18.1 Studying Viruses and Prokaryotes

KEY CONCEPT Infections can be caused in several ways.

MAIN IDEA

- Viruses, bacteria, viroids, and prions can all cause infection.

VOCABULARY

virus, p. 544
pathogen, p. 544
viroid, p. 544
prion, p. 545

Review
prokaryote, archaea

REVIEW AT CLASSZONE.COM

Connect Bacteria are everywhere, including in and on your own body—such as the bacteria that live in our digestive tracts. The relationship between you and the microorganisms in your body is usually mutually beneficial. Under certain conditions, however, normally harmless microorganisms can cause disease, and some types of microorganisms are particularly nasty—they always make you sick.

MAIN IDEA

Viruses, bacteria, viroids, and prions can all cause infection.

You are probably familiar with the terms *virus* and *bacteria,* but you may not know exactly what they are. A **virus** is an infectious particle made only of a strand of DNA or RNA surrounded by a protein coat. Bacteria, on the other hand, are one-celled microorganisms that can also cause infection. Any living organism or particle that can cause an infectious disease is called an infectious agent, or **pathogen.**

In Chapter 1, you learned that all living things share certain key characteristics: the abilities to reproduce, to use nutrients and energy, to grow and develop, and to respond to their environments. They also contain genetic material that carries the code of life. Prokaryotes—such as the bacterium shown in **FIGURE 18.1**—are clearly living things, since they have each of the traits of life. But are viruses living things? Like living cells, viruses respond to their environment. Viruses have genes and can reproduce. Unlike cells, however, viruses cannot reproduce on their own. Instead, they need living cells to help them reproduce and make proteins. Viruses are also much smaller than most cells, as you can see in **FIGURE 18.2.** While viruses have key traits similar to living cells, they also have many differences. In fact, viruses are not even given a place in the Linnaean system of biological classification.

A viroid has even less in common with living things than do viruses. **Viroids** are infectious particles that cause disease in plants. Viroids are made of single-stranded RNA without a protein coat. They are passed through seeds or pollen. Viroids have had a major economic impact on agriculture because they can stunt the growth of plants.

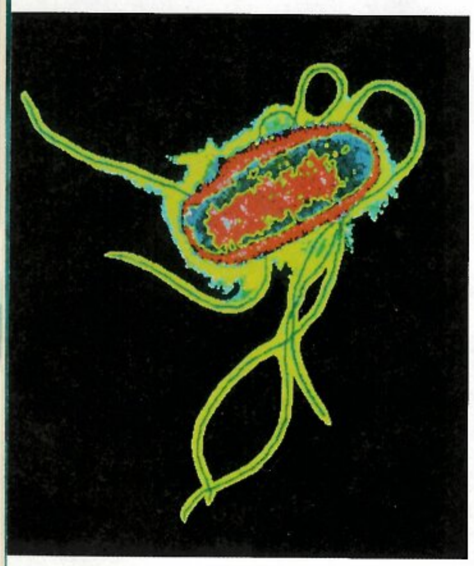
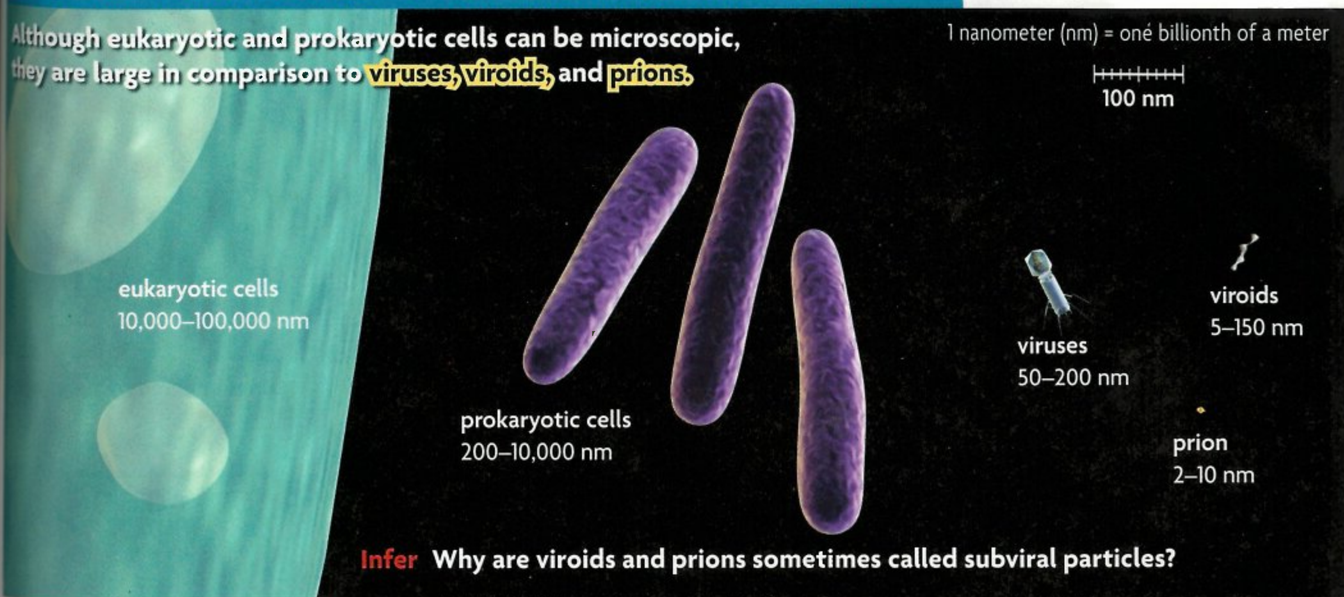


