chapter 1

Bacteria

chapter preview

sections

1 What are bacteria?
Lab *Observing Cyanobacteria*

2 Bacteria in Your Life
Lab *Composting*

Virtual Lab *What kills germs?*

The Microcosmos of Yogurt

Have you ever eaten yogurt? Yogurt has been a food source for about 4,000 years. Bacteria provide yogurt's tangy flavor and creamy texture. Bacteria also are required for making sauerkraut, cheese, buttermilk, and vinegar.

Science Journal List ways that bacteria can be harmful and ways bacteria can be beneficial. Which list is longer? Why do think that is?

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Start-Up Activities

Launch LAB

Model a Bacterium's Slime Layer

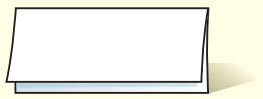
Bacterial cells have a gelatinlike, protective coating on the outside of their cell walls. In some cases, the coating is thin and is referred to as a slime layer. A slime layer can help a bacterium attach to other surfaces. Dental plaque forms when bacteria with slime layers stick to teeth and multiply there. A slime layer also can reduce water loss from a bacterium. In this lab you will make a model of a bacterium's slime layer.

1. Cut two 2-cm-wide strips from the long side of a synthetic kitchen sponge.
2. Soak both strips in water. Remove them from the water and squeeze out the excess water. Both strips should be damp.
3. Completely coat one strip with hair-styling gel. Do not coat the other strip.
4. Place both strips on a plate (not paper) and leave them overnight.
5. **Think Critically** Record your observations of the two sponge strips in your Science Journal. Infer how a slime layer protects a bacterial cell from drying out. What environmental conditions are best for survival of bacteria?

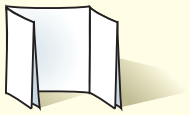
FOLDABLES™ Study Organizer

Archaebacteria and Eubacteria Make the following Foldable to compare and contrast the characteristics of bacteria.

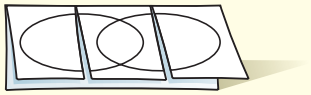
STEP 1 **Fold** one sheet of paper lengthwise.



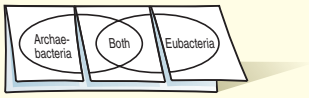
STEP 2 **Fold** into thirds.



STEP 3 **Unfold and draw** overlapping ovals. Cut the top sheet along the folds.



STEP 4 **Label** the ovals as shown.



Construct a Venn Diagram As you read the chapter, list the characteristics unique to archaebacteria under the left tab, those unique to eubacteria under the right tab, and those characteristics common to both under the middle tab.

ScienceOnline Preview this chapter's content and activities at bookb.msscience.com

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section 1

What are bacteria?

as you read

What You'll Learn

- Identify the characteristics of bacterial cells.
- Compare and contrast aerobic and anaerobic organisms.

Why It's Important

Bacteria are found almost everywhere and affect all living things.

Review Vocabulary

prokaryotic: cells without membrane-bound organelles

New Vocabulary

- flagella
- fission
- aerobe
- anaerobe

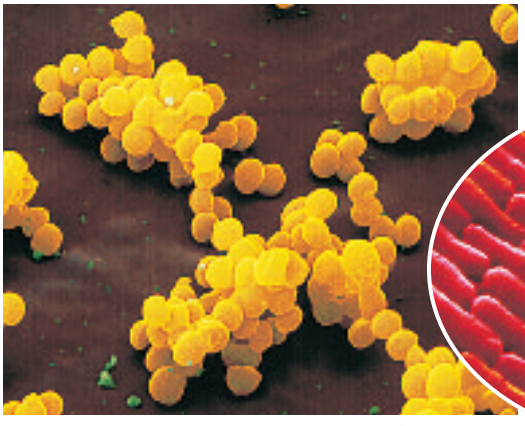
Characteristics of Bacteria

For thousands of years people did not understand what caused disease. They did not understand the process of decomposition or what happened when food spoiled. It wasn't until the latter half of the seventeenth century that Antonie van Leeuwenhoek, a Dutch merchant, discovered the world of bacteria. Leeuwenhoek observed scrapings from his teeth using his simple microscope. Although he didn't know it at that time, some of the tiny swimming organisms he observed were bacteria. After Leeuwenhoek's discovery, it was another hundred years before bacteria were proven to be living cells that carry on all of the processes of life.

Where do bacteria live? Bacteria are almost everywhere—in the air, in foods that you eat and drink, and on the surfaces of things you touch. They are even found thousands of meters underground and at great ocean depths. A shovelful of soil contains billions of them. Your skin has about 100,000 bacteria per square centimeter, and millions of other bacteria live in your body. Some types of bacteria live in extreme environments where few other organisms can survive. Some heat-loving bacteria live in hot springs or hydrothermal vents—places where water temperature exceeds 100°C. Others can live in cold water or soil at 0°C. Some bacteria live in very salty water, like that of the Dead Sea. One type of bacteria lives in water that drains from coal mines, which is extremely acidic at a pH of 1.

Figure 1 Bacteria can be found in almost any environment.
List *common terms that could be used to describe these cell shapes.*

Coccus



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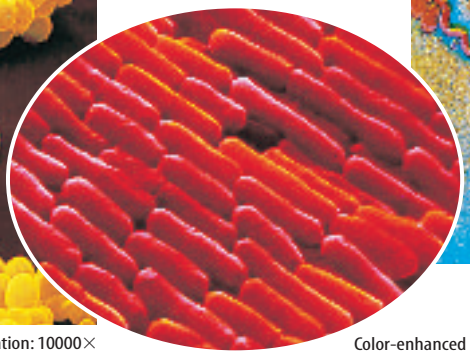
Bacillus



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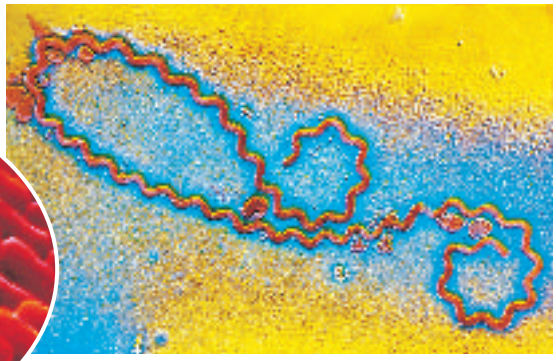
Spirillum



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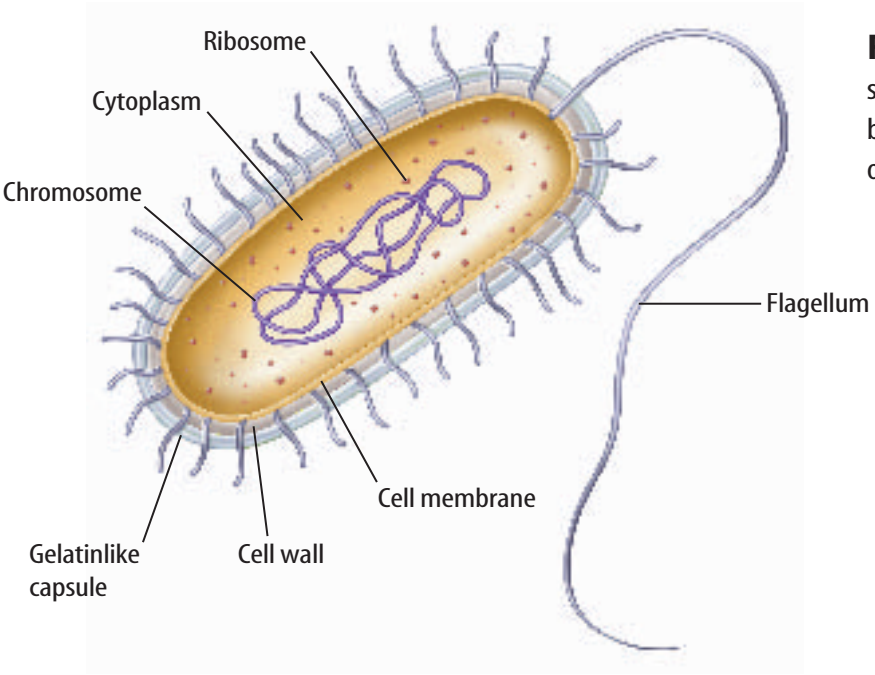

Figure 2 Bacterial cells are much smaller than eukaryotic cells. Most bacteria are about the size of some organelles found inside eukaryotic cells.

