Section 2

Bacteria

Reading Preview

Key Concepts

- How do the cells of bacteria differ from those of eukaryotes?
- What do bacteria need to survive?
- Under what conditions do bacteria thrive and reproduce?
- What positive roles do bacteria play in people's lives?

Key Terms

- bacteria
- flagellum
- binary fission
- asexual reproduction
- sexual reproduction
- conjugation
- endospore
- pasteurization
- decomposer

Target Reading Skill

Building Vocabulary After you read the section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a definition of each Key Term in your own words.

Lab zone **Discover Activity**

How Quickly Can Bacteria Multiply?

1. Your teacher will give you some beans and paper cups. Number the cups 1 through 8. Each bean will represent a bacterial cell.
2. Put one bean into cup 1 to represent the first generation of bacteria. Approximately every 20 minutes, a bacterial cell reproduces by dividing into two cells. Put two beans into cup 2 to represent the second generation of bacteria.
3. Calculate how many bacterial cells there would be in the third generation if each cell in cup 2 divided into two cells. Place the correct number of beans in cup 3.
4. Repeat Step 3 five more times. All the cups should now contain beans. How many cells are in the eighth generation? How much time has elapsed since the first generation?

Think It Over

Inferring Based on this activity, explain why the number of bacteria can increase rapidly in a short period of time.

They thrive in your container of yogurt. They lurk in your kitchen sponge. They coat your skin and swarm inside your nose. You cannot escape them because they live almost everywhere—under rocks, in the ocean, and all over your body. In fact, there are more of these organisms in your mouth than there are people on Earth! You don't notice them because they are very small. These organisms are bacteria.

The Bacterial Cell

Although there are billions of bacteria on Earth, they were not discovered until the late 1600s. A Dutch merchant named Anton van Leeuwenhoek (LAY vun hook) found them by accident. Leeuwenhoek made microscopes as a hobby. One day, while using one of his microscopes to look at scrapings from his teeth, he saw some tiny, wormlike organisms in the sample. However, Leeuwenhoek's microscopes were not powerful enough to see any details inside these organisms.