FIGURE 18.1 Prokaryotes, such as this *Escherichia coli* bacterium, are single cells that have all of the characteristics of living things. (colored TEM; magnification 6000×)

FIGURE 18.2 Relative Sizes of Cells and Infectious Particles



Although eukaryotic and prokaryotic cells can be microscopic, they are large in comparison to viruses, viroids, and prions.

Infer Why are viroids and prions sometimes called subviral particles?

At the boundary between living and nonliving, perhaps the strangest entity of all is the prion. A **prion** (PREE-ahn) is an infectious particle made only of proteins that can cause other proteins to fold incorrectly. When proteins misfold, the protein will not work properly. Prions are unusual in that they are infectious yet have no genetic material. They play a part in certain diseases of the brain such as mad cow disease, known to scientists as bovine spongiform encephalopathy, or BSE. Humans may become infected with BSE when they eat meat from animals that are infected. Food safety laws in the United States, however, try to reduce the risk of infection. Creutzfeld-Jakob (KROYTS-fehlt YAH-kawp) disease (CJD), another brain disease that affects humans, is also associated with prions. Prion diseases can incubate for a long time with no effect on their host. However, once symptoms appear, they worsen quickly and are always fatal, because the body has no immune response against a protein.

TAKING NOTES

Use a two-column chart to take notes on viruses, viroids, and prions.

Main Idea	Detail
Virus	
Viroid	
Prion	

Synthesize **Why are viruses, viroids, and prions not included in the Linnaean system**

18.1 ASSESSMENT

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REVIEWING ▶ MAIN IDEAS

1. What are the main differences between living cells and **viruses**?
2. Viruses, **viroids, prions,** and some bacteria can all be considered **pathogens.** What do all pathogens have in common?

CRITICAL THINKING

3. **Infer** Prions were not widely known to be infectious agents until the 1980s. Give two reasons why this might be so.
4. **Apply** An RNA-based disease spreads through pollen. Is it likely due to a virus, viroid, or prion? Explain.

Connecting CONCEPTS

5. **Medicine** To multiply, viruses must take over the functions of the cells they infect. Why does this make it difficult to make effective antiviral drugs?

18.2 Viral Structure and Reproduction

KEY CONCEPT Viruses exist in a variety of shapes and sizes.

MAIN IDEAS

- Viruses differ in shape and in ways of entering host cells.
- Viruses cause two types of infections.

