Unit 6

Viruses, Bacteria, Protists, and Fungi

Only about 1.8 million of an estimated 10 million species have been identified. Most of the unidentified species probably belong to kingdoms that you will study in this unit. However, some members of these kingdoms, such as those shown in the photograph, are well known.

Unit Contents

Unit Project

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Chapter

18 Viruses and Bacteria

Magnification: 4600×

What You'll Learn

- You will categorize viruses and bacteria.
- You will explain how viruses and bacteria reproduce.
- You will recognize the medical and economic importance of viruses and bacteria.

Why It's Important

Viruses and bacteria are important because some cause diseases. Bacteria are also important in nature's nutrient cycles and in the food and pharmaceutical industries.

Reading Biology

Draw a line down the middle of a sheet of paper. Label one side "Virus" and the other "Bacteria." As you read, write down different characteristics of the two. Also, write down any key terms or questions that arise.

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To find out more about viruses and bacteria, visit the Glencoe Science Web site.
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Magnification: 30 000×

You may not recognize the landscape shown here, but it is human skin. Many bacteria, such as this *Staphylococcus epidermidis* (inset), live on your skin.

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Section

18.1 Viruses

SECTION PREVIEW

Objectives

Identify the different kinds of viruses.

Compare and contrast the replication cycles of viruses.

Vocabulary

virus
host cell
bacteriophage
capsid
lytic cycle
lysogenic cycle
provirus
retrovirus
reverse transcriptase

How many childhood diseases have you had—chicken pox, mumps, German measles, whooping cough? These diseases occur mostly in children and therefore are called childhood diseases. When your grandparents were young, these childhood diseases were so common that most children got them. Today, the availability of vaccinations makes these diseases rare. However, the causes of childhood diseases still exist, and these causes will break out where people are not vaccinated against them.

Magnification: 200 000×

A child being vaccinated (above) and a *Rubella* virus (inset)

What Is a Virus?

You've probably had influenza—the flu—at some time during your life. Nonliving particles called **viruses** cause influenza. Viruses are about one-half to one-hundredth the size of the smallest bacterium. To appreciate how very tiny viruses are, try the *MiniLab* on the next page.

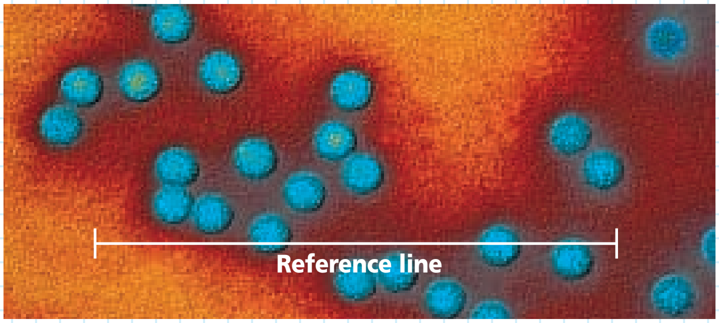
Most biologists consider viruses to be nonliving because viruses are not cells and don't exhibit all the criteria for life. For example, they don't carry out respiration, grow, or develop. All viruses can do is replicate—make copies of themselves—and they can't even do that without the help of living cells. A cell in which a virus replicates is called the **host cell.**

Because they are nonliving, viruses were not named in the same way as organisms. Viruses, such as rabies viruses and polioviruses, were named after the diseases they cause. Other viruses were named for the organ or tissue they infect. For example, scientists first found the adenovirus (uh DEN uh vyruhs), which is one cause of the common cold, in adenoid tissue between the back of the throat and the nasal cavity.

MiniLab 18-1 Measuring in SI

Measuring a Virus Can you use a light microscope to view a virus? Find out by measuring the size of a poliovirus in the photo below and then comparing it to 0.2 µm, the size limit for viewing objects with a light microscope.

Magnification: 172 500×



Procedure

1. Copy the data table below.

Data Table	
Values to measure and calculate	**Measurement**
Length of photo line in mm	
Diameter of poliovirus in mm	
Diameter of poliovirus in µm	

2. Examine the photo. The horizontal line you see would measure only 0.4 micrometer (µm) in length if the photo was not magnified 172 500×. Use this line for reference.
3. Calculate the diameter of one poliovirus. First, measure the length of the reference line in millimeters. Record the value in the table. Then, measure the diameter of a poliovirus in millimeters. Record the value in the table.
4. Use the following equation to calculate the actual diameter of the poliovirus *(X).* Record your answer in the table.

$$\frac{\text{photo line length in mm } (A)}{\text{diameter of virus in mm } (B)} = \frac{0.4\ \mu\text{m}}{\text{diameter of virus in } \mu\text{m } (X)}$$

Analysis

1. Explain why you cannot see viruses with a light microscope. Use specific numbers in your answer.
2. A bacterial cell may be 10 µm in size. How many polioviruses could fit across the top of such a bacterium?

Today, most viruses are given a genus name ending in the word "virus" and a species name. However, sometimes scientists use code numbers to distinguish among similar viruses that infect the same host. For example, seven similar-looking viruses that infect the common intestinal bacteria *Escherichia coli* have the code numbers T1 through T7 (*T* stands for "Type"). A virus that infects a bacterium is called a **bacteriophage** (bak TIHR ee uh fayj), or phage for short.

Viral structure

A virus has an inner core of nucleic acid, either RNA or DNA, and an outer coat of protein called a **capsid.** Some relatively large viruses, such as human flu viruses, may have an additional layer, called an envelope, surrounding their capsids. Envelopes are composed primarily of the same materials that are found in the plasma membranes of all cells. You can learn more about both viral capsids and envelopes in the *Focus On* at the end of this section.

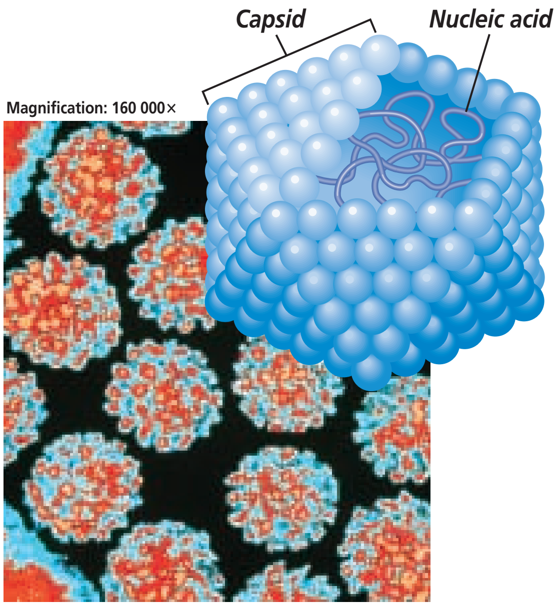
The core of nucleic acid contains a virus's genetic material. Viral nucleic acid is either DNA or RNA and contains instructions for making copies of the virus. Some viruses have only four genes. The arrangement of proteins in the capsid of a virus determines the virus's shape. Four different viral shapes are shown in ***Figure 18.1.*** The protein arrangement also plays a role in determining what cell can be infected and how the virus infects the cell.

Attachment to a host cell

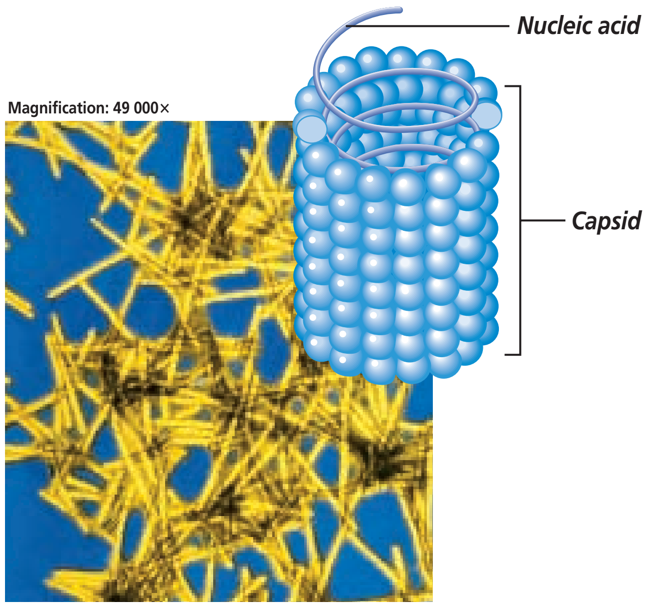
Before a virus can replicate, it must enter a host cell. Before it can enter, it must first recognize and attach to a receptor site on the plasma membrane of the host cell.

A virus recognizes and attaches to a host cell when one of its proteins interlocks with a molecular shape that is the receptor site on the host cell's plasma membrane. A protein in the tail fibers of the bacteriophage T4, shown in ***Figure 18.1,*** recognizes and attaches the T4 to its bacterial host cell. In other viruses, the attachment protein is in the capsid or in the envelope. The recognition and attachment process is like two pieces of a jigsaw puzzle fitting together. The process might also remind you of two spaceships docking.

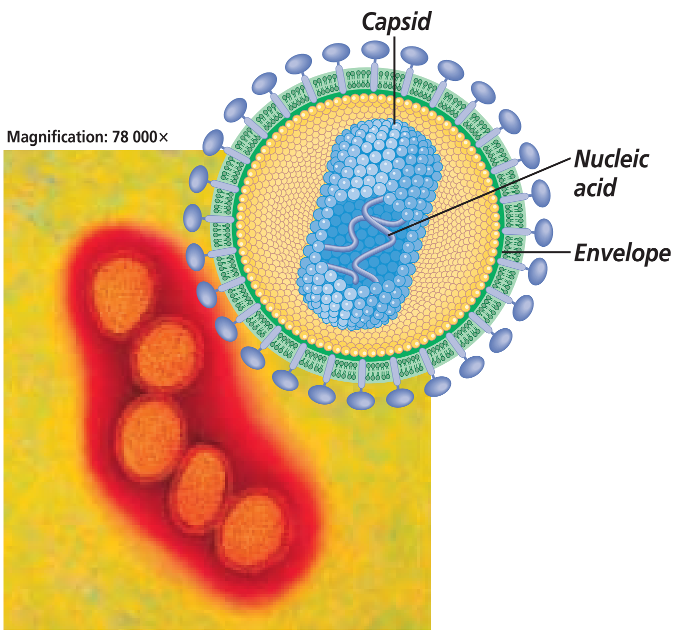
Figure 18.1
The different proteins in viral capsids produce a wide variety of viral shapes.



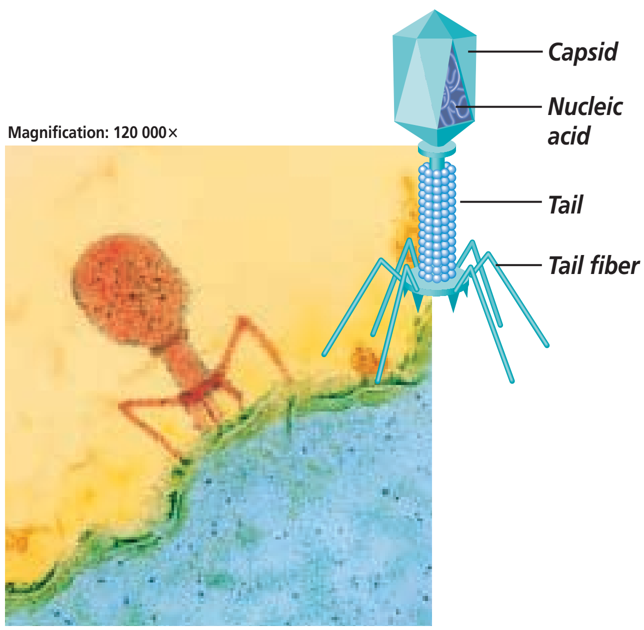
A Polyhedral viruses, such as the papilloma virus that causes warts, resemble small crystals.



B The tobacco mosaic virus has a long, narrow helical shape.



C An envelope studded with projections covers some viruses, including the influenza virus (photo) and the AIDS-causing virus (inset).



D This T4 virus, which infects *E. coli*, consists of a polyhedral-shaped head attached to a cylindrical tail with leglike fibers.

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Attachment is a specific process

Each virus has a specifically shaped attachment protein. Therefore, each virus can usually attach to only a few kinds of cells. For example, the T4 phage can infect only certain types of *E. coli* because the T4's attachment protein matches a surface molecule of only these *E. coli*. A T4 cannot infect a human, animal, or plant cell, or even another bacterium. Similarly, a tobacco mosaic virus infects only a cell of a tobacco plant. In general, viruses are species specific, and some also are cell-type specific. For example, polio viruses normally infect only human intestinal and nerve cells.