Structure of Bacterial Cells

Bacteria normally have three basic shapes—spheres, rods, and spirals, as shown in **Figure 1.** Sphere-shaped bacteria are called cocci (KAHK si) (singular, *coccus*), rod-shaped bacteria are called bacilli (buh SIH li) (singular, *bacillus*), and spiral-shaped bacteria are called spirilla (spi RIH luh) (singular, *spirillum*). Bacteria are smaller than plant or animal cells. They are one-celled organisms that occur alone or in chains or groups.

A typical bacterial cell contains cytoplasm surrounded by a cell membrane and a cell wall, as shown in **Figure 2.** Bacterial cells are classified as prokaryotic because they do not contain a membrane-bound nucleus or other membrane-bound internal structures called organelles. Most of the genetic material of a bacterial cell is in its one circular chromosome found in the cytoplasm. Many bacteria also have a smaller circular piece of DNA called a plasmid. Ribosomes also are found in a bacterial cell's cytoplasm.

Special Features

Some bacteria, like the type that causes pneumonia, have a thick, gelatinlike capsule around the cell wall. A capsule can help protect the bacterium from other cells that try to destroy it. The capsule, along with hairlike projections found on the surface of many bacteria, also can help them stick to surfaces. Some bacteria also have an outer coating called a slime layer. Like a capsule, a slime layer enables a bacterium to stick to surfaces and reduces water loss. Many bacteria that live in moist conditions also have whiplike tails called **flagella** to help them move.

Reading Check *How do bacteria use flagella?*

Mini LAB

Modeling Bacteria Size

Procedure

1. One human hair is about 0.1 mm wide. Use a **meterstick** to measure a piece of **yarn or string** that is 10 m long. This yarn represents the width of your hair.
2. One type of bacteria is 2 micrometers long (1 micrometer = 0.000001 m). Measure another piece of yarn or string that is 20 cm long. This piece represents the length of the bacterium.
3. Find a large area where you can lay the two pieces of yarn or string next to each other and compare them.

Analysis

1. Calculate how much smaller the bacterium is than the width of your hair.
2. In your **Science Journal,** describe why a model is helpful to understand how small bacteria are.

Try at Home

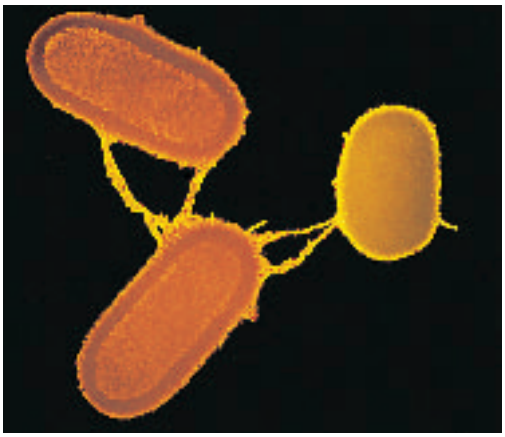

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Figure 3 Before dividing, these bacteria are exchanging DNA through the tubes that join them. This process is called conjugation.

Reproduction Bacteria usually reproduce by fission. **Fission** is a process that produces two new cells with genetic material identical to each other and that of the original cell. It is the simplest form of asexual reproduction.

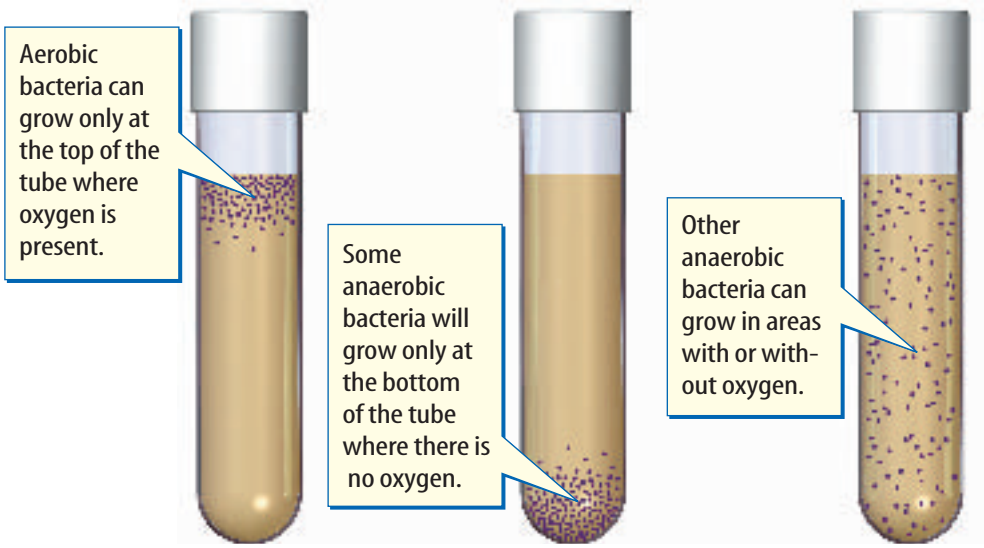
Some bacteria exchange genetic material through a process similar to sexual reproduction, as shown in **Figure 3.** Two bacteria line up beside each other and exchange DNA through a fine tube. This results in cells with different combinations of genetic material than they had before the exchange. As a result, the bacteria may acquire variations that give them an advantage for survival.

How Bacteria Obtain Food and Energy Bacteria obtain food in a variety of ways. Some make their food and others get it from the environment. Bacteria that contain chlorophyll or other pigments make their own food using energy from the Sun. Other bacteria use energy from chemical reactions to make food. Bacteria and other organisms that can make their own food are called producers.

Most bacteria are consumers. They do not make their own food. Some break down dead organisms to obtain energy. Others live as parasites of living organisms and absorb nutrients from their host.

Most organisms use oxygen when they break down food and obtain energy through a process called respiration. An organism that uses oxygen for respiration is called an **aerobe** (AY rohb). You are an aerobic organism and so are most bacteria. In contrast, an organism that is adapted to live without oxygen is called an **anaerobe** (AN uh rohb). Several kinds of anaerobic bacteria live in the intestinal tract of humans. Some bacteria cannot survive in areas with oxygen.

Figure 4 Observing where bacteria can grow in tubes of a nutrient mixture shows you how oxygen affects different types of bacteria.