VOCABULARY

capsid, p. 547
bacteriophage, p. 549
lytic infection, p. 551
lysogenic infection, p. 551
prophage, p. 551

Review
endocytosis, lipid

REVIEW AT CLASSZONE.COM

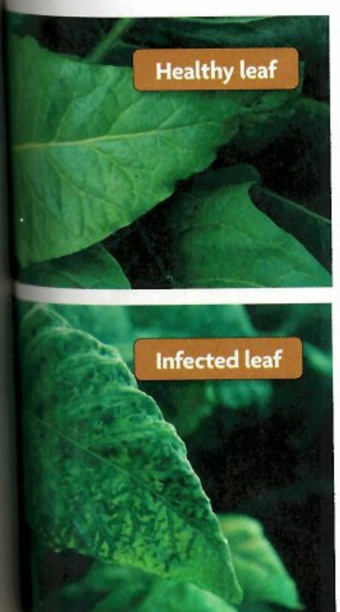
Connect Just like the computer viruses that you hear about in the news, viruses that affect living things pass from one host to the next. While computer viruses pass through networks from one computer to another, human viruses pass from person to person. Also like computer viruses, viruses of living things can be simple or complex in structure, and have several different ways to get into their hosts.

MAIN IDEA

Viruses differ in shape and in ways of entering host cells.

The idea that infectious agents cause certain diseases was a fairly new concept in 1892 when Russian scientist Dmitri Ivanovsky made a surprising observation. He was studying tobacco mosaic disease, named for the scar pattern left on affected leaves of tobacco or tomato plants. Mosaic disease, shown in **FIGURE 18.3**, was thought to be caused by a bacterium. But so far no one had been able to prove it. Ivanovsky passed extracts of diseased tobacco leaves through filter pores small enough to strain out bacteria and found that the extracts could still pass on the disease. Was this a new bacterium? Or was it some unknown type of organism?

In 1898, Dutch microbiologist Martinus Beijerinck built upon Ivanovsky's work. He showed that the disease agent passed through agar gel. He proposed that tiny particles within the extracts caused infection, and he called the particles *viruses,* from the Latin for "poison." The observations of Ivanovsky and Beijerinck laid the groundwork for more discoveries. Scientists began finding that many diseases of unknown causes could be explained by viruses.



URE 18.3 These pictures mpare a healthy leaf and a f infected by tobacco mosaic s (TMV). TMV was the first s identified by scientists.

The Structure of Viruses

Viruses have an amazingly simple basic structure. A single viral particle, called a *virion,* is made up of genetic material surrounded by a protein shell called a **capsid.** Capsids can have different shapes. In some viruses, the capsid itself is surrounded by a lipid envelope. A lipid envelope is the protective outer coat of a virus, from which spiky structures of proteins and sugars may stick out.

Some viruses attach to host cells by these spikes. The spikes are such an obvious trait of some viruses that they can be used for identification.

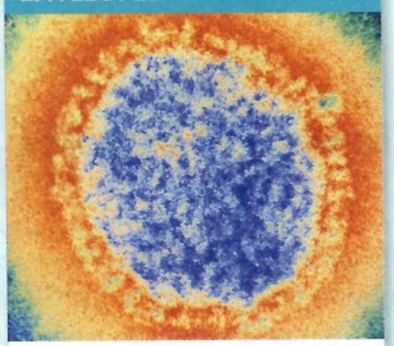
Viruses can only reproduce after they have infected host cells. Viruses are simply packaged sets of genes that move from one host cell to another. Unlike bacteria and other living parasites, a virus has no structures to maintain—no membranes or organelles needing ATP, oxygen, or glucose. All it carries into the cell is what it needs to reproduce—its genes.

The structure and shape of viruses play an important role in how they work. Each type of virus can infect only certain hosts. A virus identifies its host by fitting its surface proteins to receptor molecules on the surface of the host cell, like a key fitting a lock. Some viruses are able to infect several species, while other viruses can infect only a single species. Common viral shapes are shown in **FIGURE 18.4.**

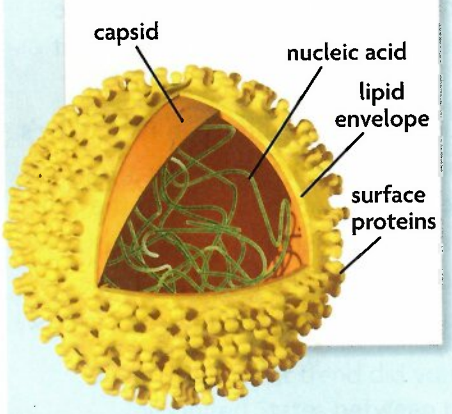
FIGURE 18.4 Viral Shapes

The different proteins that make up a viral capsid give viruses a variety of shapes.