The species specific characteristic of viruses is significant for controlling the spread of viral diseases. For example, by 1980, the World Health Organization had announced that smallpox, which is a deadly human viral disease, had been eradicated. The eradication was possible partly because the smallpox virus infects only humans. It is more difficult to eradicate a virus that is not species specific, such as the flu virus, which infects humans and other animals.

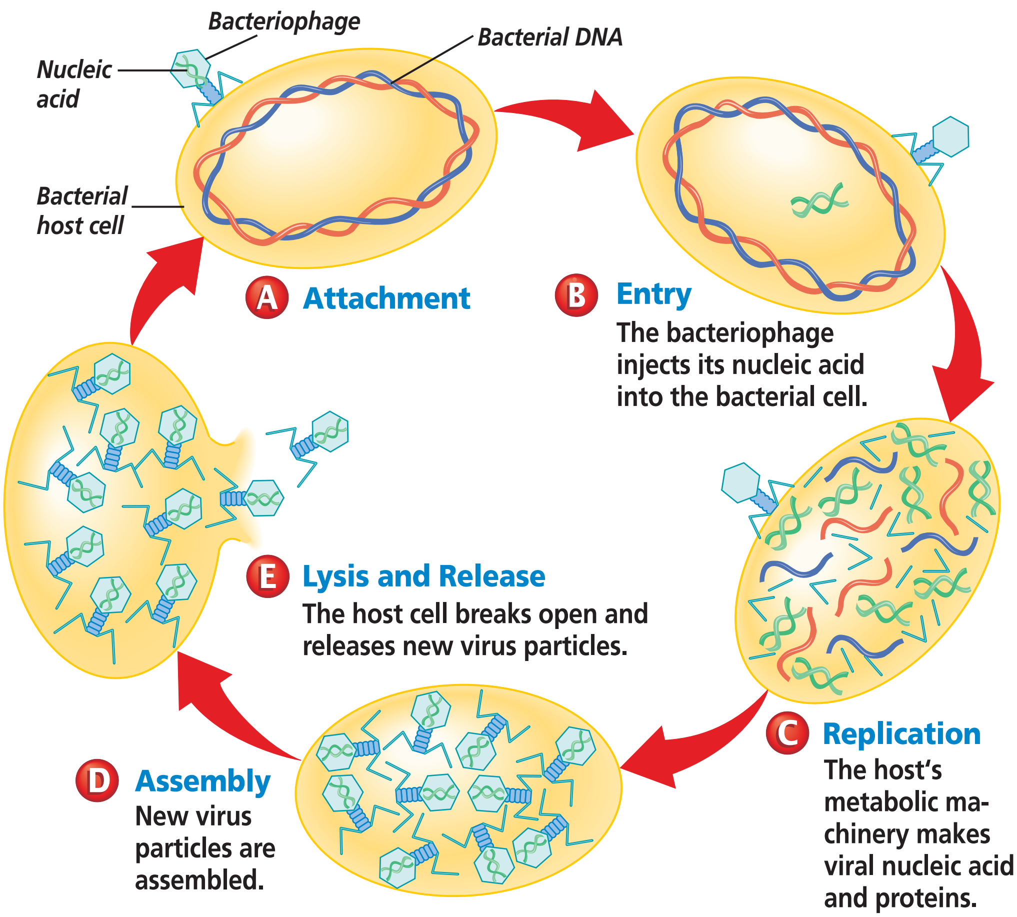
Word Origin

lytic
From the Greek word *lyein*, meaning to "break down." The host cell is destroyed during a lytic cycle.

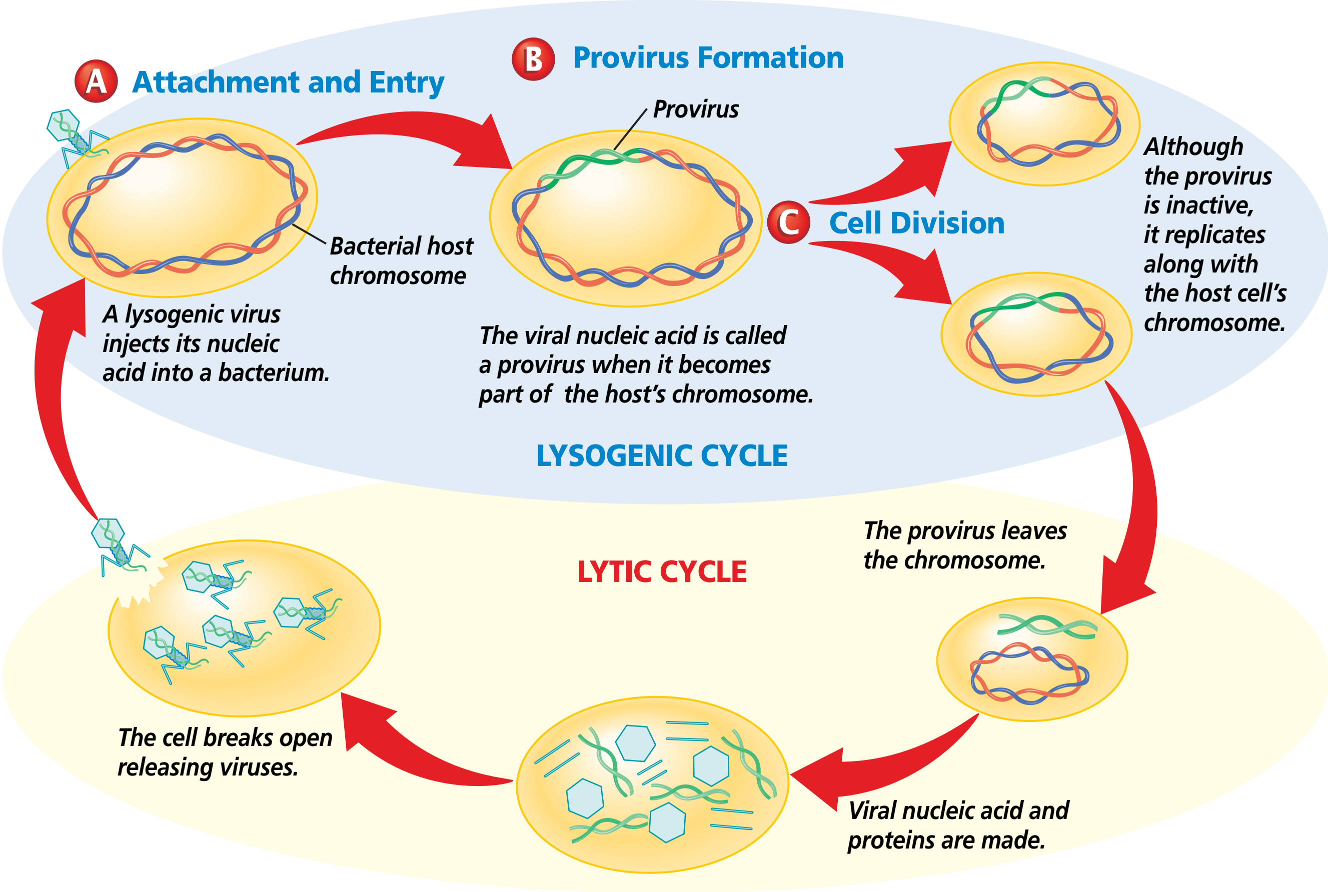
Viral Replication Cycles

Once attached to the plasma membrane of the host cell, the virus enters the cell and takes over its metabolism. Only then can the virus replicate. Viruses have two ways of getting into host cells. The virus may inject its nucleic acid into the host cell like a syringe injects a vaccine into your arm, as shown in ***Figure 18.2.*** The capsid of the virus stays attached to the outside of the host cell. An enveloped virus enters a host cell in a different way. After attachment, the plasma membrane of the host cell

Figure 18.2
In a lytic cycle, a virus uses the host cell's energy and raw materials to make new viruses. A typical lytic cycle takes about 30 minutes and produces about 200 new viruses.



CD-ROM
View an animation of *Figure 18.2* in the Presentation Builder of the Interactive CD-ROM.



surrounds the virus and produces a virus-filled vacuole inside the host cell's cytoplasm. Then, the virus bursts out of the vacuole and releases its nucleic acid into the cell.

Lytic cycle

Once inside the host cell, a virus's genes are expressed and the substances that are produced take over the host cell's genetic material. The viral genes alter the host cell to make new viruses. The host cell uses its own enzymes, raw materials, and energy to make copies of viral genes that along with viral proteins are assembled into new viruses, which burst from the host cell, killing it. The new viruses can then infect and kill other host cells. This process is called a **lytic cycle** (LIH tik). Follow the typical lytic cycle for a bacteriophage shown in ***Figure 18.2.***

Lysogenic cycle

Not all viruses kill the cells they infect. Some viruses go through a **lysogenic cycle,** a replication cycle in which the virus's nucleic acid is integrated into the host cell's chromosome. A typical lysogenic cycle for a virus that contains DNA is shown in ***Figure 18.3.***

A lysogenic cycle begins in the same way as a lytic cycle. The virus attaches to the host cell's plasma membrane and its nucleic acid enters the cell. However, in a lysogenic cycle, instead of immediately taking over the host's genetic material, the viral DNA is integrated into the host cell's chromosome.

Viral DNA that is integrated into the host cell's chromosome is called a **provirus.** A provirus may not affect the functioning of its host cell, which continues to carry out its own metabolic activity. However, every time

Figure 18.3
In a lysogenic cycle, a virus does not destroy the host cell at once. Rather, the viral nucleic acid is integrated into the genetic material of the host cell and replicates with it for a while before entering a lytic cycle.

CD-ROM
View an animation of ***Figure 18.3*** in the Presentation Builder of the Interactive CD-ROM.

Problem-Solving Lab 18-1

Analyzing Information

What type of virus causes disease? The symptoms and incubation time of a disease can indicate how the virus acts inside its host cell.

Analysis

Table 18.1 lists symptoms and incubation times for some viral diseases. Use the table to predict which diseases lytic viruses might cause and which diseases lysogenic viruses might cause.

Table 18.1 Characteristics of some viral diseases

Disease	Symptom	Incubation
Measles	rash, fever	9-11 days
Shingles	pain, itching on skin	years
Warts	bumpy areas on skin	months
Coryza (cold)	sneezing, runny nose, fever	2-4 days
HIV	fatigue, weight loss, fever	2-5 years

Thinking Critically

1. How much time is associated with the replication cycle of a lytic virus? A lysogenic virus?
2. What diseases may lytic viruses cause? Explain your answer.
3. What diseases may lysogenic viruses cause? Explain your answer.
4. What is a possible consequence of the fact that a person infected with HIV may have no symptoms for years?

Figure 18.4
Before the influenza virus leaves a host cell, it is wrapped in a piece of the host's plasma membrane, making an envelope with the same structure as the host's plasma membrane

Magnification: 18 000×

the host cell reproduces, the provirus is replicated along with the host cell's chromosome. Therefore, every cell that originates from an infected host cell has a copy of the provirus. The lysogenic phase can continue for many years. However, at any time, the provirus can be activated and enter a lytic cycle. Then the virus replicates and kills the host cell. Try to distinguish the human diseases caused by lysogenic viruses from those caused by lytic viruses in the *Problem-Solving Lab* on this page.

Disease symptoms of proviruses

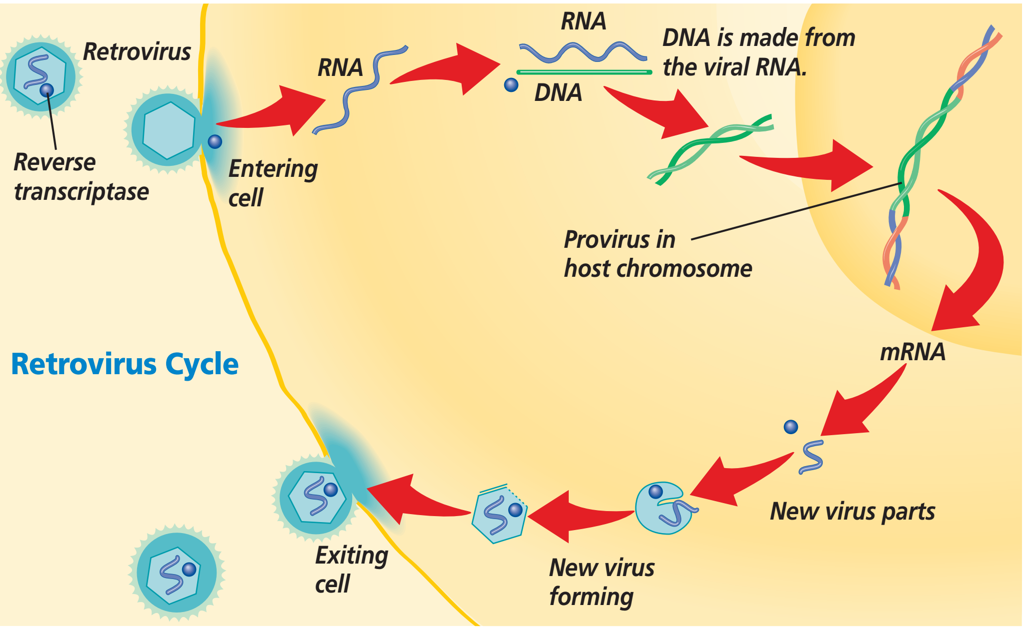
The lysogenic process explains the reoccurrence of cold sores, which are caused by the herpes simplex I virus. Even though a cold sore heals, the herpes simplex I virus remains in your cells as a provirus. When the provirus enters a lytic cycle, another cold sore erupts. No one knows what causes a provirus to be activated, but some scientists suspect that physical stress, such as sunburn, and emotional stress, such as anxiety, play a role.