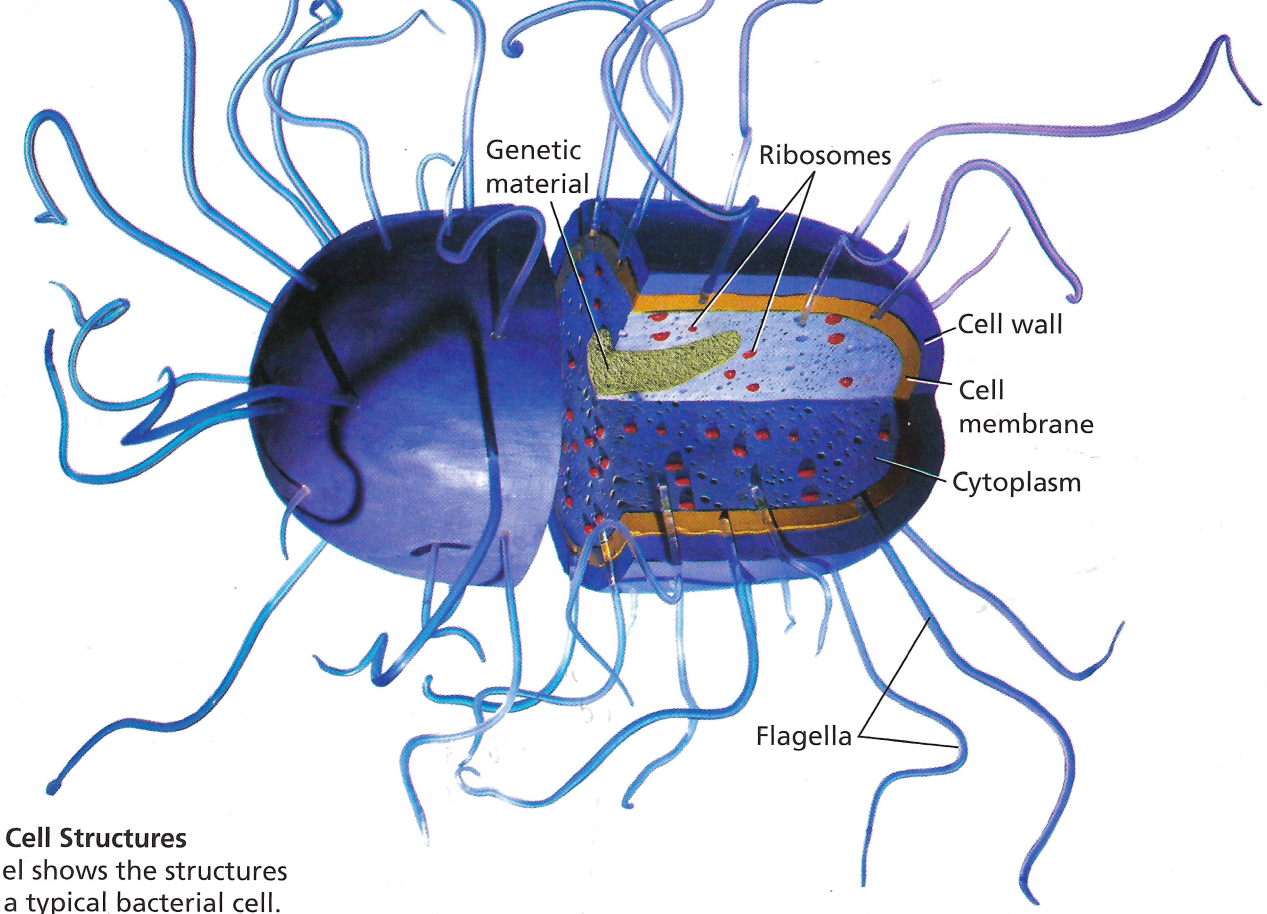
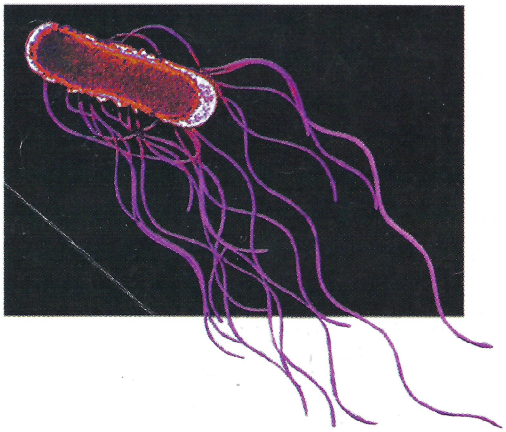


FIGURE 6
Bacterial Cell Structures
This model shows the structures found in a typical bacterial cell.
Relating Diagrams and Photos
What structures does the Salmonella *bacterium in the photograph use to move?*



Cell Structures If Leeuwenhoek had owned a modern microscope, he would have seen the single-celled organisms known as **bacteria** (singular *bacterium*) in detail. **Bacteria are prokaryotes. The genetic material in their cells is not contained in a nucleus.** A bacterial cell lacks a nucleus and also lacks many other structures, such as mitochondria and Golgi bodies, that are found in the cells of eukaryotes.

Most bacterial cells, like plant cells, are surrounded by a rigid cell wall. Just inside the cell wall is the cell membrane. The region inside the cell mambrane is called the cytoplasm. Located in the cytoplasm are ribosomes and the genetic material, which looks like a tangled string. If you could untangle the genetic material, you would see that it forms a circular shape.

A bacterial cell may also have a **flagellum** (fluh JEL um) (plural *flagella*), a long, whiplike structure that helps a cell to move. A flagellum moves the cell by spinning in place like a propeller. A bacterial cell can have many flagella, one, or none. Most bacteria that do not have flagella cannot move on their own. Instead, they are carried from place to place by the air, water currents, objects, or other methods.

Cell Sizes Bacteria vary greatly in size. The largest known bacterium is about as big as the period at the end of this sentence. An average bacterium, however, is much smaller. For example, strep throat bacteria are about 0.5 to 1 micrometer in diameter. A micrometer is one millionth of a meter.

Cell Shapes If you observed bacteria under a microscope, you would notice that most bacterial cells have one of three basic shapes: spherical, rodlike, or spiral. The chemical makeup of the cell wall determines the shape of a bacterial cell. The shape of the cell helps scientists identify the type of bacteria. For example, bacteria that cause strep throat are spherical.