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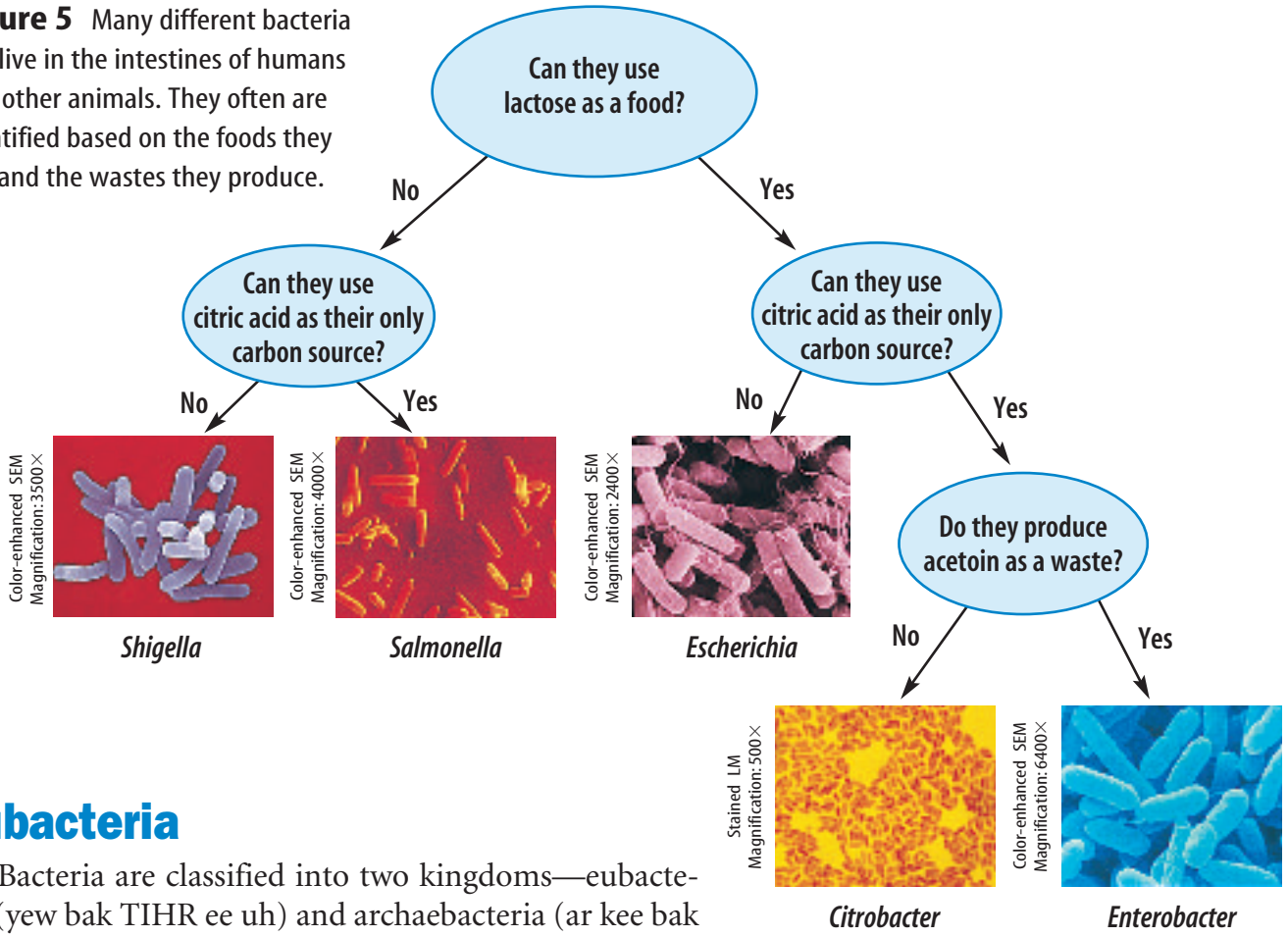

Figure 5 Many different bacteria can live in the intestines of humans and other animals. They often are identified based on the foods they use and the wastes they produce.

Eubacteria

Bacteria are classified into two kingdoms—eubacteria (yew bak TIHR ee uh) and archaebacteria (ar kee bak TIHR ee uh). Eubacteria is the larger of the two kingdoms. Scientists must study many characteristics in order to classify eubacteria into smaller groups. Most eubacteria are grouped according to their cell shape and structure, the way they obtain food, the type of food they consume, and the wastes they produce, as shown in **Figure 5.** Other characteristics used to group eubacteria include the method used for cell movement and whether the organism is an aerobe or anaerobe. New information about their genetic material is changing how scientists classify this kingdom.

Producer Eubacteria One important group of producer eubacteria is the cyanobacteria (si an oh bak TIHR ee uh). They make their own food using carbon dioxide, water, and energy from sunlight. They also produce oxygen as a waste. Cyanobacteria contain chlorophyll and another pigment that is blue. This pigment combination gives cyanobacteria their common name—blue-green bacteria. However, some cyanobacteria are yellow, black, or red. The Red Sea gets its name from red cyanobacteria.

Reading Check *Why are cyanobacteria classified as producers?*

Science Online

Topic: Producer Eubacteria

Visit bookb.msscience.com for Web links to information about the ways that producer bacteria make food.

Activity Construct a food web that illustrates a community that relies on producer bacteria as a source of energy.

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LM Magnification: 100×

Figure 6 These colonies of the cyanobacteria *Oscillatoria* can move by twisting like a screw.

Importance of Cyanobacteria Some cyanobacteria live together in long chains or filaments, as shown in **Figure 6.** Many are covered with a gelatinlike substance. This adaptation enables cyanobacteria to live in groups called colonies. They are an important source of food for some organisms in lakes, ponds, and oceans. The oxygen produced by cyanobacteria is used by other aquatic organisms.

Cyanobacteria also can cause problems for aquatic life. Have you ever seen a pond covered with smelly, green, bubbly slime? When large amounts of nutrients enter a pond, cyanobacteria increase in number. Eventually the population grows so large that a bloom is produced. A bloom looks like a mat of bubbly green slime on the surface of the water. Available resources in the water are used up quickly and the cyanobacteria die. Other bacteria that are aerobic consumers feed on dead cyanobacteria and use up the oxygen in the water. As a result of the reduced oxygen in the water, fish and other organisms die.

Consumer Eubacteria Most consumer eubacteria are grouped into one of two categories based on the results of the Gram's stain. These results can be seen under a microscope after the bacteria are treated with certain chemicals that are called stains. As shown in **Figure 7,** gram-positive cells stain purple because they have thicker cell walls. Gram-negative cells stain pink because they have thinner cell walls.

The composition of the cell wall also can affect how a bacterium is affected by medicines given to treat an infection. Some antibiotics (an ti bi AH tihks) will be more effective against gram-negative bacteria than they will be against gram-positive bacteria.

One group of eubacteria is unique because they do not produce cell walls. This allows them to change their shape. They are not described as coccus, bacillus, or spirillum. One type of bacteria in this group, *Mycoplasma pneumoniae,* causes a type of pneumonia in humans.

Ocean Vents Geysers on the floor of the ocean are called ocean vents. Research to find out how ocean vents form and what conditions are like at an ocean vent. In your Science Journal, describe organisms that have been found living around ocean vents.

Stained LM Magnification: 315×

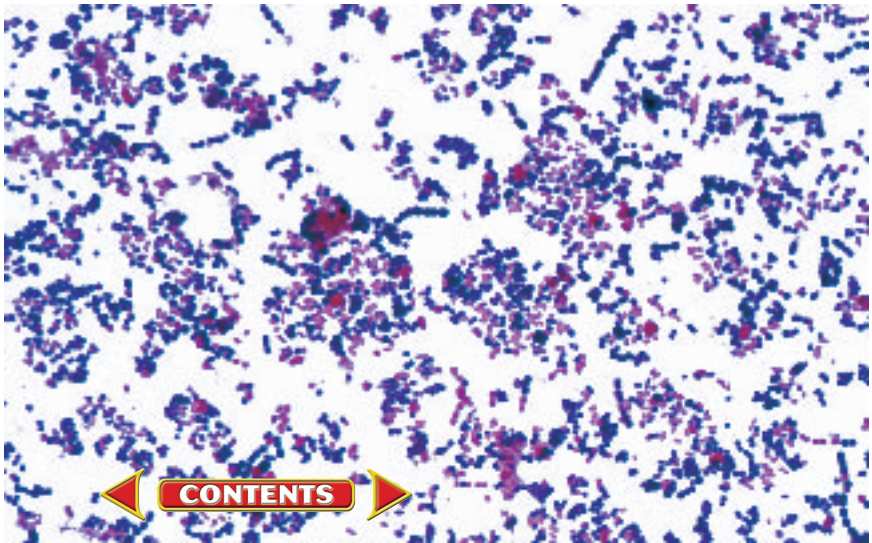

Figure 7 When stained with certain chemicals, bacteria with thin cell walls appear pink when viewed under a microscope. Those with thicker walls appear purple.

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Archaebacteria

Kingdom Archaebacteria contains certain kinds of bacteria that often are found in extreme conditions, such as hot springs. The conditions in which some archaebacteria live today are similar to conditions found on Earth during its early history. Archaebacteria are divided into groups based on where they live or how they get energy.

Salt-, Heat-, and Acid-Lovers One group of archaebacteria lives in salty environments such as the Great Salt Lake in Utah and the Dead Sea. Some of them require a habitat ten times saltier than seawater to grow.

Other groups of archaebacteria include those that live in acidic or hot environments. Some of these bacteria live near deep ocean vents or in hot springs where the temperature of the water is above 100°C.