Many disease-causing viruses have lysogenic cycles. Three examples of these viruses are herpes simplex I, herpes simplex II that causes genital herpes, and the hepatitis B virus that causes hepatitis B. Another lysogenic virus is the one that causes chicken pox. Having chicken pox, which usually occurs before age ten, gives lifelong protection from another infection by the virus. However, some chicken pox viruses may remain as proviruses in some of your body's nerve cells. Later in your life, these proviruses may enter a lytic cycle and cause a disease called shingles—a painful infection of some nerve cells.

Release of viruses

Either lysis, the bursting of a cell, or exocytosis, ***Figure 18.4***, the active

Figure 18.5
Retroviruses have an enzyme that transcribes their RNA into DNA. The viral DNA becomes a provirus that steadily produces small numbers of new viruses without immediately destroying the cell.



transport process by which materials are expelled or secreted from a cell, release new viruses from the host cell. In exocytosis, a newly produced virus approaches the inner surface of the host cell's plasma membrane. The plasma membrane surrounds the virus, enclosing it in a vacuole that then fuses with the host cell's plasma membrane. Then, the viruses are released to the outside.

Retroviruses

Many viruses, such as the human immunodeficiency virus (HIV) that causes the disease AIDS, are RNA viruses—RNA being their only nucleic acid. The RNA virus with the most complex replication cycle is the **retrovirus** (reh tro VY rus). How can RNA be integrated into a host cell's chromosome, which contains DNA?

Once inside a host cell, the retrovirus makes DNA from its RNA. To do this, it uses **reverse transcriptase** (trans KRIHP taz), an enzyme it carries inside its capsid. This enzyme helps produce double-stranded DNA from the viral RNA. Then the double-stranded viral DNA is integrated into the host cell's chromosome and becomes a provirus. If reverse transcriptase is found in a person, it is evidence for infection by a retrovirus. You can see how a retrovirus replicates in its host cell in ***Figure 18.5.***

Careers in Biology

Dairy Farmer

Did you grow up on a farm, or do you wish you did? Would you enjoy a chance to work with animals and be outdoors? Perhaps you should be a dairy farmer.

Skills for the Job

In the past, most dairy farms were family owned, but now corporations own some of these farms. A person can learn dairy farming on the job, or by completing two- and four-year college programs in agriculture. A degree in agriculture can lead to certification as a farm manager. Dairy farmers must keep their herds healthy and producing both milk and calves. Like all farming, dairy farming is a risky business that depends on factors such as the weather, the cost of feed, the amount of milk the herds produce, and the market price for milk and milk products.

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HIV: An infection of white blood cells

Once inside a human host, HIV infects white blood cells. Newly made viruses are released into the blood stream by exocytosis. Then these viruses infect other white blood cells. Infected host cells still function normally because the viral genetic material is a provirus that produces only a small number of new viruses at a time. Because the infected cells are still able to function normally, an infected person may not appear sick. However, people who are infected with HIV but have no symptoms can transmit the virus in their body fluids.

An HIV-infected person can experience no AIDS symptoms for a long time. However, most people with an HIV infection eventually get AIDS because, over time, more and more white blood cells are infected and produce new viruses, ***Figure 18.6.*** People will gradually lose white blood cells because proviruses enter a lytic cycle and kill their host cells. Because white blood cells are part of a body's disease-fighting system, their destruction interferes with the body's ability to protect itself from organisms that cause disease, a symptom of AIDS.

Viruses and Cancer

Retroviruses are one kind of virus that may cause some cancers. The retroviruses that convert, or transform, normal cells to tumor cells are known as tumor viruses. The first tumor virus was discovered in chickens. In addition to retroviruses, the papilloma virus, which is a DNA virus that causes warts, and the hepatitis B virus, a DNA virus thought to cause liver cancer in humans, are also tumor viruses.

Plant Viruses

The first virus to be identified was a plant virus, called tobacco mosaic virus, that causes disease in tobacco plants. Biologists know of more than 400 viruses that infect a variety of plants. These viruses cause as many as 1000 plant diseases.

Not all viral plant diseases are fatal or even harmful. For example, there are some mosaic viruses that cause striking patterns of color in the flowers

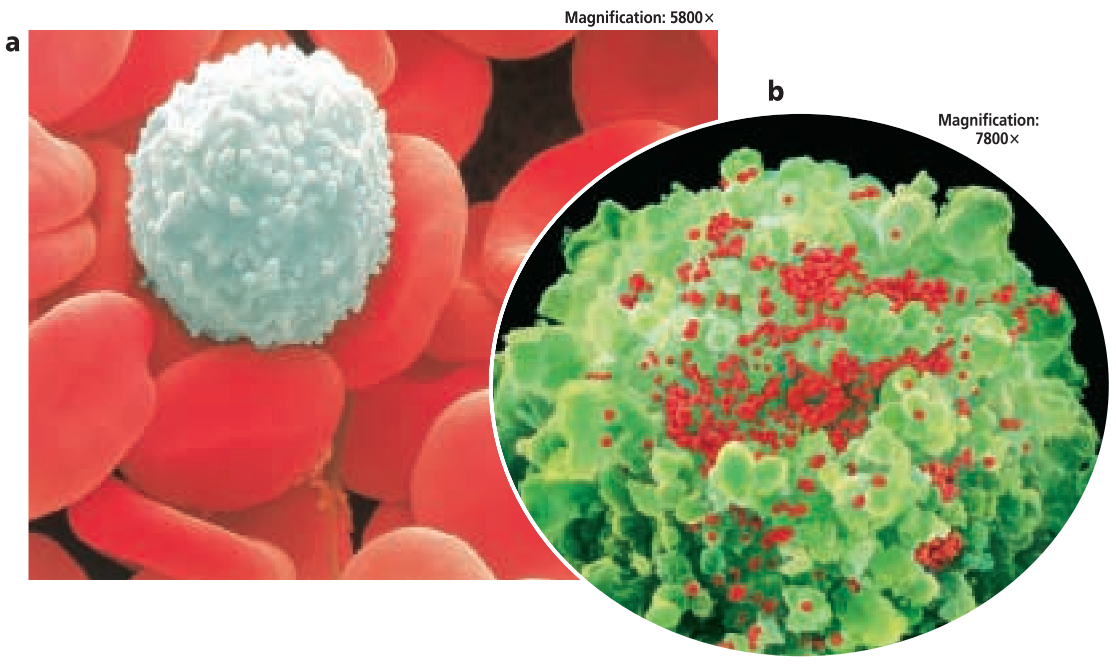


Figure 18.6
Normal white blood cells are an essential part of a human's immune system (a). In an HIV infected person, white blood cells are eventually destroyed by HIV proviruses that enter lytic cycles (b).

a

b

Figure 18.7
Tobacco mosaic virus causes yellow spots on tobacco leaves, making them unmarketable (a). In contrast, another virus causes the beautiful stripes of Rembrandt tulips, making them more desirable (b).

of plants such as some tulips, gladioli, and pansies. The infected flowers, like the one shown in ***Figure 18.7***, have streaks of vibrant, contrasting colors in their petals. These viruses are easily spread among plants when you cut an infected stem and then cut healthy stems with the same tool.

Origin of Viruses

You might assume that viruses represent an ancestral form of life because of their relatively uncomplicated structure. This is probably not so. For replication, viruses need host cells; therefore, scientists suggest that viruses might have originated from their host cells.

Some scientists suggest that viruses are nucleic acids that break free from their host cells while maintaining an ability to replicate parasitically within the host cells. The fact that tumor viruses contain genes that are identical to ones found in normal cells is evidence for this hypothesis. According to this hypothesis, viruses are more closely related to their host cells than they are to each other.

Section Assessment

Understanding Main Ideas

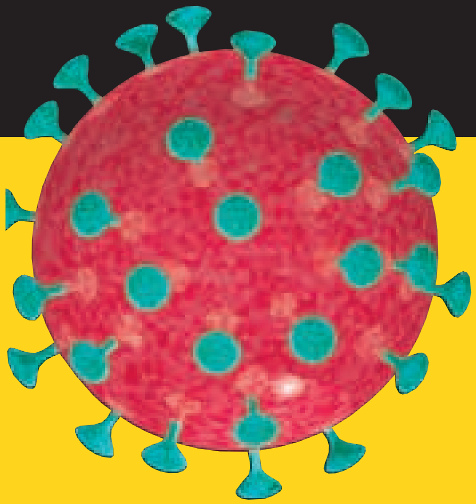
1. Why is a virus considered to be nonliving?
2. What is the difference between a lytic cycle and a lysogenic cycle?
3. What is a provirus?
4. How do retroviruses convert their RNA to DNA?

Thinking Critically

5. Describe the state of a herpes virus in a person who had cold sores several years ago but who does not have them now.

Skill Review

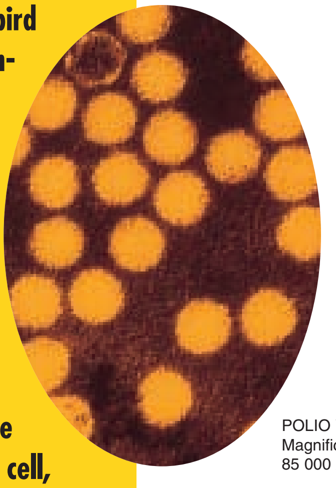
6. **Making and Using Graphs** A microbiologist added some viruses to a bacterial culture. Every hour from noon to 4:00 p.m., she determined the number of viruses present in a sample of the culture. Her data were 3, 3, 126, 585, and 602. Graph these results. How would the graph look if the culture had initially contained dead bacteria? For more help, refer to *Organizing Information* in the **Skill Handbook.**



MODEL OF AIDS VIRUS

FOCUS ON Viruses

Viruses lurk everywhere—on computer keyboards, in bird droppings, under your fingernails—just waiting to get inside your body or some other living thing. Smaller than the smallest bacteria, viruses are not alive. By themselves, they cannot move, grow, or reproduce. But give viruses the chance to invade a living cell, and they will take over its metabolic machinery, reprogramming it to churn out more viruses to attack other cells.



POLIO VIRUS
Magnification: 85 000 x

INVISIBLE INVADERS

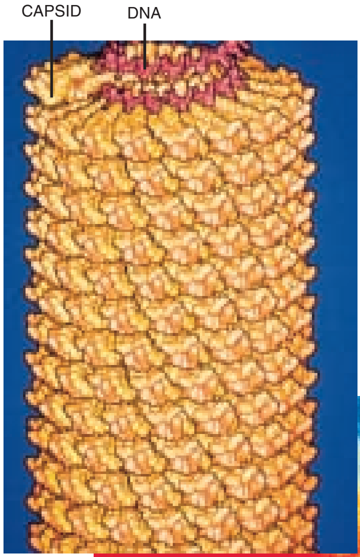
Scientists have identified thousands of viruses. Some invade plants, others attack animals, and still others target bacteria.

In humans, viruses are responsible for chicken pox, warts, cold sores, and the common cold, as well as dreaded diseases such as rabies, influenza, hepatitis, and AIDS.