Obtaining Food and Energy

From the bacteria that live in soil to those that live in the pores of your skin, all bacteria need certain things to survive. **Bacteria must have a source of food and a way of breaking down the food to release its energy.**

Obtaining Food Some bacteria are autotrophs and make their own food. Autotrophic bacteria make food in one of two ways. Some capture and use the sun's energy as plants do. Others, such as bacteria that live deep in mud, do not use the sun's energy. Instead, these bacteria use the energy from chemical substances in their environment to make their food.

Some bacteria are heterotrophs and cannot make their own food. Instead, these bacteria consume other organisms or the food that other organisms make. Heterotrophic bacteria consume a variety of foods—from milk and meat, which you might also eat, to the decaying leaves on a forest floor.

Respiration Like all organisms, bacteria need a constant supply of energy. This energy comes from breaking down food in the process of respiration. Like many other organisms, most bacteria need oxygen to break down their food. But a few kinds of bacteria do not need oxygen for respiration. In fact, those bacteria die if oxygen is present in their surroundings.

Reading Checkpoint **Where does the energy that bacteria need come from?**

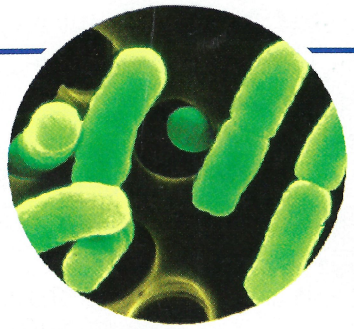
Lab zone Try This Activity

Bacteria for Breakfast

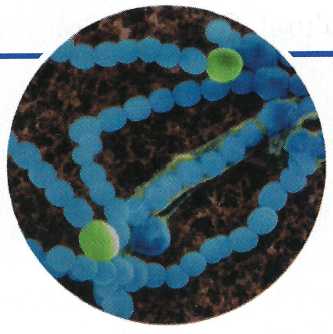
1. Put on your apron. Add water to plain yogurt to make a thin mixture.
2. With a plastic dropper, place a drop of the mixture on a glass slide.
3. Use another plastic dropper to add one drop of methylene blue dye to the slide. **CAUTION:** *This dye can stain your skin.*
4. Put a coverslip on the slide. Observe the slide under both the low- and high-power lenses of a microscope.

Observing Draw what you see under high power.

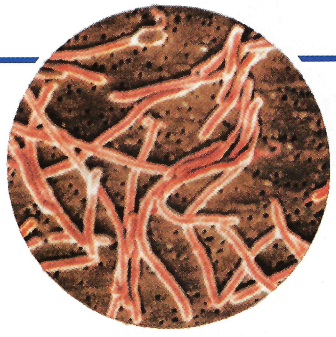
FIGURE 7
Obtaining Food
Bacteria obtain food in several ways.



▲ These heterotrophic bacteria, found in yogurt, break down the sugars in milk for food.



▲ The autotrophic bacteria that cause the green, cloudy scum in some ponds use the sun's energy to make food.



▲ These autotrophic bacteria, found in hot springs, use chemical energy from their environment to make food.

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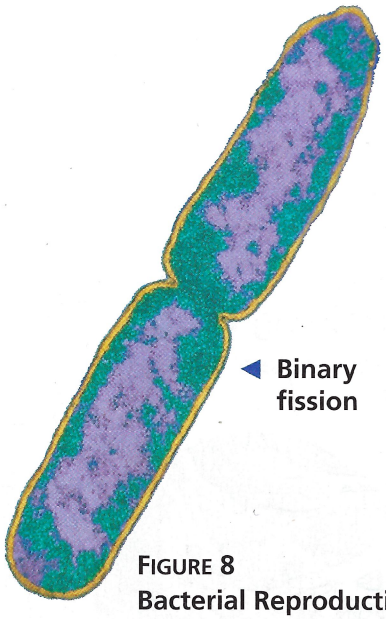
Reproduction

When bacteria have plenty of food, the right temperature, and other suitable conditions, they thrive and reproduce frequently. Under these ideal conditions, some bacteria can reproduce as often as once every 20 minutes. So it's a good thing that growing conditions for bacteria are rarely ideal!