Methane Producers Bacteria in this group of archaebacteria are anaerobic. They live in muddy swamps, the intestines of cattle, and even in you. Methane producers, as shown in **Figure 8,** use carbon dioxide for energy and release methane gas as a waste. Sometimes methane produced by these bacteria bubbles up out of swamps and marshes. These archaebacteria also are used in the process of sewage treatment. In an oxygen-free tank, the bacteria are used to break down the waste material that has been filtered from sewage water.

Color-enhanced SEM Magnification: 6000×

Figure 8 Some methane-producing bacteria live in the digestive tracts of cattle. They help digest the plants that cattle eat.

section 1 review

Summary

Characteristics of Bacteria

- Bacteria live almost everywhere and usually are one of three basic shapes.
- A bacterium lacks a nucleus, most bacteria reproduce asexually, and they can be aerobes or anaerobes.

Eubacteria

- Eubacteria are grouped by cell shape and structure, how they obtain food, and whether they are gram-positive or gram-negative.

Archaebacteria

- Archaebacteria can be found in extreme environments.
- Some break down sewage and produce methane.

Self Check

1. **List** three shapes of bacteria cells.
2. **Compare and contrast** aerobic organisms and anaerobic organisms.
3. **Explain** how most bacteria reproduce.
4. **Identify** who is given credit for first discovering bacteria.
5. **Think Critically** A pond is surrounded by recently fertilized farm fields. What effect would rainwater runoff from the fields have on the organisms in the pond?

Applying Math

6. **Solve One-Step Equations** Some bacteria reproduce every 20 min. Suppose that you have one bacterium. How long would it take for the number of bacteria to increase to more than 1 million?

LAB

Observing Cyanobacteria

You can obtain many species of cyanobacteria from ponds. When you look at these organisms under a microscope, you will find that they have similarities and differences. In this lab, compare and contrast species of cyanobacteria.

Real-World Question

What do cyanobacteria look like?

Goals

- **Observe** several species of cyanobacteria.
- **Describe** the structure and function of cyanobacteria.

Materials

micrograph photos of *Oscillatoria* and *Nostoc*
**prepared slides of* Oscillatoria *and* Nostoc
prepared slides of *Gloeocapsa* and *Anabaena*
**micrograph photos of* Anabaena *and* Gloeocapsa
microscope
**Alternate materials*

Safety Precautions

Procedure

1. Copy the data table in your Science Journal. As you observe each cyanobacterium, record the presence or absence of each characteristic in the data table.
2. **Observe** prepared slides of *Gloeocapsa* and *Anabaena* under low and high power of the microscope. Notice the difference in the arrangement of the cells. In your Science Journal, draw and label a few cells of each.
3. **Observe** photos of *Nostoc* and *Oscillatoria.* In your Science Journal, draw and label a few cells of each.

Conclude and Apply

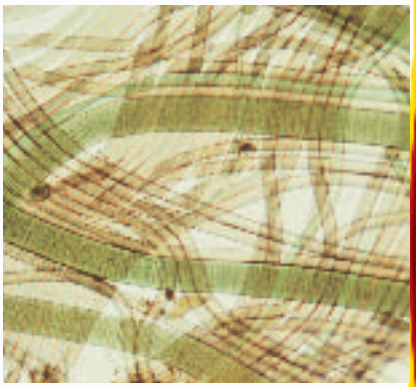
1. **Infer** what the color of each cyanobacterium means.
2. **Explain** how you can tell by observing that a cyanobacterium is a eubacterium.

Communicating Your Data

Compare your data table with those of other students in your class. **For more help, refer to the Science Skill Handbook.**

Cyanobacteria Observations

Structure	*Anabaena*	*Gloeocapsa*	*Nostoc*	*Oscillatoria*
Filament or colony				
Nucleus				
Chlorophyll				
Gel-like layer				



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section 2

Bacteria in Your Life

Beneficial Bacteria

When you hear the word *bacteria,* you probably associate it with sore throats or other illnesses. However, few bacteria cause illness. Most are important for other reasons. The benefits of most bacteria far outweigh the harmful effects of a few.

Bacteria That Help You Without bacteria, you would not be healthy for long. Bacteria, like those in **Figure 9,** are found inside your digestive system. These bacteria are found in particularly high numbers in your large intestine. Most are harmless to you, and they help you stay healthy. For example, some bacteria in your intestines are responsible for producing vitamin K, which is necessary for normal blood clot formation.

Some bacteria produce chemicals called **antibiotics** that limit the growth of other bacteria. For example, one type of bacteria that is commonly found living in soil produces the antibiotic streptomycin. Another kind of bacteria, *Bacillus,* produces the antibiotic found in many nonprescription antiseptic ointments. Many bacterial diseases in humans and animals can be treated with antibiotics.

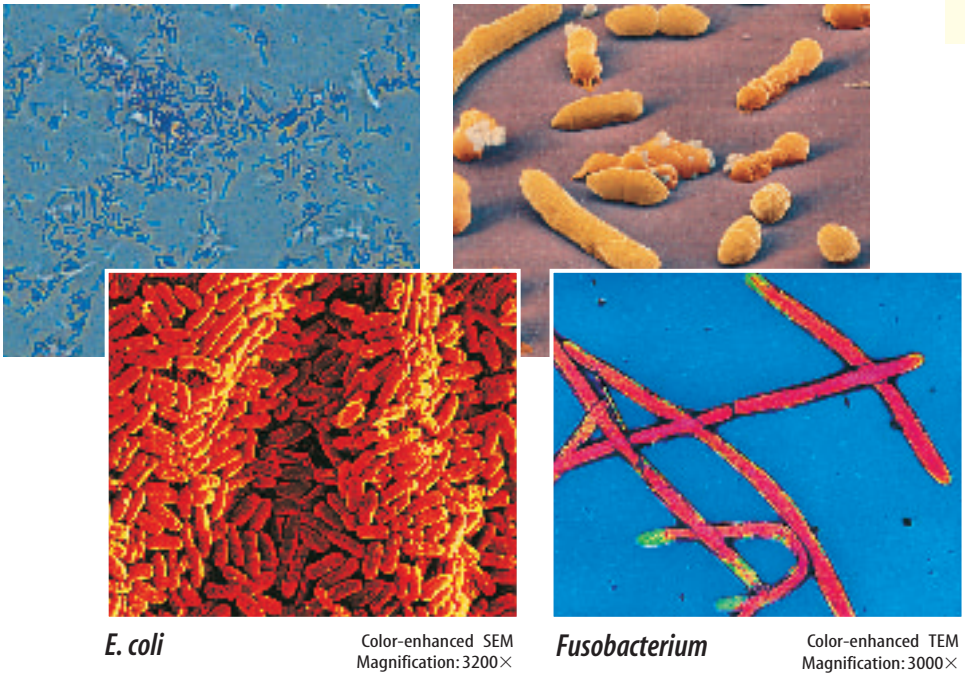

Figure 9 Many types of bacteria live naturally in your large intestine. They help you digest food and produce essential vitamins.

as you read

What You'll Learn

- **Identify** some ways bacteria are helpful.
- **Determine** the importance of nitrogen-fixing bacteria.
- **Explain** how some bacteria can cause human disease.

Why It's Important

Discovering the ways bacteria affect your life can help you understand biological processes.

Review Vocabulary

disease: a condition with symptoms that interferes with normal body functions

New Vocabulary

- antibiotic
- saprophyte
- nitrogen-fixing bacteria
- pathogen
- toxin
- endospore
- vaccine

Figure 10 Air is bubbled through the sewage in this aeration tank so that bacteria can break down much of the sewage wastes. **Determine** *whether the bacteria that live in this tank are aerobes or anaerobes.*

Bacteria and the Environment

Without bacteria, there would be layers of dead material all over Earth deeper than you are tall. Consumer bacteria called saprophytes (SAP ruh fites) help maintain nature's balance. A **saprophyte** is any organism that uses dead organisms as food and energy sources. Saprophytic bacteria help recycle nutrients. These nutrients become available for use by other organisms. As shown in **Figure 10,** most sewage-treatment plants use saprophytic aerobic bacteria to break down wastes into carbon dioxide and water.