WOMAN EXPERIENCING SYMPTOMS OF THE COMMON COLD

STRUCTURE

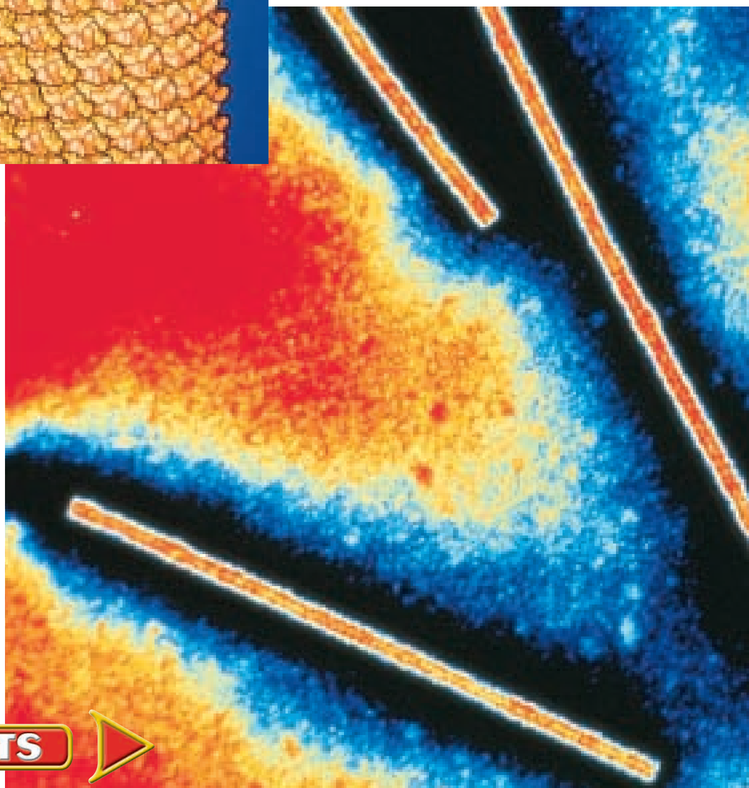
A single drop of blood can contain six billion viruses. Despite their incredibly small size, many viruses, such as this tobacco mosaic virus (below), have complex structures. All viruses consist of a core of nucleic acid—either DNA or RNA—enclosed in a protein coat called a capsid. Both the type and arrangement of proteins in the capsid give different viruses characteristic shapes.



MODEL OF TOBACCO MOSAIC VIRUS

ICOSAHEDRAL VIRUSES

Many animal viruses—such as polio (above) and adenovirus—have 20-sided, or icosahedral, capsids. Viewed under an electron microscope, icosahedral viruses look like perfectly symmetrical crystals.



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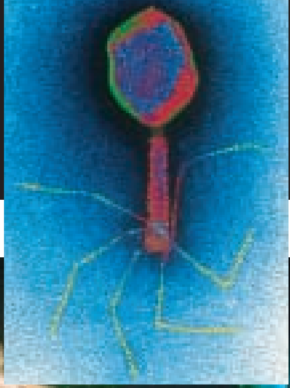
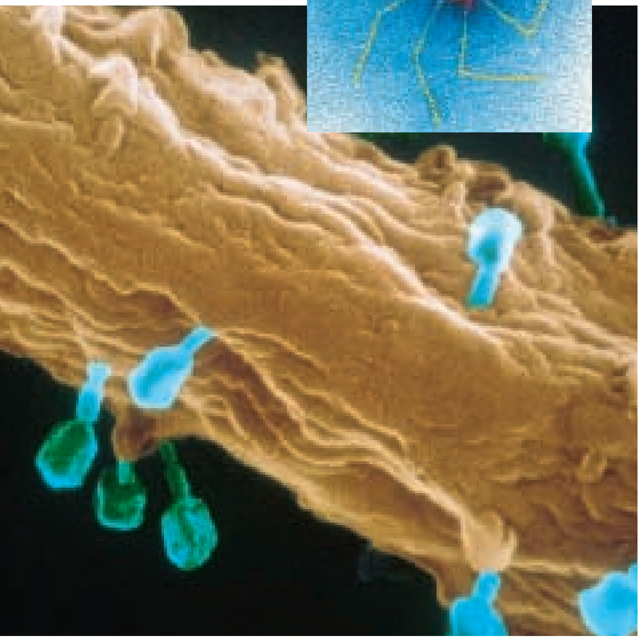


T-PHAGE



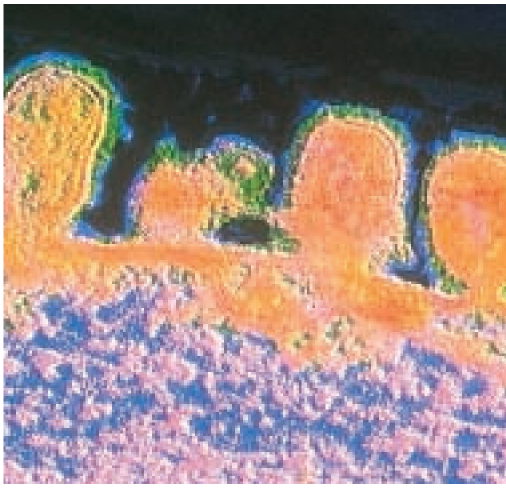
T-PHAGES, IN BLUE, INFECTING *E. COLI* BACTERIUM
Magnification: 90 000 x

PHAGES

Bacteriophages, or phages for short, are viruses that infect bacteria. This T4-phage (top left), looks like a miniature lunar-landing module. It has a DNA-containing head, a protein tail, and protein tail fibers that attach to the surface of a bacterium. Once viruses are attached (left), the tail section contracts and pierces the cell wall, and viral DNA is injected into the host cell.

ENVELOPED VIRUSES

Some viruses, such as influenza and HIV (the virus that causes AIDS), are enclosed in an envelope composed of lipids, carbohydrates, and proteins. Envelope proteins (right) form spiky projections that help the virus gain entry to a host cell, much like keys fitting into a lock.



INFLUENZA VIRUS
Magnification: 17 150 x

HELICAL VIRUSES

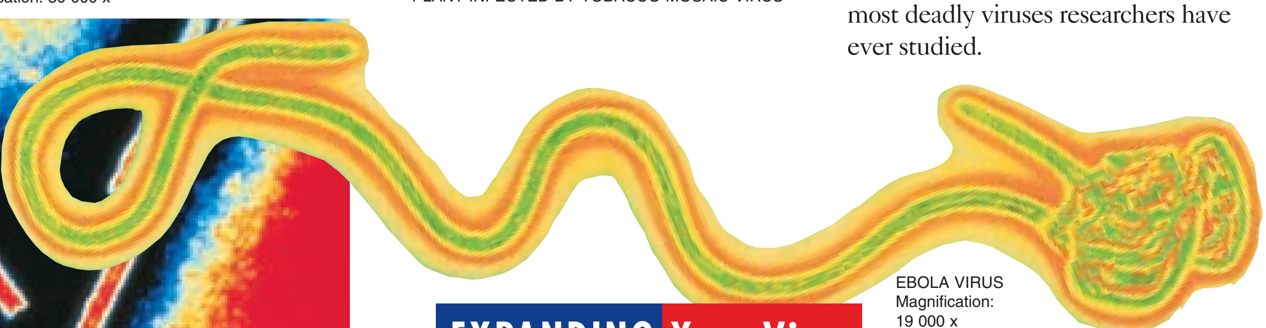
Helical viruses are shaped like tiny cylinders, with the viral genetic material spiraling down the center of a hollow protein tube. Tobacco mosaic virus (below), which infects plants (right), is a long helical virus.

PLANT INFECTED BY TOBACCO MOSAIC VIRUS

TOBACCO MOSAIC VIRUS
Magnification: 30 000 x

DEADLY BEAUTY

Some viruses have irregular shapes. The Ebola virus (below), which causes massive internal bleeding in humans, has a twisted, worm-like form. A strain of Ebola virus from Zaire, Africa, is one of the most deadly viruses researchers have ever studied.



EBOLA VIRUS
Magnification: 19 000 x

EXPANDING Your View

1. **THINKING CRITICALLY** In what way might viruses like those that cause common colds be considered "more successful" than viruses such as Ebola?

2. **JOURNAL WRITING** Read *The Andromeda Strain* (1969) by Michael Crichton, a science fiction story about an alien virus that comes to Earth. In your journal, record your reactions to the book. What similarities did you notice between how scientists in the story handled the alien virus and how present-day scientists study viruses such as Ebola?

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Objectives

Compare the types of prokaryotes.

Explain the characteristics and adaptations of bacteria.

Evaluate the economic importance of bacteria.

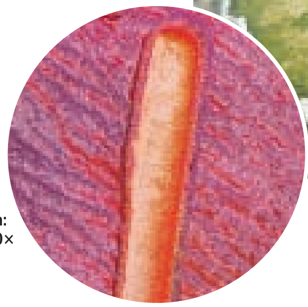
Vocabulary

chemosynthesis
binary fission
conjugation
obligate aerobe
obligate anaerobe
endospore
toxin
nitrogen fixation

Section

18.2 Archaebacteria and Eubacteria

Imagine yourself going back three-and-a-half billion years. You wander around the young Earth and find yourself alone with the first life on this planet. Dinosaurs? Saber-toothed tigers? No. You would be alone with what have become some of the most diverse forms of life on Earth—prokaryotes.



Magnification: 17 280×

A hot spring (above) and the archaebacterium *Thermoproteus tenax* (inset)

Diversity of Prokaryotes

Recall that prokaryotes are unicellular organisms that do not have membrane-bound organelles. They are classified in two kingdoms—archaebacteria and eubacteria. Many biochemical differences exist between these two types of prokaryotes. For example, their cell walls and the lipids in their plasma membranes differ. In addition, the structure and function of the genes of archaebacteria are more similar to those of eukaryotes than to those of bacteria.

Because they are so different, many scientists propose that archaebacteria and eubacteria arose separately from a common ancestor several billion years ago. The exact time is unknown.

Archaebacteria: Often the extremists

There are three types of archaebacteria that live mainly in extreme habitats where there is usually no free oxygen available. You can see some of these inhospitable places in ***Figure 18.8.*** One type of archaebacterium lives in oxygen-free environments and produces methane gas. These methane-producing archaebacteria live in marshes, lake sediments, and the digestive tracts of some mammals, such as cows. They also are found at sewage disposal plants, where they play a role in the breakdown of sewage.

A second type of archaebacterium lives only in water with high concentrations of salt, such as in Utah's Great Salt Lake and the Middle East's

Figure 18.8
Archaebacteria live in extreme environments.

A **Methane-producing archaebacteria flourish in this swamp and also live in the stomachs of cows.**

B **Salt-loving archaebacteria live in these salt pools left after this lake in British Columbia, Canada evaporated. These pools have high levels of magnesium and potassium salts.**

C **Heat- and acid-loving archaebacteria live around deep ocean vents where water temperatures are often above 100°C.**

Dead Sea. A third type lives in the hot, acidic waters of sulfur springs. This type of anaerobic archaebacterium also thrives near cracks deep in the Pacific Ocean's floor, where it is the autotrophic producer for a unique animal community's food chain.

Eubacteria: The heterotrophs

Eubacteria, the other kingdom of prokaryotes, includes those prokaryotes that live in more hospitable places than archaebacteria inhabit and that vary in nutritional needs. The heterotrophic eubacteria live almost everywhere and use organic molecules as a food source. Some bacterial heterotrophs are parasites, obtaining their nutrients from living organisms. They are not adapted for trapping food that contains organic molecules or for making organic molecules themselves. Others are saprophytes, which are organisms that feed on dead organisms or organic wastes. Recall that saprophytes break down and thereby recycle the nutrients locked in the body tissues of dead organisms.

Eubacteria: Photosynthetic autotrophs

A second type of eubacterium is the photosynthetic autotroph. These eubacteria live in places with sunlight because they need light to make the organic molecules that are their food. Cyanobacteria are photosynthetic autotrophs. They contain the pigment chlorophyll that traps the sun's energy, which they then use in photosynthesis. Most cyanobacteria, like the *Anabaena* shown in ***Figure 18.9***, are blue-green and some are red or yellow in color. Cyanobacteria commonly live in ponds, streams, and moist areas of land. They are composed of chains of independent cells—an exception to the unicellular form of most other bacteria.

WORD Origin

cyanobacterium
From the Greek words *kyanos*, meaning "blue," and *bakterion*, meaning "small rod." The cyanobacteria are blue-green bacteria.

Eubacteria: Chemosynthetic autotrophs

A third type of eubacterium is the chemosynthetic autotroph. Like photosynthetic bacteria, these bacteria make organic molecules that are their food. However, unlike the photosynthetic bacteria, the chemosynthetic bacteria do not obtain the energy they need to make food from sunlight. Instead, they break down and release the energy of inorganic compounds containing sulfur and nitrogen in the process called **chemosynthesis** (kee moh SIHN thuh sus). Some chemosynthetic bacteria are very important to other organisms because they are able to convert atmospheric nitrogen into the nitrogen-containing compounds that plants need.