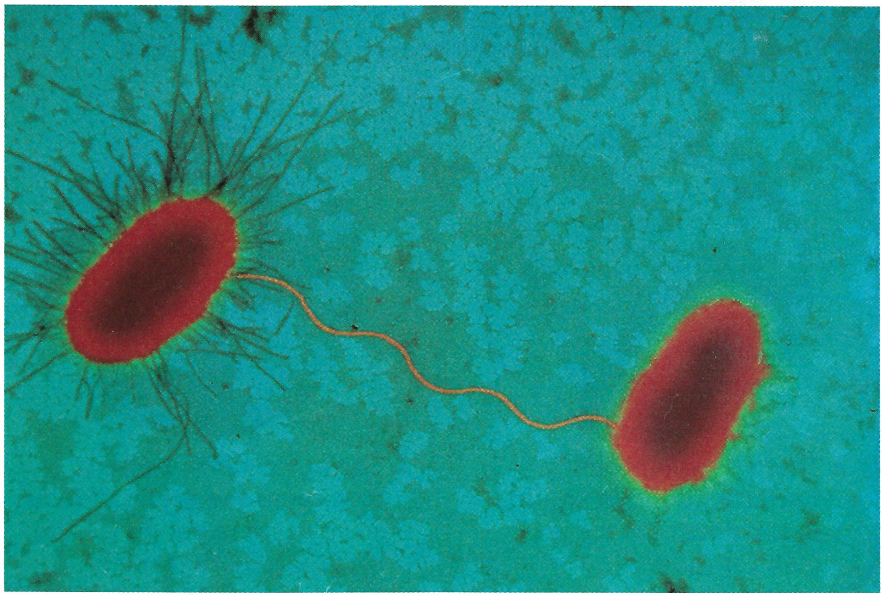
Asexual Reproduction Bacteria reproduce by a process called **binary fission,** in which one cell divides to form two identical cells. Binary fission is a form of asexual reproduction. **Asexual reproduction** is a reproductive process that involves only one parent and produces offspring that are identical to the parent. During binary fission, a cell first duplicates its genetic material and then divides into two separate cells. Each new cell gets its own complete copy of the parent cell's genetic material as well as some of the parent's ribosomes and cytoplasm.

Sexual Reproduction Some bacteria may at times undergo a form of sexual reproduction. In **sexual reproduction,** two parents combine their genetic material to produce a new organism, which differs from both parents. During a process called **conjugation** (kahn juh GAY shun), one bacterium transfers some genetic material to another bacterium through a threadlike bridge. After the transfer, the cells separate.

Conjugation results in bacteria with new combinations of genetic material. Then, when these bacteria divide by binary fission, the new combinations of genetic material pass to the offspring. Conjugation does not increase the number of bacteria. However, it does result in bacteria that are genetically different.



◀ Binary fission



Conjugation ▶

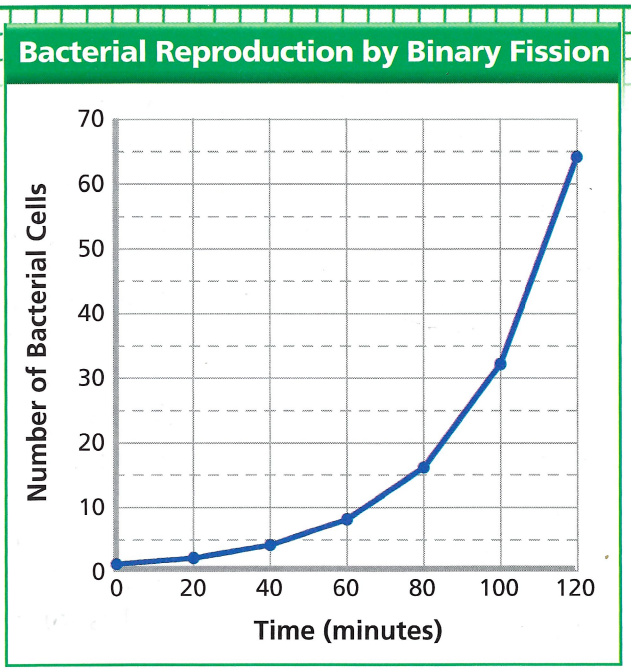
FIGURE 8
Bacterial Reproduction
In binary fission, one cell divides to form two identical cells. During conjugation, one bacterium transfers genetic material to another bacterium.

