of agar, sprinkle some of the soil from the container that was in the freezer overnight. Cover the dishes and place them in an incubator overnight. The next day, have students observe both dishes for evidence of bacterial colonies growing on the agar. L1 L2

Answers to . . .

CHECKPOINT *Photoautotrophs and chemoautotrophs*

Figure 19–4 *No, because sunlight does not reach deep into the ocean*

Figure 19–5 *In conjugation, genetic information is transferred from one cell to another by way of a hollow bridge. In binary fission, a cell replicates its DNA and divides in half, producing two daughter cells.*

19–1 (continued)

Importance of Bacteria

Use Community Resources

Encourage interested students to schedule a visit to a local wastewater treatment plant to find out how bacteria are utilized in purifying wastewater. Have students who visit the treatment plant gather information and any pamphlets about the process used and then make a report to the class. L2 L3

Use Visuals

Figure 19–7 Point out that the relationship between the soybean plant and the *Rhizobium* bacteria is an example of mutualism, a symbiotic relationship in which both organisms benefit. Ask students: **What process in the plant provides food for the bacteria?** *(Photosynthesis)* Then, have students take a deep breath, and emphasize that most of what they take into their lungs is nitrogen. Ask: **Can you use any of this nitrogen?** *(Some students may know that none of the nitrogen is used.)* Remind students that nitrogen is an essential element in protein and that we need proteins to survive. Ask: **How do humans and other animals get the nitrogen needed to make proteins?** *(They eat plants or animals that have eaten plants, which get nitrogen from such nitrogen-fixing bacteria as* Rhizobium *that can use nitrogen from the air.)* Tell students that soybeans are a good food source of protein, and now they know why. L2

Go Online NSTA SCILINKS
Download a worksheet on bacteria for students to complete, and find additional teacher support from NSTA SciLinks.

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.

Go Online NSTA SCILINKS
For: Links on bacteria
Visit: www.SciLinks.org
Web Code: cbn-6191

BIO INSIGHTS

FACTS AND FIGURES

Earth's cycles depend on bacteria
Earth's environment depends on a cycling of substances through the world ecosystem. These substances include water, carbon, nitrogen, sulfur, phosphorus, sodium, potassium, and other materials. Their cycles are sometimes called biogeochemical cycles, because they involve both biological and geologic parts of the ecosystem. Bacteria play essential roles in all of these cycles. For instance, the cyanobacteria are a primary component of the carbon cycle, for through their photosynthesis they contribute much of the oxygen to the atmosphere that is used in cellular respiration. The nitrogen-fixing bacteria, such as *Rhizobium*, are central to the nitrogen cycle. The many bacteria that decompose dead organisms contribute to all of the cycles.

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.

19–1 Section Assessment

1. Archaebacteria lack peptidoglycan, and their membrane lipids are quite different. Also, the DNA of key archaebacterial genes are like those of eukaryotes.
2. They are identified by their shapes, the chemical natures of their cell walls, the ways they move, and the ways they obtain energy.
3. Bacteria are vital to maintaining the living world. Some are producers, others are decomposers, and others have human uses.
4. Cell wall, cell membrane, cytoplasm, DNA, ribosomes, pili, and flagella
5. Some consume organic molecules made by other organisms, whereas others make their own food from inorganic molecules.
6. Gram-positive bacteria have only one cell membrane, whereas gram-negative bacteria have a second, outer, layer of lipid and carbohydrates. Therefore, gram-negative bacteria might be more difficult to kill.

Build Science Skills

Observing Tell students that you are preparing a microscope slide to examine fresh yogurt under the microscope. As you prepare the slide, involve them by asking questions about the process. Add water to a tiny amount of plain yogurt to make a thin, cloudy mixture. The sample has to be thinned for light to pass through and for individual particles to be more visible. Place a drop of the yogurt mixture on a microscope slide. Stain the sample with a drop of methylene blue. Put on a coverslip. Then, have students observe the slide under high magnification. Ask students: **What do you see?** (*Blue ovals or cylinders*) Explain that the cylinders are *Lactobacillus* bacteria. Ask: **Why might there be bacteria in yogurt?** *(Students might suggest that the yogurt is spoiled or that the bacteria are used to make yogurt.)* Explain that *Lactobacillus* is used to make milk into yogurt. L1 L2

3 ASSESS

Evaluate Understanding

Call on students to explain the differences between eubacteria and archaebacteria.

Reteach

Direct students' attention to the labeled illustration of a eubacterium in Figure 19–2, and review the basic structure and function of prokaryotes.

Thinking Visually

Students' Venn diagrams should show that both eubacteria and archaebacteria are prokaryotic, have cell walls, and contain DNA. The diagrams should also show that archaebacteria lack peptidoglycan, have different membrane lipids, and have different DNA sequences in key genes.

Interactive Textbook

If your class subscribes to the iText, use it to review the Key Concepts in Section 19–1.

Answer to . . .

Figure 19–7 *Mutualism*