Magnification: 1100×

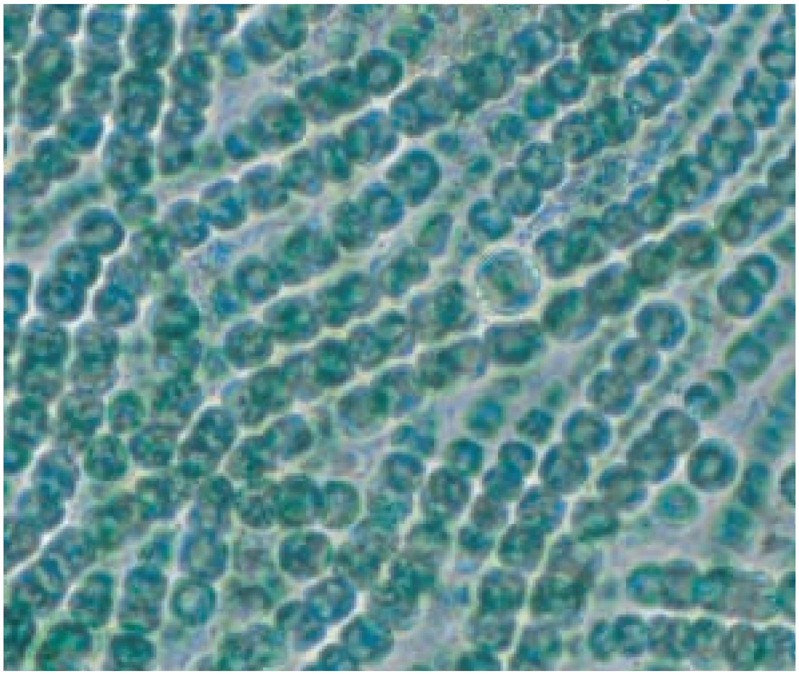


Figure 18.9
Cyanobacteria, such as *Anabaena*, have a blue-green color.

What Is a Bacterium?

A bacterium consists of a very small cell. Although tiny, a bacterial cell has all the structures necessary to carry out its life functions.

The structure of bacteria

Prokaryotic cells have ribosomes, but their ribosomes are smaller than those of eukaryotes. They also have genes that are located for the most part in a single circular chromosome, rather than in paired chromosomes. What structures can protect a bacterium? Look at the *Inside Story* on the next page to learn about other structures located in bacterial cells.

One structure that supports and protects a bacterium is the cell wall. The cell wall protects the bacterium by preventing it from bursting. Because most bacteria live in a hypotonic environment, one in which there is a higher concentration of water molecules outside than inside the cell, water is always trying to enter a bacterial cell. A bacterial cell remains intact, however, and does not burst open as long as its cell wall is intact. If the cell wall is damaged, water will enter the cell by osmosis, causing the cell to burst. Scientists used a bacterium's need for an intact cell wall to develop a weapon against bacteria that cause disease.

INSIDE STORY

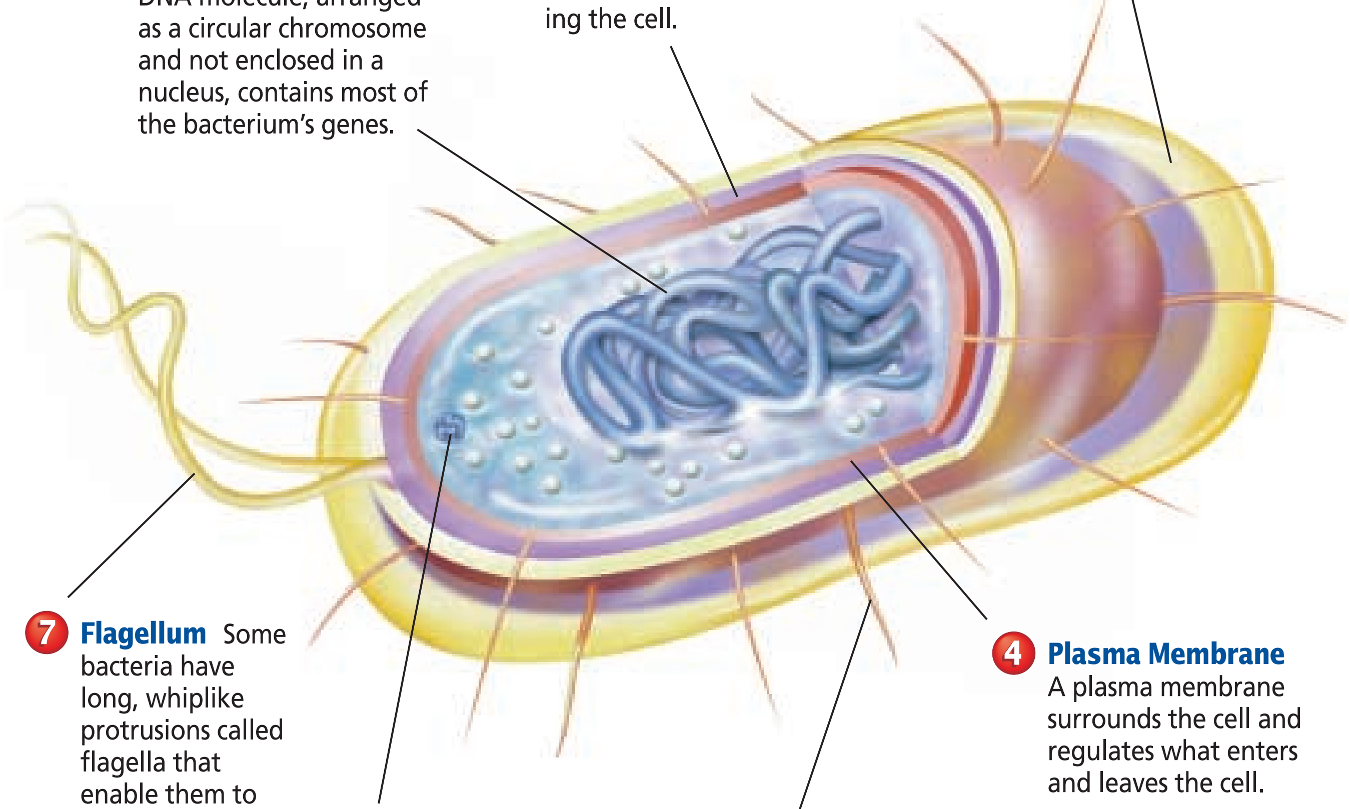
A Typical Bacterial Cell

***B**acteria are microscopic, prokaryotic cells. The great majority of bacteria are unicellular. A typical bacterium would have some or all of the structures shown in this diagram of a bacterial cell.*

Critical Thinking *Which structures of bacteria are involved in reproduction?*

Magnification: 4275×

Escherichia coli



1 Chromosome A single DNA molecule, arranged as a circular chromosome and not enclosed in a nucleus, contains most of the bacterium's genes.

2 Cell wall A cell wall surrounds the plasma membrane. It gives the cell its shape, and prevents osmosis from bursting the cell.

3 Capsule Some bacteria have a sticky gelatinous capsule around the cell wall. A bacterium with a capsule is more likely to cause disease than a bacterium without a capsule.

4 Plasma Membrane A plasma membrane surrounds the cell and regulates what enters and leaves the cell.

5 Pilus Some bacteria have pili—extensions of their plasma membranes. A hairlike pilus helps a bacterium stick to a surface. It is also like a bridge through or on which two bacteria can exchange DNA.

6 Plasmid A few genes are located in a small circular chromosome piece called a plasmid. A bacterium may have one or more plasmids.

7 Flagellum Some bacteria have long, whiplike protrusions called flagella that enable them to move.

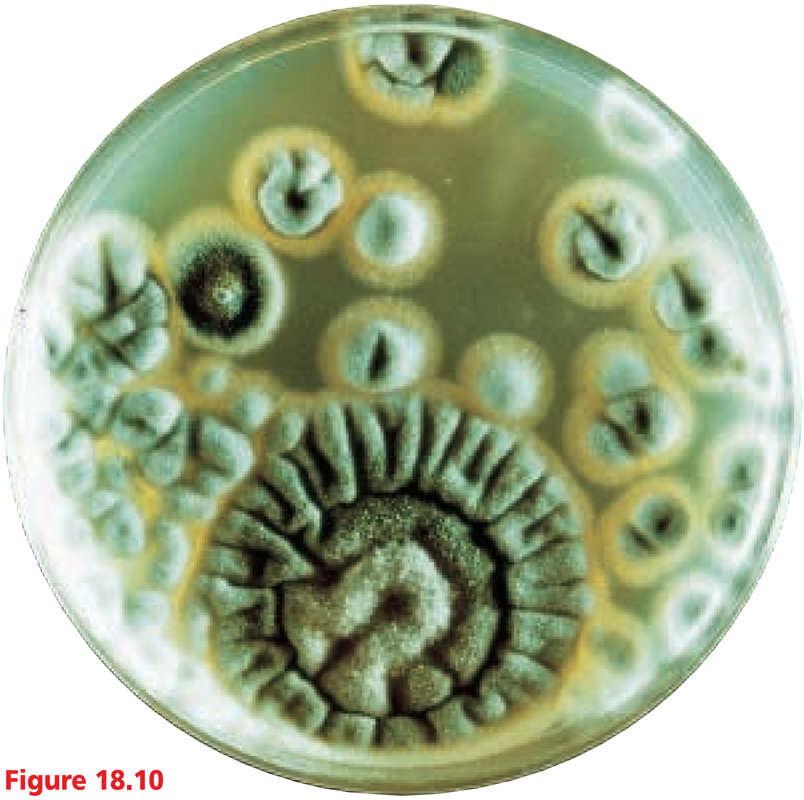


Figure 18.10
The mold known as *Penicillium notatum* produces the antibiotic penicillin.

In 1928, Sir Alexander Fleming accidentally discovered penicillin, the first antibiotic used in humans. He was growing bacteria when an airborne mold, *Penicillium notatum*, contaminated his culture plates. He noticed that the mold, shown in ***Figure 18.10***, secreted a substance—now known as the antibiotic penicillin—that killed the bacteria he was growing. Later, biologists discovered that penicillin interferes with the ability of some bacteria to make cell walls. When such bacteria grow in penicillin, holes develop in their cell walls, water enters their cells, and they rupture and die.

Identifying bacteria

You may think of bacteria as all the same, but scientists have developed ways to distinguish among them. For example, one trait that helps categorize bacteria is how they react to Gram stain. Gram staining is a technique that distinguishes two groups of bacteria because the stain reflects a basic difference in the composition of bacterial cell walls. The cell walls of all bacteria are made of interlinked sugar and amino acid molecules that differ in arrangement and therefore react differently to Gram stain. After staining, gram-positive bacteria are purple and Gram-negative bacteria are pink. Gram-positive bacteria are affected by different antibiotics—substances that can destroy bacterial cells—than the antibiotics that affect Gram-negative bacteria.

Not only do bacterial cell walls react differently to Gram stain, but they also give bacteria different shapes. Shape is another way to categorize bacteria. The three most common shapes are spheres, rods, and spirals, as shown in ***Figure 18.11.*** In addition to having one of these shapes, bacterial cells often grow in characteristic patterns that provide another way of categorizing them. Diplo- is a prefix that refers to a paired arrangement of cell growth. The prefix staphylo- describes an arrangement of cells that resemble grapes. Strepto- is a prefix that refers to an arrangement of chains of cells.

Reproduction by binary fission

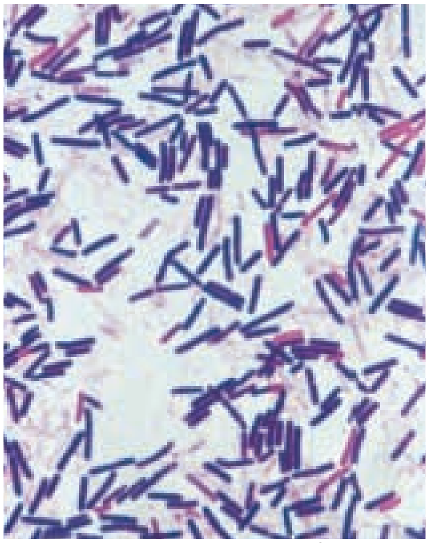
Bacteria cannot reproduce by mitosis or meiosis because they have no nucleus, and instead of pairs of chromosomes, they have one circular chromosome and varying numbers of smaller circular pieces of DNA called plasmids. Therefore, they have other ways to reproduce.

Bacteria reproduce asexually by a process known as **binary fission.** To reproduce in this way, a bacterium first copies its chromosome. Then the original chromosome and the copy become attached to the cell's plasma membrane for a while. The cell grows larger, and eventually the

CONTENTS

Magnification: 1100×

A These spherical, Gram-positive ***Streptococcus mutans*** bacteria cause tooth decay.



Magnification: 1500×

B This rodlike, Gram-positive bacterium, ***Clostridium botulinum***, produces a poison that can result in food poisoning.