Math Analyzing Data

Population Explosion

Suppose a bacterium reproduces by binary fission every 20 minutes. The new cells survive and reproduce at the same rate. This graph shows how the bacterial population would grow from a single bacterium.

1. **Reading Graphs** What variable is being plotted on the horizontal axis? What is being plotted on the vertical axis?
2. **Interpreting Data** According to the graph, how many cells are there after 20 minutes? After 1 hour? After 2 hours?
3. **Drawing Conclusions** Describe the pattern you see in the way the bacterial population increases over 2 hours.



Endospore Formation Sometimes, conditions in the environment become unfavorable for the growth of bacteria. For example, food sources can disappear, water can dry up, or the temperature can fall or rise dramatically. Some bacteria can survive harsh conditions by forming endospores like those in Figure 9. An **endospore** is a small, rounded, thick-walled, resting cell that forms inside a bacterial cell. It contains the cell's genetic material and some of its cytoplasm.

Because endospores can resist freezing, heating, and drying, they can survive for many years. For example, the bacteria that cause botulism, *Clostridium botulinum*, produce heat-resistant endospores that can survive in improperly canned foods. Endospores are also light—a breeze can lift and carry them to new places. If an endospore lands in a place where conditions are suitable, it opens up. Then the bacterium can begin to grow and multiply.

Reading Checkpoint **Under what conditions do endospores form?**

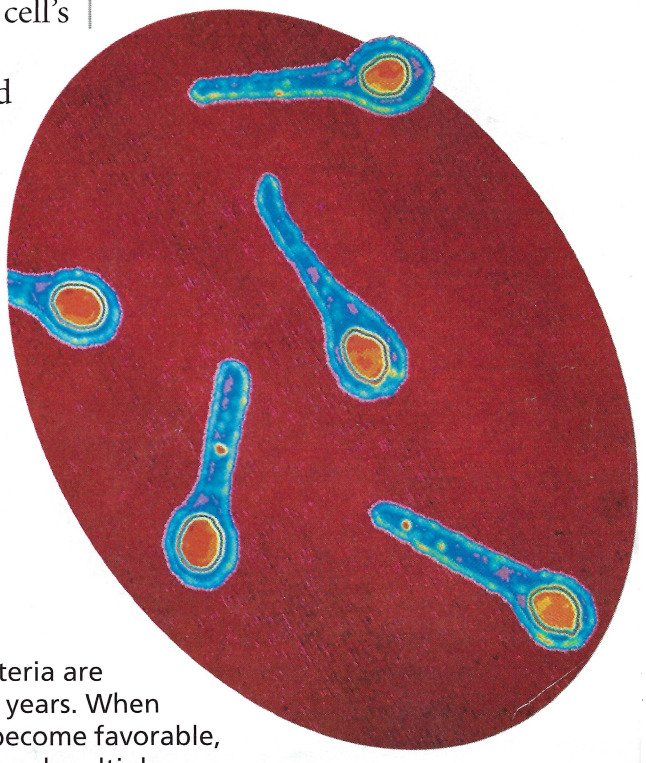


FIGURE 9
Endospores
The red circles within these bacteria are endospores that can survive for years. When conditions in the environment become favorable, the bacteria can begin to grow and multiply.

The Role of Bacteria in Nature

When you hear the word *bacteria*, you may think about getting sick. After all, strep throat, many ear infections, and other diseases are caused by bacteria. However, most bacteria are either harmless or helpful to people. In fact, in many ways, people depend on bacteria. **Bacteria are involved in oxygen and food production, environmental recycling and cleanup, and in health maintenance and medicine production.**

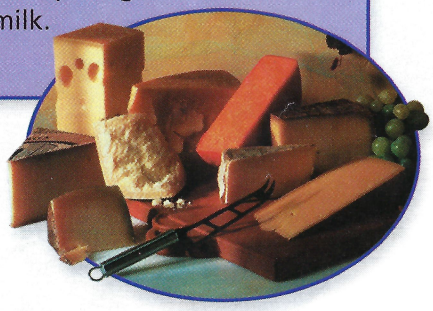
Oxygen Production Would it surprise you to learn that the air you breathe depends in part on bacteria? As autotrophic bacteria use the sun's energy to produce food, they also release oxygen into the air. Billions of years ago, there was little oxygen in Earth's atmosphere. Scientists think that autotrophic bacteria were responsible for first adding oxygen to Earth's atmosphere. Today, the distant offspring of those bacteria help keep oxygen levels in the air stable.