Reading Check ***What is a saprophyte?***

Plants and animals must take in nitrogen to make needed proteins and nucleic acids. Animals can eat plants or other animals that contain nitrogen, but plants need to take nitrogen from the soil or air. Although air is about 78 percent nitrogen, neither animals nor plants can use it directly. **Nitrogen-fixing bacteria** change nitrogen from the air into forms that plants and animals can use. The roots of some plants such as peanuts and peas develop structures called nodules that contain nitrogen-fixing bacteria, as shown in **Figure 11.** It is estimated that nitrogen-fixing bacteria save U.S. farmers millions of dollars in fertilizer costs every year. Many of the cyanobacteria also can fix nitrogen and are important in providing nitrogen in usable forms to aquatic organisms.

Bioremediation

Using organisms to help clean up or remove environmental pollutants is called bioremediation. One type of bioremediation uses bacteria to break down wastes and pollutants into simpler harmless compounds. Other bacteria use certain pollutants as a food source. Every year about five percent to ten percent of all wastes produced by industry, agriculture, and cities are treated by bioremediation. Sometimes bioremediation is used at the site where chemicals, such as oil, have been spilled. Research continues on ways to make bioremediation a faster process.

Mini LAB

Observing Bacterial Growth

Procedure

1. Obtain two or three **dried beans.**
2. Carefully break them into halves and place the halves into 10 mL of **distilled water** in a **glass beaker.**
3. Observe how many days it takes for the water to become cloudy and develop an unpleasant odor.

Analysis

1. How long did it take for the water to become cloudy?
2. What do you think the bacteria were using as a food source?

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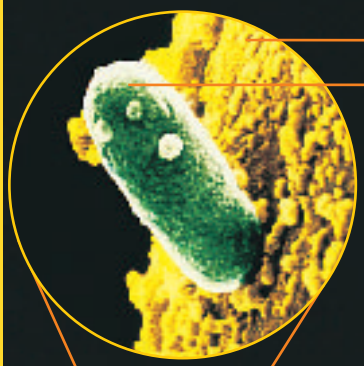
NATIONAL GEOGRAPHIC

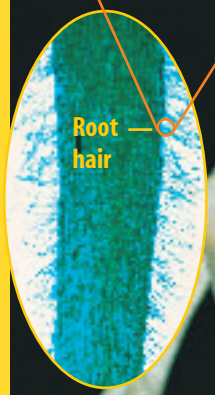
VISUALIZING NITROGEN-FIXING BACTERIA

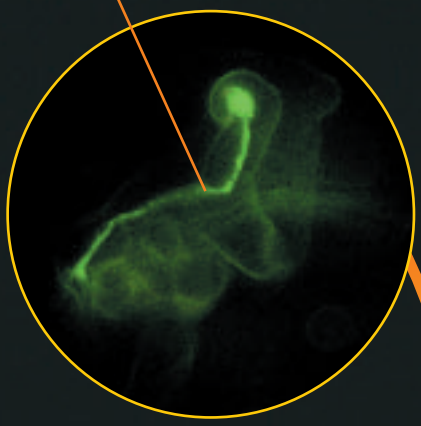
Figure 11

Although 78 percent of Earth's atmosphere is nitrogen gas (N_2), most living things are unable to use nitrogen in this form. Some bacteria, however, convert N_2 into the ammonium ion (NH_4^+) that organisms can use. This process is called nitrogen fixation. Nitrogen-fixing bacteria in soil can enter the roots of plants, such as beans, peanuts, alfalfa, and peas, as shown in the background photo. The bacteria and the plant form a relationship that benefits both of them.

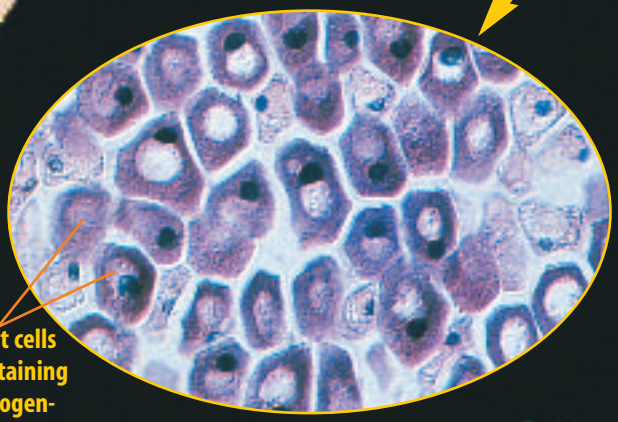


◀ Nitrogen-fixing bacteria typically enter a plant through root hairs—thin-walled cells on a root's outer surface.





▲ Once inside the root hair, the bacteria enlarge and cause the plant to produce a sort of tube called an infection thread. The bacteria move through the thread to reach cells deeper inside the root.



▲ The bacteria rapidly divide in the root cells, which in turn divide repeatedly to form tumorlike nodules on the roots. Once established, the bacteria (purple) fix nitrogen for use by the host plant. In return, the plant supplies the bacteria with sugars and other vital nutrients.

Beadlike nodules full of bacteria cover the roots of a pea plant.

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Bioreactor Landfills As Earth's population grows and produces more waste, traditional landfills, which take 30 to 100 years to decompose waste, no longer fulfill the need for solid-waste disposal. Bioreactor landfills, which take 5 to 10 years to decompose waste, are beginning to be used instead. Bioreactor landfills can use aerobic or anaerobic bacteria, or a combination of the two, for rapid degradation of wastes.

Bacteria and Food

Have you had any bacteria for lunch lately? Even before people understood that bacteria were involved, they were used in the production of foods. One of the first uses of bacteria was for making yogurt, a milk-based food that has been made in Europe and Asia for hundreds of years. Bacteria break down substances in milk to make many dairy products. Cheeses and buttermilk also can be produced with the aid of bacteria. Cheese making is shown in **Figure 12.**

Other foods you might have eaten also are made using bacteria. Sauerkraut, for example, is made with cabbage and a bacterial culture. Vinegar, pickles, olives, and soy sauce also are produced with the help of bacteria.

Bacteria in Industry

Many industries rely on bacteria to make many products. Bacteria are grown in large containers called bioreactors. Conditions inside bioreactors are carefully controlled and monitored to allow for the growth of the bacteria. Medicines, enzymes, cleansers, and adhesives are some of the products that are made using bacteria.

Methane gas that is released as a waste by certain bacteria can be used as a fuel for heating, cooking, and industry. In landfills, methane-producing bacteria break down plant and animal material. The quantity of methane gas released by these bacteria is so large that some cities collect and burn it, as shown in **Figure 13.** Using bacteria to digest wastes and then produce methane gas could supply large amounts of fuel worldwide.

What waste gas produced by some bacteria can be used as a fuel?

Curds and whey

Curds

Figure 12 When bacteria such as *Streptococcus lactis* are added to milk, it causes the milk to separate into curds (solids) and whey (liquids). Other bacteria are added to the curds, which ripen into cheese. The type of cheese made depends on the bacterial species added to the curds.

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Figure 13 Methane gas produced by bacteria in this landfill is burning at the top of these collection tubes.

Harmful Bacteria

Not all bacteria are beneficial. Some bacteria are known as pathogens. A **pathogen** is any organism that causes disease. If you have ever had strep throat, you have had firsthand experience with a bacterial pathogen. Other pathogenic bacteria cause diphtheria, tetanus, and whooping cough in humans, as well as anthrax in humans and livestock.

How Pathogens Make You Sick Bacterial pathogens can cause illness and disease by several different methods. They can enter your body through a cut in the skin, you can inhale them, or they can enter in other ways. Once inside your body, they can multiply, damage normal cells, and cause illness and disease.

Some bacterial pathogens produce poisonous substances known as **toxins.** Botulism—a type of food poisoning that can result in paralysis and death—is caused by a toxin-producing bacterium. Botulism-causing bacteria are able to grow and produce toxins inside sealed cans of food. However, when growing conditions are unfavorable for their survival, some bacteria, like those that cause botulism, can produce thick-walled structures called **endospores.** Endospores, shown in **Figure 14,** can exist for hundreds of years before they resume growth. If the endospores of the botulism-causing bacteria are in canned food, they can grow and develop into regular bacterial cells and produce toxins again. Commercially canned foods undergo a process that uses steam under high pressure, which kills bacteria and most endospores.