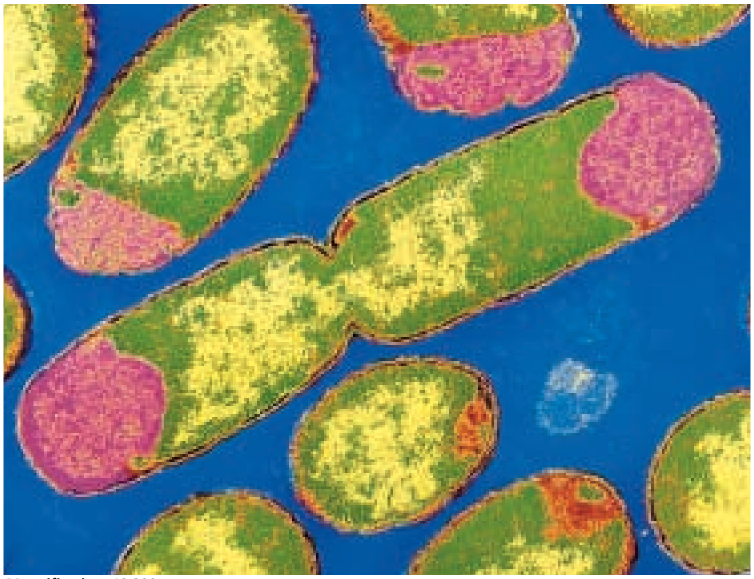
Magnification: 875×

C This spiral-shaped, Gram-negative ***Spirillum volutans*** bacterium has flagella.

Figure 18.11
Scrub, shampoo, and gargle as you will, you'll remove only a small fraction of the bacteria that live on and in you.

two chromosomes separate and move to opposite ends of the cell. Then, a partition forms between the chromosomes, as shown in ***Figure 18.12.*** This partition separates the cell into two similar cells. Because each new cell has either the original or the copy of the chromosome, the resulting cells are genetically identical.

Bacterial reproduction can be rapid. In fact, under ideal conditions, some bacteria can reproduce every 20 minutes, producing enormous numbers of bacteria quickly. If bacteria always reproduced this fast, they would cover the surface of Earth within a few weeks. But, this doesn't happen, because bacteria don't always have ideal growing conditions. They run out of nutrients and water, they poison themselves with their own wastes, and predators eat them.

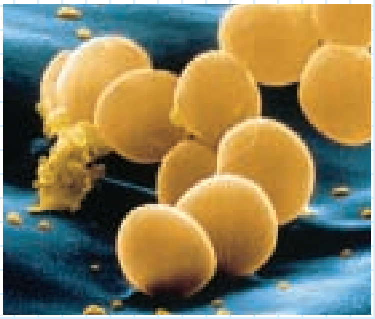


Magnification: 18 300×

Figure 18.12
This *Escherichia coli* cell is starting to divide. The newly forming partition is visible in the center of the cell.

MiniLab 18-2 Observing

Bacteria Have Different Shapes Bacteria come in three shapes: spherical (coccus), rodlike (bacillus), and spiral shaped (spirillum). They may appear singly or in pairs, chains, or clusters. Each species has a typical shape and reaction to Gram stain.



Staphylococcus bacteria

Procedure

1. Obtain slides of bacteria from your teacher.
2. Using low power, locate bacteria of one shape. Switch to high power. Look for individual cells and observe their shape. Observe also the size of the cells and their color. Then look for groups of bacterial cells to determine their arrangement. **CAUTION:** ***Use caution when working with a microscope and microscope slides.***
3. Repeat step 2 for bacteria with the other shapes. Then, compare the sizes of the bacteria.
4. Draw a diagram of each type of bacteria.

Analysis

1. How do the sizes of the three bacteria compare?
2. Which of the bacteria were Gram negative?
3. What adaptive advantage might there be for bacteria to form groups of cells?

Sexual reproduction

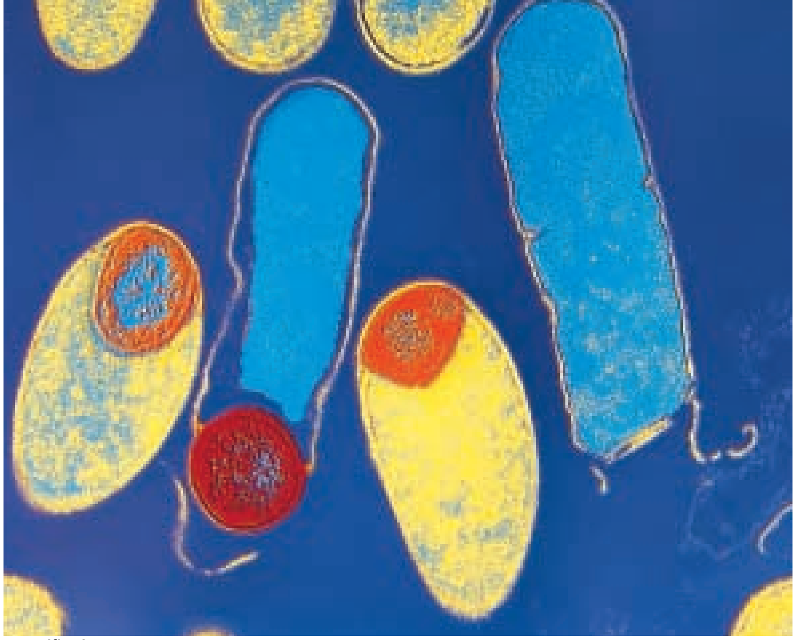
In addition to binary fission, some bacteria have a form of sexual reproduction called conjugation. During **conjugation** (kahn juh GAY shun), one bacterium transfers all or part of its chromosome to another cell through or on a bridgelike structure called a pilus (plural, pili) that connects the two cells. In ***Figure 18.13***, you can see how this genetic transfer occurs. Conjugation results in a bacterium with a new genetic composition. This bacterium can then undergo binary fission, producing more cells with the same genetic makeup.

Try the *MiniLab* on this page to see some bacterial staining reactions, cell shapes, and patterns of growth.

Adaptations in Bacteria

Based on fossil evidence, some scientists propose that anaerobic bacteria were probably among the first photosynthetic organisms, producing not only their own food but also oxygen. As the concentration of oxygen increased in Earth's atmosphere,

Figure 18.13
The *E. coli* at the bottom is attached to the other bacteria by pili, through or on which genetic material is being transferred.



Magnification: 25 500×

Figure 18.14
This TEM shows bacteria in three different stages of endospore production

some bacteria probably adapted over time to use oxygen for respiration.

Diversity of metabolism

Recall that the breaking down food to release its energy is called cellular respiration. Modern bacteria have diverse types of respiration.

Many bacteria require oxygen for respiration. These bacteria are called **obligate aerobes.** *Mycobacterium tuberculosis*, the organism that causes the lung disease called tuberculosis, is an obligate aerobe. There are other bacteria, called **obligate anaerobes,** that are killed by oxygen. Among bacteria that are obligate anaerobes is the bacterium *Treponema pallidum* that causes syphilis, a sexually transmitted disease, and the bacterium that causes botulism, a type of food poisoning that you will learn more about soon. There are still other bacteria that can live either with or without oxygen, releasing the energy in food aerobically by cellular respiration or anaerobically by fermentation.

A survival mechanism

Some bacteria, when faced with unfavorable environmental conditions, produce endospores, shown in ***Figure 18.14.*** An **endospore** is a tiny structure that contains a bacterium's DNA and a small amount of its cytoplasm, encased by a tough outer covering that resists drying out, temperature extremes, and harsh chemicals. As an endospore, the bacterium rests and does not reproduce. When environmental conditions improve, the endospore germinates, or produces a cell that begins to grow and reproduce. Some endospores have germinated after thousands of years in the resting state.

Although endospores are useful to bacteria, they can cause problems for people. Endospores can survive a temperature of 100°C, which is the boiling point of water. To kill endospores, items must be sterilized—heated under high pressure in either a pressure cooker or an autoclave. Under pressure, water will boil at a higher temperature than its usual 100°C, and this higher temperature kills endospores.

Canned foods must be sterilized and acidified. This is because the endopores of the bacterium called *Clostridium botulinum* easily get into foods being canned. These bacteria belong to the group clostridia—all obligate anaerobic bacteria that form endospores. If the endospores

Problem-Solving Lab 18-2 Hypothesizing

Can you get food poisoning from eating home-canned foods? *Clostridium botulinum* is a bacterial species that causes food poisoning.

Analysis

C. botulinum is an obligate anaerobic soil bacterium, and it easily spreads onto plants. It forms endospores that are highly heat-resistant and germinate only in anaerobic conditions. The bacterium produces a heat-resistant toxin that can kill humans. Commercially canned foods are heated to 121°C for a minimum of 20 minutes to ensure that all spores are killed.

Thinking Critically

1. Hypothesize why you don't get food poisoning if you eat fresh vegetables that are contaminated with the endospores of *C. botulinum.*
2. Hypothesize how the endospores of *C. botulinum* get into home-canned vegetables.
3. Hypothesize how *C. botulinum* endospores can survive inadequate home-canning procedures.
4. Explain why endospores of *C. botulinum* germinate inside canning jars.

of *C. botulinum* get into improperly sterilized canned food, they germinate. Bacteria grow in the anaerobic environment of the can and produce a powerful and deadly poison, called a **toxin,** as they grow. This deadly toxin saturates the food and, if eaten, causes the disease called botulism. Although rare, botulism is often fatal, and it can be transmitted in many ways other than poorly canned food, as shown in ***Figure 18.15.*** Try the *Problem-Solving Lab* on this page to learn more about *C. botulinum.*

Another clostridia, *Clostridium tetani*, produces a powerful nerve toxin that causes the disease called tetanus, which is often fatal. Because endospores of *C. tetani* exist almost everywhere, they will often enter a wound. Deep wounds and puncture wounds are hard to clean and provide the conditions needed for the growth of anaerobes. The endospores germinate in the wound, and the bacteria grow and produce a toxin that the blood carries to nerve cells in the spinal cord. Fortunately, there is an immunization for tetanus. You probably received this shot as a child. You

Figure 18.15
CAUTION: When a foil-wrapped potato is baked, any *Clostridium botulinum* spores on its skin can survive. If the potato is eaten immediately, the spores cannot germinate. However, if the still-wrapped potato cools at room temperature, the spores can germinate in the anaerobic environment of the foil, and the bacteria will produce their deadly toxin.

need a booster shot periodically, or immediately if you receive a puncture wound and are seriously injured.

The Importance of Bacteria

When you think about bacteria, your first thought may be disease. But disease-causing bacteria are few compared with the number of harmless and beneficial bacteria on Earth. Bacteria help to fertilize fields, to recycle nutrients on Earth, and to produce foods and medicines.

Nitrogen fixation

Most of the nitrogen on Earth exists in the form of nitrogen gas, N_2, which makes up 80 percent of the atmosphere. All organisms need nitrogen because the element is a component of their proteins, DNA, RNA, and ATP. Yet few organisms, including most plants, can directly use nitrogen from the air.

Several species of bacteria have enzymes that convert N_2 into ammonia (NH_3) in a process known as **nitrogen fixation.** Other bacteria then convert the ammonia into nitrite (NO_2^-) and nitrate (NO_3^-), which plants can use. Bacteria are the only organisms that can perform these chemical changes.

Some nitrogen-fixing bacteria live symbiotically within the roots of some trees and legumes—plants such as peas, peanuts, and soybeans—in swollen areas called nodules. You can see some nodules in ***Figure 18.16.*** Farmers grow legume crops after the harvesting of crops such as corn, which depletes the soil of nitrogen. Not only do legumes replenish the soil's nitrogen supply, they are an economically useful crop.