Science and History

Bacteria and Foods of the World

Ancient cultures lacked refrigeration and other modern methods of preventing food spoilage. People in these cultures developed ways of using bacteria to preserve foods. You may enjoy some of these foods today.

2300 B.C. Cheese
Ancient Egyptians made cheese from milk. Cheese-making begins when bacteria feed on the sugars in milk. The milk separates into solid curds and liquid whey. The curds are processed into cheeses, which keep longer than milk.



1000 B.C. Pickled Vegetables
The Chinese salted vegetables and packed them in containers. Naturally occurring bacteria fed on the vegetables and produced a sour taste. The salt pulled water out of the vegetables and left them crisp. These vegetables were part of the food rations given to workers who built the Great Wall of China.

500 B.C. Dried Meat
People who lived in the regions around the Mediterranean Sea chopped meat, seasoned it with salt and spices, rolled it, and hung it to dry. Bacteria in the drying meat gave unique flavors to the food. The rolled meat would keep for weeks in cool places.

2500 B.C. | 1500 B.C. | 500 B.C.

Food Production Do you like cheese, sauerkraut, or pickles? The activities of helpful bacteria produce all of these foods and more. For example, bacteria that grow in apple cider change the cider to vinegar. Bacteria that grow in milk produce dairy products such as buttermilk, yogurt, sour cream, and cheeses.

However, some bacteria cause food to spoil when they break down the food's chemicals. Spoiled food usually smells or tastes foul and can make you very sick. Refrigerating and heating foods are two ways to slow down food spoilage. Another method, called pasteurization, is most often used to treat beverages such as milk and juice. During **pasteurization,** the food is heated to a temperature that is high enough to kill most harmful bacteria without changing the taste of the food. As you might have guessed, this process was named after Louis Pasteur, its inventor.

Writing in Science

Research and Write Find out more about one of these ancient food-production methods and the culture that developed it. Write a report about the importance of the food to the culture.

A.D. 500
Soy Sauce

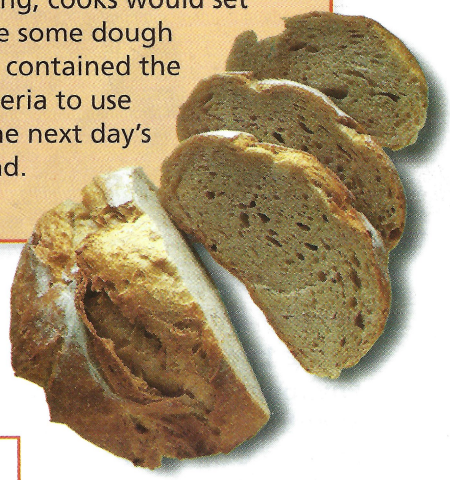
People in China crushed soybeans into mixtures of wheat, salt, bacteria, and other microorganisms. The microorganisms fed on the proteins in the wheat and soybeans. The salt pulled water out of the mixture. The protein-rich soy paste that remained was used to flavor foods. The soy sauce you may use today is made in a similar manner.

A.D. 1500
Chocolate Beverage

People in the West Indies mixed beans from the cocoa plant with bacteria and other microorganisms and then dried and roasted them. The roasted beans were then brewed to produce a beverage with a chocolate flavor. The drink was served cold with honey, spices, and vanilla.

A.D. 1850
Sourdough Bread

Gold prospectors in California ate sourdough bread. The *Lactobacillus sanfrancisco* bacteria gave the bread its sour taste. Each day before baking, cooks would set aside some dough that contained the bacteria to use in the next day's bread.



A.D. 500 A.D. 1500 A.D. 2500

FIGURE 10
Environmental Recycling
Decomposing bacteria are at work recycling the chemicals in these leaves. **Predicting** *What might a forest be like if there were no decomposing bacteria in the soil?*

Environmental Recycling If you recycle glass or plastic, then you have something in common with some heterotrophic bacteria. These bacteria, which live in the soil, are **decomposers**—organisms that break down large chemicals in dead organisms into small chemicals.