Science Online

Topic: Pathogens

Visit bookb.msscience.com for Web links to information about pathogenic bacteria and antibiotics.

Activity Compile a list of common antibiotics and the bacterial pathogens they are used to treat.

Figure 14 Bacterial endospores can survive harsh winters, dry conditions, and heat.
Describe *possible ways endospores can be destroyed.*

LM Magnification: 600×

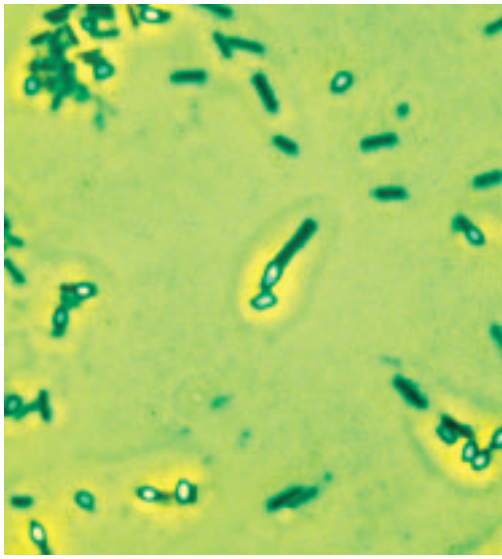

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Figure 15 Pasteurization lowers the amount of bacteria in foods. Products, such as juice, ice cream, and yogurt, are pasteurized.

Pasteurization Unless it has been sterilized, all food contains bacteria. But heating food to sterilizing temperatures can change its taste. Pasteurization is a process of heating food to a temperature that kills most harmful bacteria but causes little change to the taste of the food. You are probably most familiar with pasteurized milk, but some fruit juices and other foods, as shown in **Figure 15,** also are pasteurized.

Applying Science

Controlling Bacterial Growth

Bacteria can be controlled by slowing or preventing their growth, or killing them. When trying to control bacteria that affect humans, it is often desirable just to slow their growth because substances that kill bacteria or prevent them from growing can harm humans. For example, bleach often is used to kill bacteria in bathrooms or on kitchen surfaces, but it is poisonous if swallowed. *Antiseptic* is the word used to describe substances that slow the growth of bacteria.

Identifying the Problem

Advertisers often claim that a substance kills bacteria, when in fact the substance only slows its growth. Many mouthwash advertisements make this claim. How could you test three mouthwashes to see which one is the best antiseptic?

Solving the Problem

1. Describe an experiment that you could do that would test which of three mouthwash products is the most effective antiseptic.
2. Identify the control in your experiment.
3. Read the ingredients labels on bottles of mouthwash. List the ingredients in the mouthwash. What ingredient do you think is the antiseptic? Explain.

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Figure 16 Each of these paper disks contains a different antibiotic. Clear areas where no bacteria are growing can be seen around four of the disks.
Infer *which one of these disks contains an antibiotic that is most effective against the bacteria growing on the plate.*

INTEGRATE Health

Treating Bacterial Diseases

Bacterial diseases in humans and animals usually are treated effectively with antibiotics. Penicillin, a well-known antibiotic, works by preventing bacteria from making cell walls. Without cell walls, certain bacteria cannot survive. **Figure 16** shows antibiotics at work.

Vaccines can prevent some bacterial diseases. A **vaccine** can be made from damaged particles taken from bacterial cell walls or from killed bacteria. Once the vaccine is injected, white blood cells in the blood recognize that type of bacteria. If the same type of bacteria enters the body at a later time, the white blood cells immediately attack them. Vaccines have been produced that are effective against many bacterial diseases.

section 2 review

Summary

Beneficial Bacteria

- Many types of bacteria help you stay healthy.
- Antibiotics are produced by some bacteria.
- Bacteria decompose dead material.
- Certain bacteria change nitrogen in the air to forms that other organisms can use.
- Some bacteria are used to remove pollutants.
- Bacteria help to produce some foods.

Harmful Bacteria

- Some bacteria cause disease.
- Some bacteria have endospores that enable them to adapt to harsh environments.

Self Check

1. **Explain** why saprophytic bacteria are helpful.
2. **Summarize** how nitrogen-fixing bacteria benefit plants and animals.
3. **List** three uses of bacteria in food production and other industry.
4. **Describe** how some bacteria cause disease.
5. **Think Critically** Why is botulism associated with canned foods and not fresh foods?

Applying Skills

6. **Measure in SI** Air can have more than 3,500 bacteria per cubic meter. How many bacteria might be in your classroom?

LAB

Design Your Own

Composting

Goals

- **Predict** which of several items will decompose in a compost pile and which will not.
- **Demonstrate** the decomposition, or lack thereof, of several items.
- **Compare and contrast** the speed at which various items break down.

Possible Materials

widemouthed, clear-glass jars (at least 4)
soil
water
watering can
banana peel
apple core
scrap of newspaper
leaf
plastic candy wrapper
scrap of aluminum foil

Safety Precautions

Real-World Question

Over time, landfills fill up and new places to dump trash become more difficult to find. One way to reduce the amount of trash that must be dumped in a landfill is to recycle. Composting is a form of recycling that changes plant wastes into reusable, nutrient-rich compost. How do plant wastes become compost? What types of organisms can assist in the process? What types of items can be composted and what types cannot?

Form a Hypothesis

Based on readings or prior knowledge, form a hypothesis about what types of items will decompose in a compost pile and which will not.

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Test Your Hypothesis

Make a Plan

1. **Decide** what items you are going to test. Choose some items that you think will decompose and some that you think will not.
2. **Predict** which of the items you chose will or will not decompose. Of the items that will, which do you think will decompose fastest? Slowest?
3. **Decide** how you will test whether or not the items decompose. How will you see the items? You may need to research composting in books, magazines, or on the Internet.
4. **Prepare** a data table in your Science Journal to record your observations.
5. **Identify** all constants, variables, and controls of the experiment.

Follow Your Plan

1. Make sure your teacher approves of your plan and your data table before you start.
2. **Observe** Set up your experiment and collect data as planned.
3. **Record Data** While doing the experiment, record your observations and complete your data tables in your Science Journal.

Analyze Your Data

1. **Describe** your results. Did all of the items decompose? If not, which did and which did not?
2. Were your predictions correct? Explain.
3. **Compare** how fast each item decomposed. Which items decomposed fastest and which took longer?

Conclude and Apply

1. What general statement(s) can you make about which items can be composted and which cannot? What about the speed of decomposition?
2. **Determine** whether your results support your hypothesis.
3. **Explain** what might happen to your compost pile if antibiotics were added to it.
4. **Describe** what you think happens in a landfill to items similar to those that you tested.

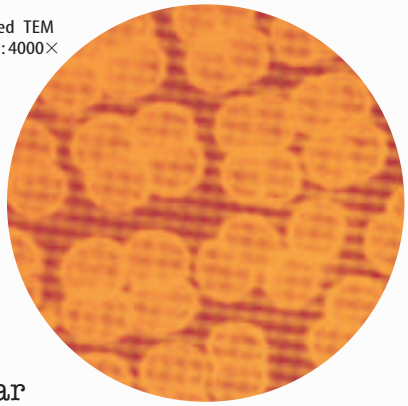
Communicating Your Data

Point of View Write a letter to the editor of a local newspaper describing what you have learned about composting and encouraging more community composting.

John Evans

SCIENCE Stats

Unusual Bacteria

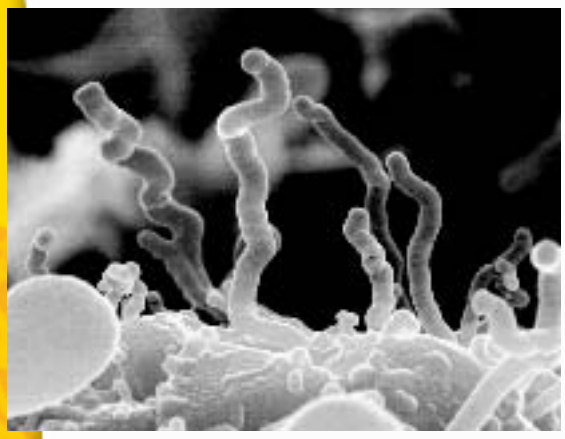


Color-enhanced TEM
Magnification: 4000×

D. radiodurans

Did you know...