Recycling of nutrients

You learned that life could not exist if decomposing bacteria did not break down the organic materials in

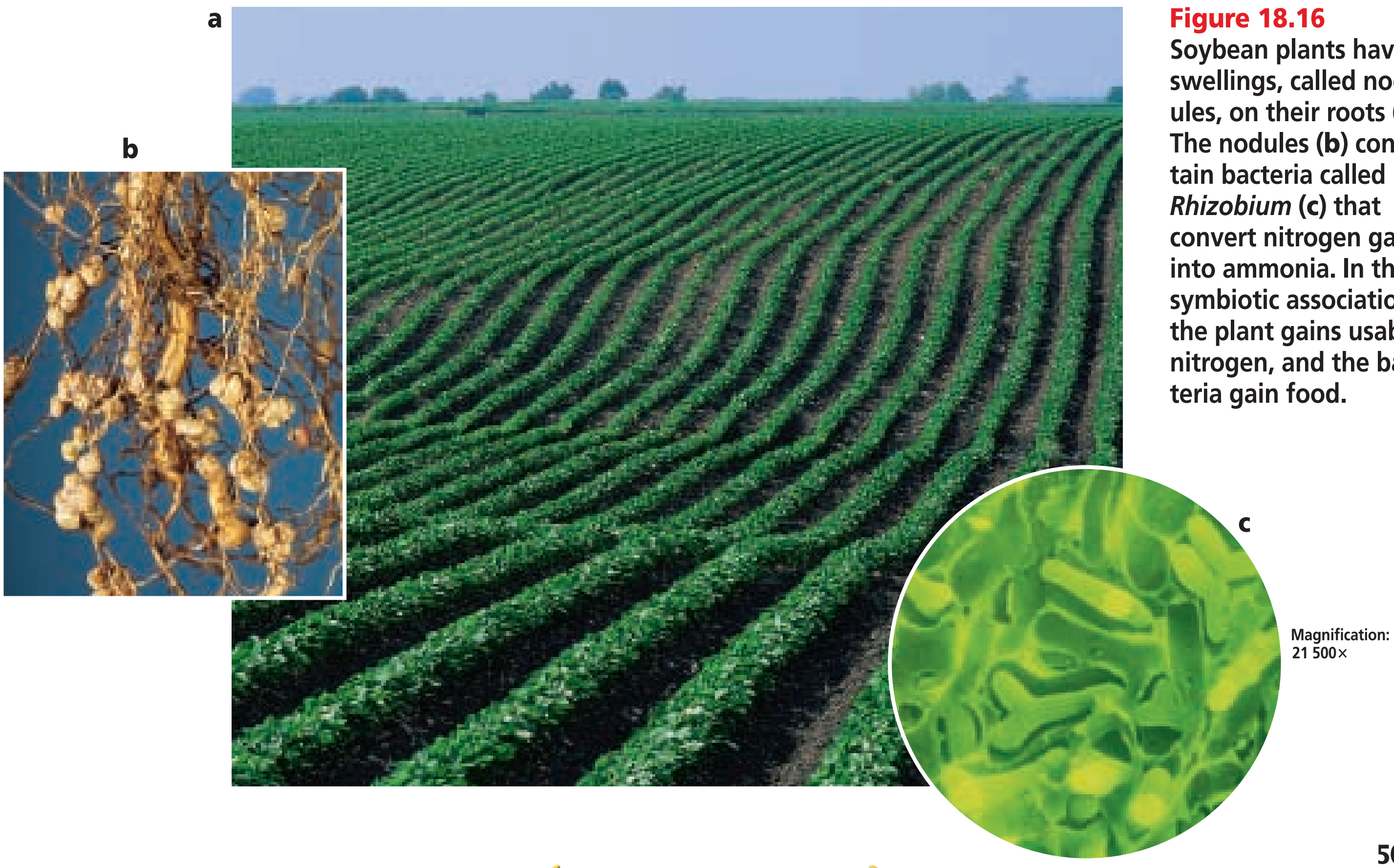


Figure 18.16
Soybean plants have swellings, called nodules, on their roots (a). The nodules (b) contain bacteria called *Rhizobium* (c) that convert nitrogen gas into ammonia. In this symbiotic association, the plant gains usable nitrogen, and the bacteria gain food.

dead organisms and wastes, returning nutrients, both organic materials and inorganic materials, to the environment. Autotrophic bacteria and also plants and algae, which are at the bottom of the food chains, use the nutrients in the food they make.

This food is passed from one heterotroph to the next in food chains and webs. In the process of making food, many autotrophs replenish the supply of oxygen in the atmosphere. You can see from all this that other life depends on bacteria.

Food and medicines

Some foods that you eat—mellow Swiss cheese, shown in ***Figure 18.17***, crispy pickles, tangy yogurt—would not exist without bacteria. During respiration, different bacteria produce diverse products, many of which have distinctive flavors and aromas. As a result, specific bacteria are used to make different foods, such as vinegar, cheeses, and sauerkraut.

In addition to food, some bacteria produce important antibiotics that destroy other types of bacteria. Streptomycin, erythromycin, bacitracin, and neomycin are some of these antibiotics. How do you know which antibiotic you need when you are sick? The *BioLab* at the end of this chapter will help you learn how scientists have obtained such information.

Figure 18.17
Bacteria not only give Swiss cheese (a) its flavor but also its holes as they produce carbon dioxide that bubbles through the cheese (b). Useful bacteria are grown in large industrial fermenting vats (c).

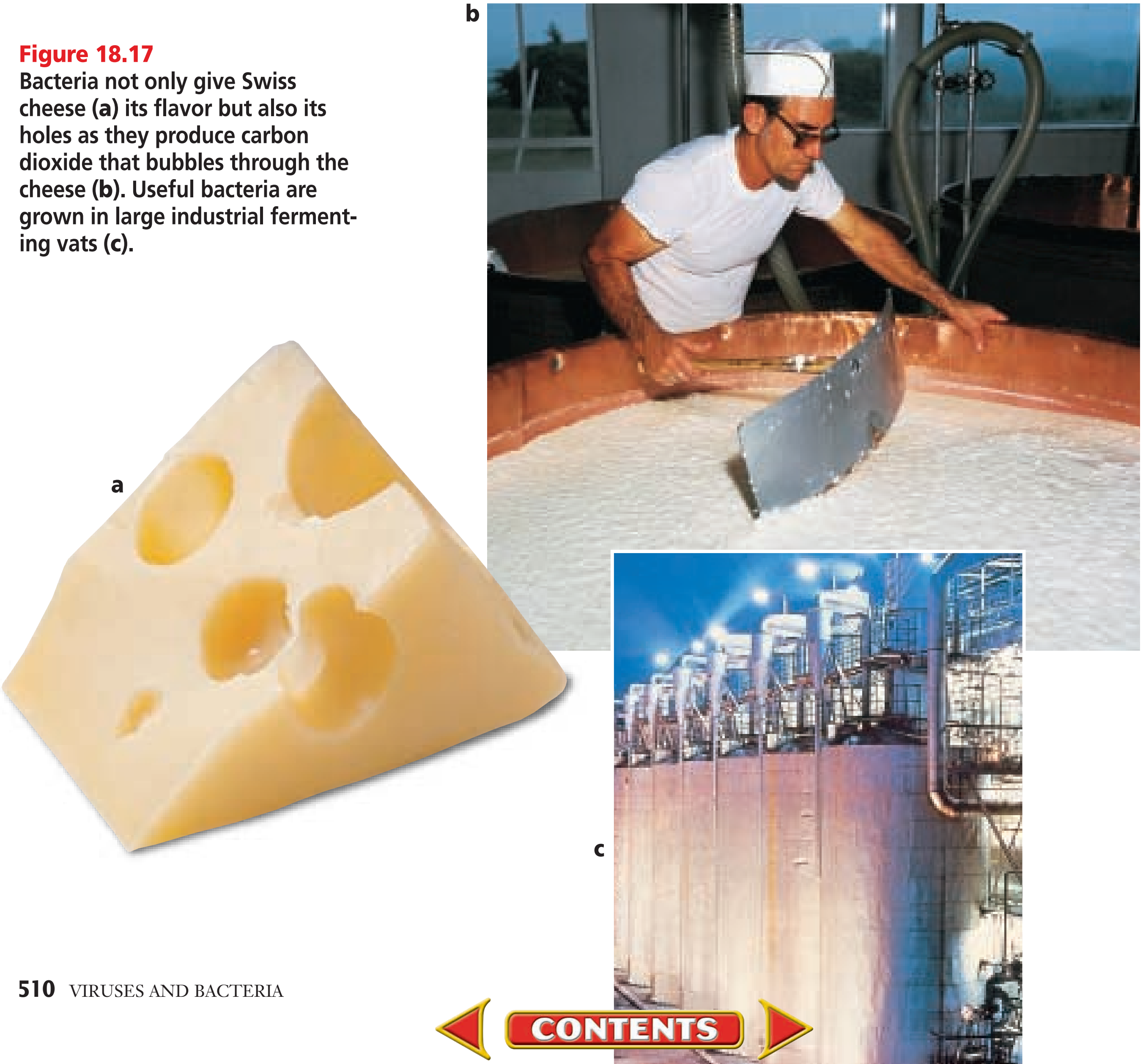


Table 18.2 Diseases caused by bacteria

Disease	Transmission	Symptoms	Treatment
Strep throat	Inhale or ingest through mouth	Fever, sore throat, swollen neck glands	Antibiotic
Tuberculosis	Inhale	Fatigue, fever, night sweats, cough, weight loss, chest pain	Antibiotic
Tetanus	Puncture wound	Stiff jaw, muscle spasms, paralysis	Open and clean wound, antibiotic; give antitoxin
Lyme disease	Bite of infected tick	Rash at site of bite, chills, body aches, joint swelling	Antibiotic
Dental cavities (caries)	Bacteria in mouth	Destruction of tooth enamel, tooth ache	Remove and fill the destroyed area of tooth
Cholera	Drinking contaminated water	Diarrhea, vomiting, dehydration	Replace body fluids, antibiotics

Bacteria cause disease

Although only a few kinds of bacteria cause diseases, those that do greatly affect human lives. Bacteria cause about half of all human diseases, some of which you can see listed in ***Table 18.2.*** Disease-causing bacteria can enter human bodies through openings, such as the mouth. They are carried in air, food, and water and sometimes invade humans through skin wounds.

In the past, bacterial illnesses had a greater effect on human populations than they do now. As recently as 1900, life expectancy in the United States was only 47 years. The most dangerous diseases at that time were the bacterial illnesses tuberculosis and pneumonia. In the last 100 years, human life expectancy has increased to about 75 years. This increase is due to many factors, including better public health systems, improved water and sewage treatment, better nutrition, and better medical care. These improvements, along with antibiotics, have reduced the death rates from bacterial diseases to low levels. However, this is starting to change as you can read in the *Biology & Society* at the end of this chapter.

Section Assessment

Understanding Main Ideas

1. Describe six parts of a typical bacterial cell. State the function of each.
2. What are endospores? How do they help bacteria survive?
3. Explain how penicillin affects a bacterial cell.
4. Explain how bacteria avoid osmotic rupture.

Thinking Critically

5. Some scientists have proposed that bacterialike cells were probably among the earliest organisms to live on Earth. Draw up a list of reasons why such a suggestion is feasible. Then explain each reason on your list.

Skill Review

6. **Making and Using Tables** Construct a table comparing and contrasting archaebacteria and eubacteria. Include at least three ways they are alike and three ways they are different. For more help, refer to *Organizing Information* in the **Skill Handbook.**

DESIGN YOUR OWN BioLab

How sensitive are bacteria to antibiotics?

Doctors must know which antibiotic kills each disease-causing bacterium. You can use a test similar to the one in this BioLab *to provide this information. You will use sterile, agar-containing Petri dishes and sterile, antibiotic disks. When you place a disk on the agar, the antibiotic diffuses into the agar. A clear ring that develops around a disk—a zone of inhibition—is where the antibiotic killed sensitive bacteria.*

PREPARATION

Problem

How can you determine which antibiotic most effectively kills specific bacteria?

Hypotheses

Decide on one hypothesis that you will test. Your hypothesis might be that the antibiotic with the widest zone of inhibition most effectively kills bacteria.

Objectives

In this BioLab, you will:

- **Compare** how effectively different antibiotics kill specific bacteria.
- **Determine** the most effective antibiotic to treat an infection that these bacteria might cause.

Possible Materials

cultures of bacteria
sterile nutrient agar Petri dishes
antibiotic disks
sterile disks of blank filter paper
marking pen
long-handled cotton swabs
forceps
37°C incubator
metric ruler

Safety Precautions

Always wear goggles in the lab. Although the bacteria you will work with are not disease-causing, do not spill them. Wash your hands with soap immediately after handling any bacterial culture. Carefully clean your work area after you finish. Follow your teacher's instructions about disposal of your swabs, cultures, and Petri dishes.

Skill Handbook

Use the **Skill Handbook** if you need additional help with this lab.

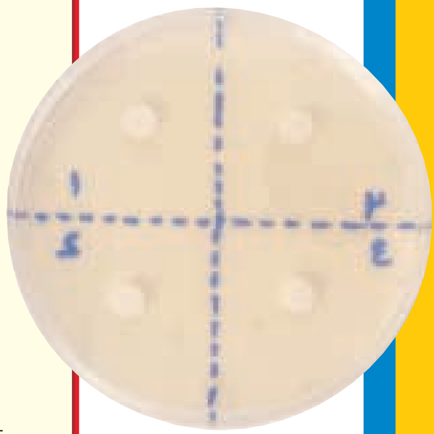
Plan the Experiment

1. Examine the materials provided by your teacher, and study the photos in this lab. As a group, make a list of ways you might investigate your hypothesis.
2. Agree on one way that your group could investigate your hypothesis. Design an experiment in which you can collect quantitative data.
3. Make a list of numbered directions. In your list, include the amounts of each material you will need. If possible, use no more than one Petri dish for each person.
4. Design and construct a table for recording data. To do this, carefully consider what data you need to record and how you will measure the data. For example, how will you measure what happens around the antibiotic disks as the antibiotic diffuses into the agar?