Decomposers are "nature's recyclers." They return basic chemicals to the environment for other living things to reuse. For example, the leaves of many trees die in autumn and drop to the ground. Decomposing bacteria spend the next months breaking down the chemicals in the dead leaves. The broken-down chemicals mix with the soil and can then be absorbed by the roots of nearby plants.

Another type of recycling bacteria, called nitrogen-fixing bacteria, help plants survive. Nitrogen-fixing bacteria live in the soil and in swellings on the roots of certain plants, such as peanut, pea, and soybean. These helpful bacteria convert nitrogen gas from the air into nitrogen products that plants need to grow. On their own, plants cannot use nitrogen present in the air. Therefore, nitrogen-fixing bacteria are vital to the plants' survival.

Environmental Cleanup Some bacteria help to clean up Earth's land and water. Can you imagine having a bowl of oil for dinner instead of soup? Well, some bacteria prefer the oil. They convert the poisonous chemicals in oil into harmless substances. Scientists have put these bacteria to work cleaning up oil spills in oceans and gasoline leaks in the soil under gas stations.

Reading Checkpoint **What role do bacterial decomposers play in the environment?**

FIGURE 11
Environmental Cleanup
Scientists use bacteria such as these *Ochrobactrum anthropi* to help clean up oil spills.

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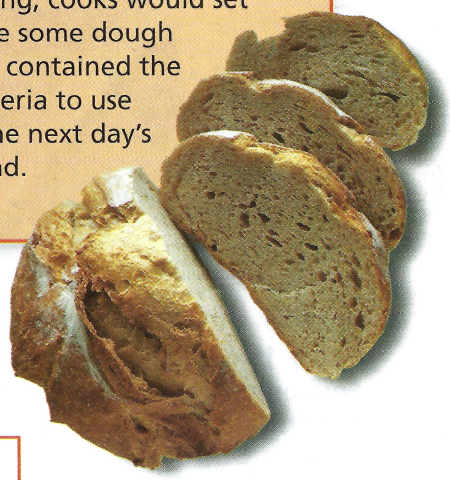

A.D. 500 A.D. 1500 A.D. 2500

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Health and Medicine Did you know that many of the bacteria living in your body actually keep you healthy? In your digestive system, for example, your intestines teem with bacteria. Some help you digest your food. Some make vitamins that your body needs. Others compete for space with disease-causing organisms, preventing the harmful bacteria from attaching to your intestines and making you sick.

Scientists have put some bacteria to work making medicines and other substances. The first medicine-producing bacteria were made in the 1970s. By manipulating the bacteria's genetic material, scientists engineered bacteria to produce human insulin. Although healthy people can make their own insulin, those with some types of diabetes cannot. Many people with diabetes need to take insulin daily. Thanks to bacteria's fast rate of reproduction, large numbers of insulin-making bacteria can be grown in huge vats. The human insulin they produce is then purified and made into medicine.

FIGURE 12
Bacteria and Digestion
Bacteria living naturally in your intestines help you digest food.

Section 2 Assessment

Target Reading Skill **Building Vocabulary**
Use your definitions to help answer the questions below.

Reviewing Key Concepts

1. a. **Reviewing** Where is the genetic material located in a bacterial cell?
   b. **Describing** What is the role of flagella in a bacterial cell?
2. a. **Listing** What are the three ways in which bacteria obtain food?
   b. **Describing** How do bacteria obtain energy to carry out their functions?
   c. **Inferring** You have just discovered a new bacterium that lives inside sealed cans of food. How do you think these bacteria obtain food and energy?
3. a. **Defining** What is binary fission?
   b. **Explaining** Under what conditions do bacteria thrive and reproduce frequently by binary fission?
   c. **Inferring** Why might bacteria that undergo conjugation be better able to survive when conditions become less than ideal?
4. a. **Listing** A friend states that all bacteria are harmful to people. List three reasons why this statement is inaccurate.
   b. **Applying Concepts** In what ways might bacteria contribute to the success of a garden in which pea plants are growing?

Lab zone At-Home Activity

Edible Bacteria With a family member, look around your kitchen for foods that are made using bacteria. Read the food labels to see if bacteria are used in the food's production. Discuss with your family member the helpful roles that bacteria play in people's lives.