...The hardiest bacteria, *Deinococcus radiodurans* (DE no KO kus·RA de oh DOOR anz), has a nasty odor, which has been described as similar to rotten cabbage. It might have an odor, but it can survive 3,000 times more radiation than humans because it quickly repairs damage to its DNA molecule. These bacteria were discovered in canned meat when they survived sterilization by radiation.



Nanobes

...The smallest bacteria, nanobes (NA nobes), are Earth's smallest living things. They have been found 5 km beneath the ocean floor near Australia. These tiny cells are 20 to 150 nanometers long. That means, depending on their size, it would take about 6,500,000 to 50,000,000 nanobes lined up to equal 1 m!

Applying Math What is the difference in size between the largest nanobe and the smallest nanobe?

...Earth's oldest living bacteria are thought to be 250 million years old. These ancient bacteria were revived from a crystal of rock salt buried 579 m below the desert floor in New Mexico.

Bacillus permians

Find Out About It

Do research about halophiles, the bacteria that can live in highly salty environments. What is the maximum salt concentration in which extreme halophiles can survive? How does this compare to the maximum salt concentration at which nonhalophilic bacteria can survive? Visit bookb.msscience.com/science_stats to learn more.

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Reviewing Main Ideas

Section 1 What are bacteria?

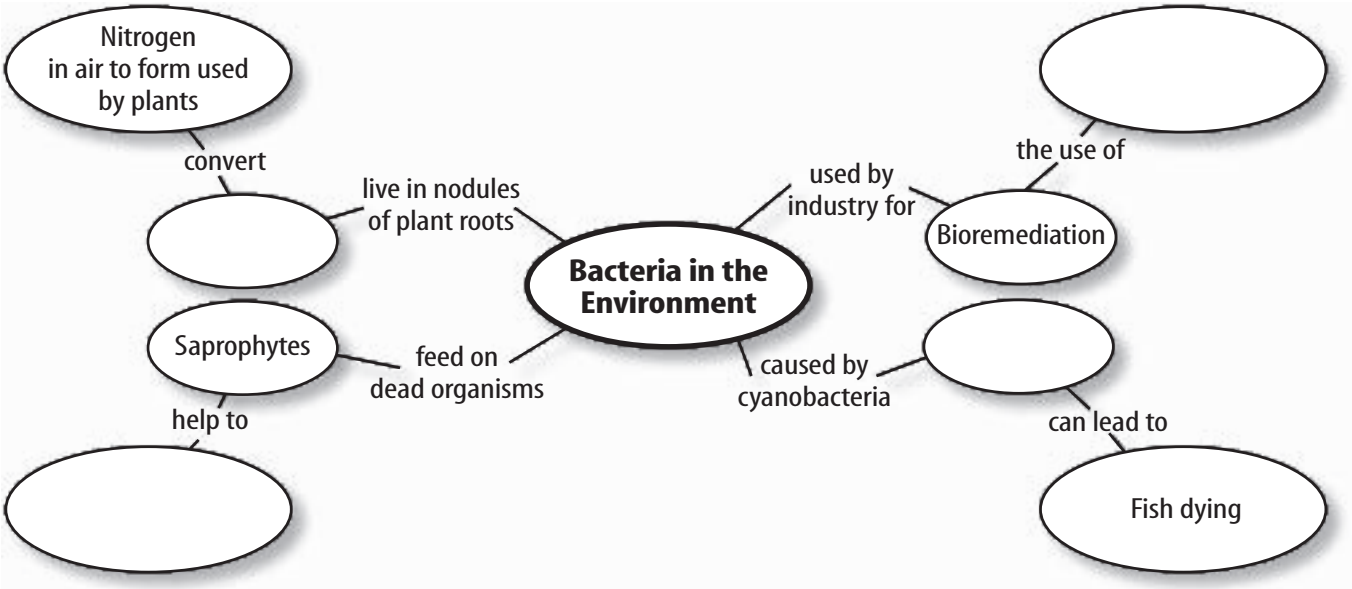
1. Bacteria can be found almost everywhere. They have one of three basic shapes—coccus, bacillus, or spirillum.
2. Bacteria are prokaryotic cells that usually reproduce by fission. All bacteria contain DNA, ribosomes, and cytoplasm but lack a membrane-bound nucleus.
3. Most bacteria are consumers, but some can make their own food. Anaeroic bacteria live without oxygen, but aerobic bacteria need oxygen to survive.
4. Cell shape and structure, how they get food, if they use oxygen, and their waste products can be used to classify eubacteria.
5. Cyanobacteria are producer eubacteria. They are an important source of food and oxygen for some aquatic organisms.
6. Archaebacteria are bacteria that often exist in extreme conditions, such as near ocean vents or in hot springs.

Section 2 Bacteria in Your Life

1. Most bacteria are helpful. They aid in recycling nutrients, fixing nitrogen, or helping in food production. They even can be used to break down pollutants.
2. Some bacteria that live in your body help you stay healthy and survive.
3. Other bacteria are harmful because they can cause disease in organisms.
4. Pasteurization can prevent the growth of harmful bacteria in food.

Visualizing Main Ideas

Copy and complete the following concept map on how bacteria affect the environment.



Using Vocabulary

aerobe p. 10
anaerobe p. 10
antibiotic p. 15
endospore p. 19
fission p. 10
flagella p. 9
nitrogen-fixing bacteria p. 16
pathogen p. 19
saprophyte p. 16
toxin p. 19
vaccine p. 21

Fill in the blanks with the correct word or words.

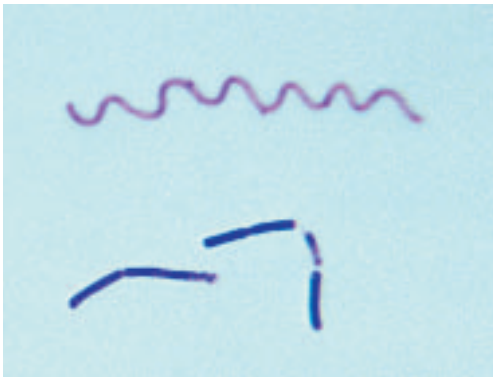
1. A(n) _____ uses dead organisms as a food source.
2. A(n) _____ can prevent some bacterial diseases.
3. A(n) _____ causes disease.
4. A bacterium that needs oxygen to carry out respiration is a(n) _____.
5. Bacteria reproduce using _____.
6. _____ are bacteria that convert nitrogen in the air to a form used by plants.
7. A(n) _____ can live without oxygen.

Checking Concepts

Choose the word or phrase that best answers the question.

8. What is a way of cleaning up an ecosystem using bacteria to break down harmful compounds?
   A) landfill **C)** toxic waste dumps
   B) waste storage **D)** bioremediation
9. What pigment do cyanobacteria need to make food?
   A) chlorophyll **C)** plasmids
   B) chromosomes **D)** ribosomes
10. Which of the following terms describes most bacteria?
    A) anaerobic **C)** many-celled
    B) pathogens **D)** beneficial
11. What is the name for rod-shaped bacteria?
    A) bacilli **C)** spirilla
    B) cocci **D)** colonies
12. What structure allows bacteria to stick to surfaces?
    A) capsule **C)** chromosome
    B) flagella **D)** cell wall
13. What organisms can grow as blooms in ponds?
    A) archaebacteria **C)** cocci
    B) cyanobacteria **D)** viruses
14. Which of these organisms are recyclers in the environment?
    A) producers **C)** saprophytes
    B) flagella **D)** pathogens
15. Which of the following is caused by a pathogenic bacterium?
    A) an antibiotic **C)** nitrogen fixation
    B) cheese **D)** strep throat

Use the photo below to answer questions 16 and 17.