Check the Plan

Discuss the following points with other group members to decide on your final procedure.

1. How will you set up your Petri dishes? How many antibiotics can you test on one Petri dish? How will you measure the effectiveness of each antibiotic? What will be your control?
2. Will you add the bacteria or the antibiotic disks first?
3. What will you do to prevent other bacteria from contaminating the Petri dishes?
4. How often will you observe the Petri dishes?
5. ***Make sure your teacher has approved your experimental plan before you proceed.***
6. Carry out your experiment. **CAUTION:** ***Wash your hands with soap and water after handling dishes of bacteria.***



Analyze and Conclude

1. **Measuring in SI** How did you measure the zones of inhibition? Why did you do it this way?
2. **Drawing Conclusions** Suppose you were a physician treating a patient infected with these bacteria. Which antibiotic would you use? Why?
3. **Analyzing the Procedure** What limitations does this technique have? If these bacteria were infecting a person, what other tests might increase your confidence about treating the person with the antibiotic that appears most effective against these bacteria?

Going Further

Application Use a similar procedure to test the effectiveness of four commercial antibacterial soaps. Prepare your disks by soaking them in the different soap solutions.

BIOLOGY Online To find out more about antibiotics, visit the Glencoe Science Web site.
science.glencoe.com

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Biology & SOCIETY

Super Bugs Defy Drugs

You have strep throat—a bacterial infection. After taking an antibiotic for six days, you feel fine, so you stop taking it. A few weeks later, you have strep throat again. Your doctor prescribes the same antibiotic. But this time the sore throat doesn't go away. You have to take a different antibiotic to get rid of the infection.

Antibiotics have prevented millions of deaths from bacterial diseases in the past. Today, however, antibiotics do not always cure disease because many disease-causing bacteria have developed resistance to many antibiotics.

Antibiotics

Different Viewpoints

During the past 50 years, antibiotics have been used for preventive medical reasons and in agriculture. With the development of resistant bacteria, these uses are being reassessed.

How Much Is Too Much? Because antibiotics have worked well and had few side effects, some physicians prescribe them for preventive reasons. For example, physicians may prescribe antibiotics before surgery to prevent the chance of infection from bacteria during the surgery. In addition, some physicians prescribe antibiotics for patients with viral infections because a viral infection makes a body vulnerable to a bacterial infection.

Because antibiotics hasten the growth of healthy cattle, chickens, and other domestic animals, many animal feeds contain small amounts of antibiotics. Similarly, antibiotics are used to coat fruit and other agricultural products. These antibiotics may produce resistant bacteria, which pass to people when they eat the food.

A Public Health Crisis? More than 100 antibiotics are available, and many bacteria that they once killed are now resistant to one or more of them. Tuberculosis, for example, is a deadly, highly contagious disease that a combination of antibiotics usually treats effectively. But strains of resistant tuberculosis bacteria have appeared, and the number of deaths from the disease are beginning to increase.

Staphylococcus aureus and *Enterococcus faecalis* are common bacteria. *S. aureus* causes serious infections in hospital patients and is beginning to show resistance to the last antibiotic effective against it—vancomycin. The body's immune system usually controls *E. faecalis.* But in patients with weakened immune systems, this bacterium causes life-threatening illness. Like *S. aureus*, it is resistant to most antibiotics. Bacteria often pass traits among species, and health workers fear that *S. aureus* could pass its vancomycin resistance to *E. faecalis.*

INVESTIGATING THE ISSUE

Thinking Critically Antibacterial products—from soaps and lotions to kitchen cutting boards and sponges—cram market shelves. Is it a good idea to rely on them to keep kitchens and bathrooms free of harmful bacteria? Why or why not?

BIOLOGY Online To find out more about bacteria that are antibiotic-resistant, visit the Glencoe Science Web site. **science.glencoe.com**

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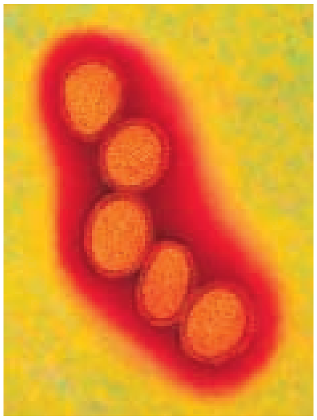
Chapter 18 Assessment

Summary

Section 18.1

Viruses



Main Ideas

- Viruses are nonliving particles that have a nucleic acid core and a protein-containing capsid.
- To replicate, a virus must first recognize a host cell, then attach to it, and finally enter the host cell and take over its metabolism.
- During a lytic cycle, a virus replicates and kills the host cell. In a lysogenic cycle, a virus's DNA is integrated into a chromosome of the host cell, but the host cell does not die.
- Retroviruses contain RNA. Reverse transcriptase is an enzyme that helps convert viral RNA to DNA, which is then integrated into the host cell's chromosome.
- Viruses probably originated from their host cells.

Vocabulary

bacteriophage (p. 490)
capsid (p. 490)
host cell (p. 489)
lysogenic cycle (p. 493)
lytic cycle (p. 493)
provirus (p. 493)
retrovirus (p. 495)
reverse transcriptase (p. 495)
virus (p. 489)

Section 18.2

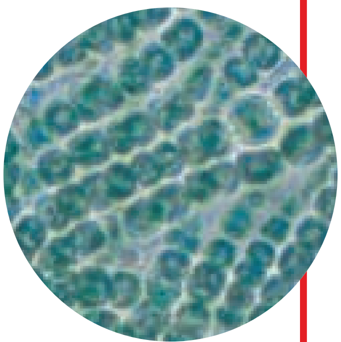
Archaebacteria and Eubacteria

Main Ideas

- There are two kingdoms of prokaryotes: archaebacteria and eubacteria. Archaebacteria inhabit extreme environments. Eubacteria live almost everywhere else. They probably arose separately from a common ancestor billions of years ago.
- Some bacteria are heterotrophs, some are photosynthetic autotrophs, and others are chemosynthetic autotrophs. Some bacteria are obligate aerobes, some obligate anaerobes, and some are both aerobes and anaerobes.
- Bacteria usually reproduce by binary fission. Some have a type of sexual reproduction called conjugation. Some bacteria form endospores that enable them to survive when conditions are unfavorable.
- Bacteria fix nitrogen, recycle nutrients, and help make food products and medicines. Some bacteria cause diseases.

Vocabulary

binary fission (p. 504)
chemosynthesis (p. 502)
conjugation (p. 506)
endospore (p. 507)
nitrogen fixation (p. 509)
obligate aerobe (p. 507)
obligate anaerobe (p. 507)
toxin (p. 508)

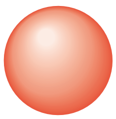
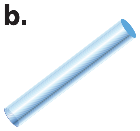
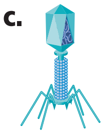


Understanding Main Ideas

1. A ________ is never a part of a virus.
   a. nucleic acid
   b. protein coat
   c. viral envelope
   d. cell wall

2. The cell walls of bacteria ________.
   a. control what enters and leaves the cell
   b. prevent osmotic rupture
   c. are involved in penicillin synthesis
   d. are involved in protein synthesis

3. Which of the following is NOT a common bacterial shape?

a. 
b. 
c. 
d. 

4. What characteristic do viruses share with all living organisms?
   a. respiration
   b. metabolism
   c. replication
   d. movement

5. During a lytic cycle, after a virus enters the cell, the virus ________.
   a. forms a provirus
   b. replicates
   c. dies
   d. becomes inactive

6. Prokaryotic cells have ________.
   a. organelles
   b. a nucleus
   c. mitochondria
   d. a cell wall

7. In ________, bacteria convert gaseous nitrogen into ammonia, nitrates, and nitrites.
   a. nitrogen fixation
   b. binary fission
   c. conjugation
   d. attachment

8. Bacteria that require ________ for respiration are called ________.
   a. food—obligate saprophytes
   b. hydrogen—archaebacteria
   c. oxygen—obligate anaerobes
   d. oxygen—obligate aerobes

9. Some bacteria, when faced with unfavorable environmental conditions, produce structures called ________.
   a. pili
   b. capsules
   c. toxins
   d. endospores

10. Which of the following would be most likely to live in Utah's Great Salt Lake?
   a. Archaebacteria
   b. staphylococci
   c. Eubacteria
   d. viruses

THE PRINCETON REVIEW

Test-Taking Tip

Investigate

Ask what kinds of questions to expect on the test. Ask for practice tests so that you can become familiar with the test-taking materials.

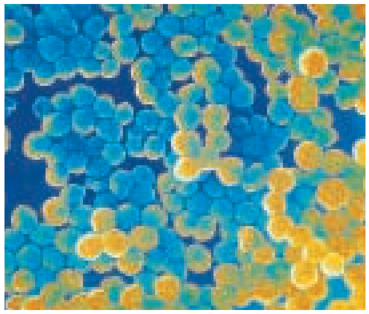
11. The nucleic acid core of a virus contains ________ or ________.

12. Viruses are species specific so that the T4 bacteriophage can infect only organisms known as ________.

13. In the ________ cycle, viruses use the cell's energy and raw materials to copy themselves, then burst from the cell.

14. ________ are the prokaryotes that have genes most similar to those of eukaryotes.

15. ________ is a prefix that describes the pattern of growth of the bacteria shown here.



16. ________ results in two bacteria, each genetically identical to the original.

17. The World Health Organization has successfully eradicated the disease ________ from the world's population.

18. Penicillin kills bacteria by interfering with the enzymes that link the sugar chains in the ________.

19. All viruses contain a coat of ________ and core of ________.

20. Some bacteria have a form of sexual reproduction called ________.

Applying Main Ideas

21. Why are bacteria essential to life?

22. Discuss two ways that prokaryotic cells differ from eukaryotic cells.

23. Discuss three factors that limit bacterial growth.

24. Scientists cannot grow about 99 percent of all bacteria in the laboratory. How might this inability interfere with understanding bacteria?

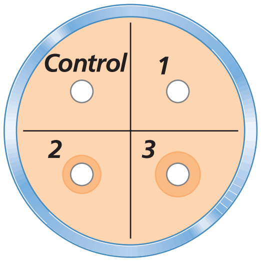
Chapter 18 Assessment

Thinking Critically

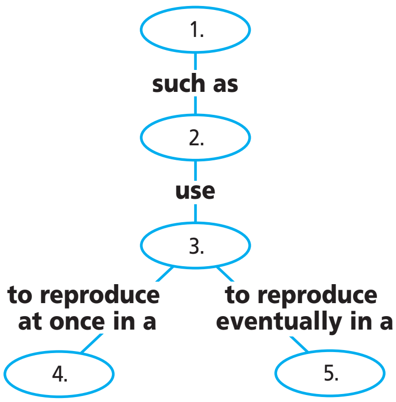
25. Applying Concepts Although bacteria grow on nutrient agar in a laboratory, viruses will not grow on agar. What kind of substance would you need to grow viruses in the laboratory? Explain your answer.

26. Observing and Inferring If you were offered the choice of either a million dollars or a sum of money equal to a penny that doubles every day for 64 days in a row, which would you choose? Relate your choice to the growth rate of bacteria cells.

27. Interpreting Scientific Illustrations Bacteria from an infected person were tested for their sensitivity to three antibiotics. The results of the test are shown in the petri dish at right. If you were the patient's physician, which antibiotic would you prescribe and why?



28. Concept Mapping Complete the concept map by using the following vocabulary terms: host cells, viruses, lysogenic cycle, bacteriophages, lytic cycle.



CD-ROM

For additional review, use the assessment options for this chapter found on the ***Biology: The Dynamics of Life Interactive CD-ROM*** and on the Glencoe Science Web site.
science.glencoe.com

Assessing Knowledge & Skills

One milliliter of *E. coli* culture was added to each of three Petri dishes (A, B, and C). The dishes were incubated for 36 hours, and then the number of bacterial colonies on each were counted.

Table 18.3 Growth of *E. coli* under various conditions

Petri dish number	Medium	Colonies per dish
I	Agar and carbohydrates	35
II	Agar, carbohydrates, and vitamins	250
III	Agar and vitamins	0

Interpreting data Study the table and answer the following questions.

1. Which of the above dishes demonstrate that carbohydrates are necessary for the growth of *E. coli?*
   a. Dish I alone
   b. Dishes I and II
   c. Dishes I and III
   d. Dish III
2. Which of the above dishes demonstrate that vitamins enhance the growth of *E. coli?*
   a. Dishes I and II
   b. Dishes II and III
   c. Dishes I and III
   d. None of the dishes
3. Which of the following is a variable in this experiment?
   a. *E. coli*
   b. agar
   c. carbohydrates
   d. number of colonies
4. **Making a Graph** Construct a bar graph from the data in the above table.