16. What shape are the gram-positive bacteria in the above photograph?
    A) coccus **C)** spirillum
    B) bacillus **D)** ovoid
17. What shape are the gram-negative bacteria in the above photograph?
    A) coccus **C)** spirillum
    B) bacillus **D)** ovoid

Carolina Biological /Visuals Unlimited

Thinking Critically

18. Infer what would happen if nitrogen-fixing bacteria could no longer live on the roots of some plants.

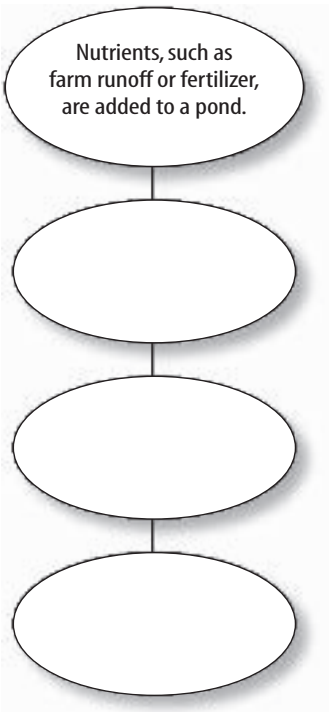
19. Explain why bacteria are capable of surviving in almost all environments of the world.

20. Draw a conclusion as to why farmers often rotate crops such as beans, peas, and peanuts with other crops such as corn, wheat, and cotton.

21. Describe One organism that causes bacterial pneumonia is called pneumococcus. What is its shape?

22. List the precautions that can be taken to prevent food poisoning.

23. Concept Map Copy and complete the following events-chain concept map about the events surrounding a cyanobacteria bloom.



24. Design an experiment to decide if a kind of bacteria could grow anaerobically.

25. Describe the nitrogen-fixing process in your own words, using numbered steps. You will probably have more than four steps.

26. Infer the shape of pneumococcus bacteria.

Performance Activities

27. Poster Create a poster that illustrates the effects of bacteria. Use photos from magazines and your own drawings.

28. Poem Write a poem that demonstrates your knowledge of the importance of bacteria to human health.

Applying Math

Use the table below to answer questions 29 and 30.

Bacterial Reproduction Rates

Temperature (°C)	Doubling Rate Per Hour
20.5	2.0
30.5	3.0
36.0	2.5
39.2	1.2

29. Doubling Rate Graph the data from the table above. Using the graph, determine where the doubling rate would be at 20°C. Where would the doubling rate be at 40°C?

30. Bacterial Reproduction Bacteria can reproduce rapidly. At 30.5°C, some species of bacteria can double their numbers in 3.0 hours. A biologist places a single bacterium on growth medium at 6:00 A.M. and incubates the bacteria until 4:00 P.M. the same afternoon. How many bacterium will there be?

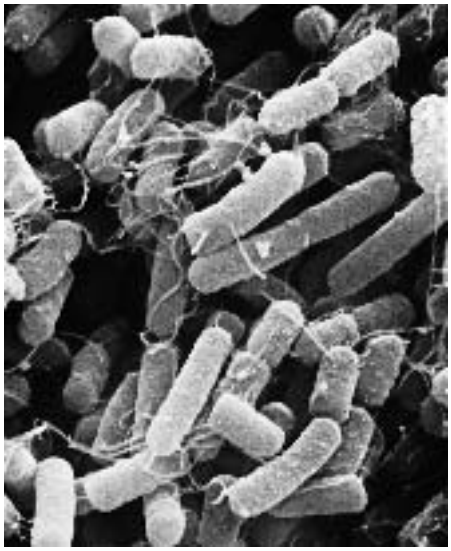
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Most pathogenic bacteria are consumer eubacteria and are grouped according to what characteristic?
A. chlorophyll **C.** cell wall
B. ribosomes **D.** plasmids

2. Which of the following cannot be found in a bacterial cell?
A. ribosomes **C.** chromosome
B. nucleus **D.** cytoplasm

Use the photo below to answer questions 3 and 4.

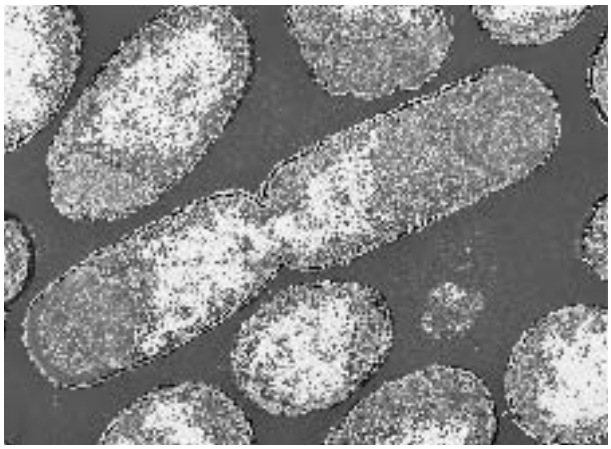


3. What shape are the bacterial cells shown above?
A. bacillus **C.** spirillum
B. coccus **D.** tubular

4. These bacteria are methane producers. Which of the following statements is true of these bacteria?
A. They are aerobic.
B. They are in Kingdom Eubacteria.
C. They are used in sewage treatment.
D. They live only near deep ocean vents.

5. Which of the following foods is not processed with the help of bacteria?
A. beef **C.** yogurt
B. cheese **D.** pickles

Use the photo below to answer questions 6 and 7.



6. What process is occurring in the above photograph?
A. mitosis **C.** fusion
B. fission **D.** conjugation

7. The above is an example of what kind of reproduction?
A. sexual **C.** meitotic
B. asexual **D.** symbiotic

8. What characteristic probably was used in naming cyanobacteria?
A. pigments **C.** cell shape
B. slime layer **D.** cell wall

9. Each bacterium has
A. a nucleus. **C.** ribosomes.
B. mitochondria. **D.** a capsule.

Test-Taking Tip

Listen and Read Listen carefully to the instructions from the teacher and read the directions and each question carefully.

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Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

10. What characteristics can be used in naming eubacteria?

11. What does an antiseptic do? Why would an antiseptic be dangerous to humans if it killed all bacteria?

Use the photo below to answer questions 12 and 13.

12. The figure above shows plant roots that have nodules, which contain nitrogen-fixing bacteria. How does this benefit the plant?

13. This symbiotic relationship is mutualistic. Explain how bacteria benefit from this relationship.

14. What happens to dead plant material that is plowed into the soil following a crop harvest? Why is this plowing beneficial to the quality of the soil?

15. What is bioremediation? Give an example of how it is used.

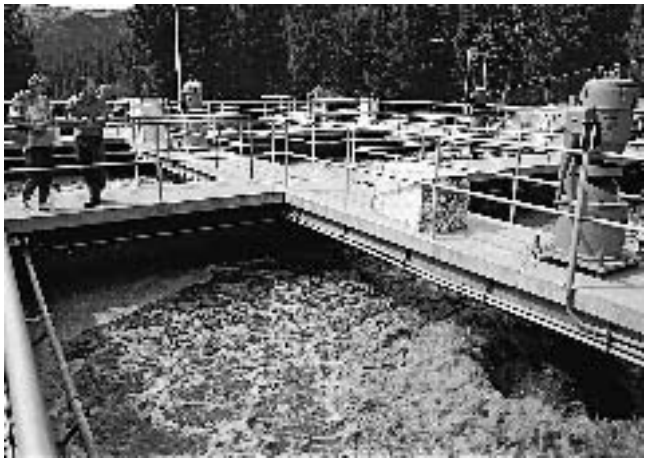
16. Most of the dairy products that you buy are pasteurized. What is pasteurization? How is it different from sterilization?

Part 3 Open Ended

Record your answers on a sheet of paper.

17. An antibiotic is prescribed to a patient to take for 10 days. After two days the patient feels better and stops taking the antibiotic. Several days later, the infection returns, but this time a greater amount of antibiotic was needed to cure the infection. Why? How could the patient have avoided the recurrence of the infection?

Use the photo below to answer questions 18 and 19.



18. Describe how aerobic bacteria in the wastewater treatment tank shown above clean the water. Where does the energy that was in the waste go?

19. Aerobic bacteria removed from the tanks, along with some solid waste, form sludge. After the sludge is dried, detoxified, and sterilized, it is either burned or applied to soil. What would be the benefit of applying it to soil? Why is it important to detoxify and sterilize the sludge first?

20. What causes a bloom of cyanobacteria? Explain how it can cause fish and other organisms in a pond to die.