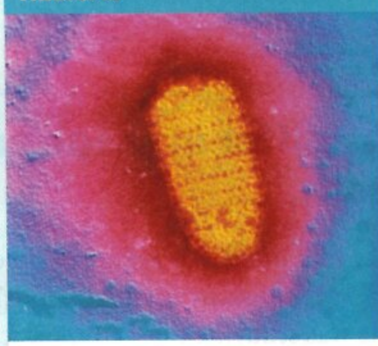
ENVELOPED



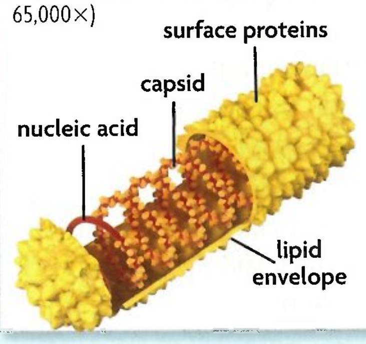
Enveloped viruses, such as this influenza virus, often have spikes. The envelope is shown in orange. (colored TEM; magnification 255,000×)



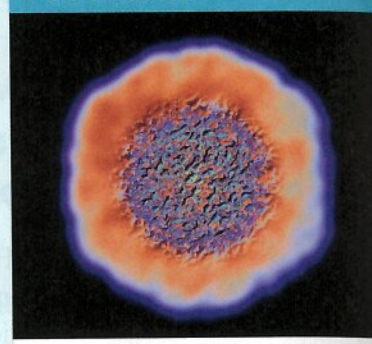
HELICAL



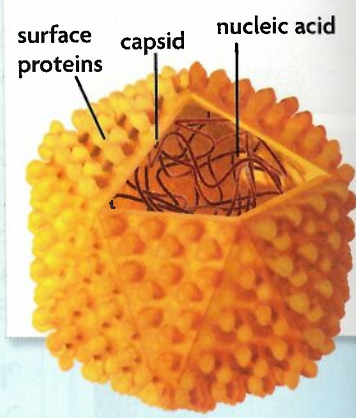
Some viruses have a long, narrow, coiled shape called a helix. The rabies virus is an example of a helical virus that also has an envelope. (colored TEM; magnification 65,000×)



POLYHEDRAL



Polyhedral viruses are many-sided, like the one shown here that causes foot-and-mouth disease in animals. (computer illustration)



Compare and Contrast **What are the similarities and differences between the three types of viruses shown above?**

In some viruses, capsids form a 20-sided polyhedral. Rod-shaped and strandlike viruses often have capsids shaped in coils, like a spring or helix.

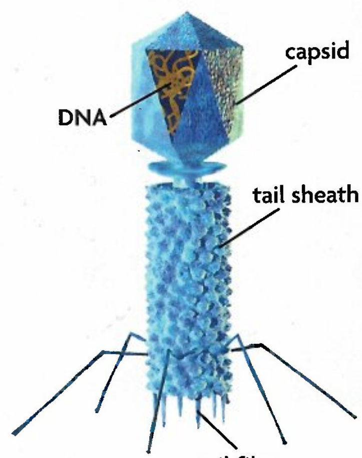
In contrast to prokaryotes and eukaryotes, in which DNA is always the main genetic material, a virus can have either DNA or RNA but never both. The genetic material of viruses can be single-stranded or double-stranded, and linear, circular, or segmented.

Viruses that Infect Bacteria

One group of viruses is the bacteriophages, often called simply "phages." **Bacteriophages** (bak-TEER-ee-uh-FAYJ-ihz) are viruses that infect bacteria. One example is the T-bacteriophage that infects *Escherichia coli,* the bacteria commonly found in the intestines of mammals. The T-bacteriophage shown in **FIGURE 18.5** has a 20-sided capsid connected to a long protein tail with spiky footlike fibers. The capsid contains the genetic material. The tail and its spikes help attach the virus to the host cell. After attachment, the bacteriophage's tail releases an enzyme that breaks down part of the bacterial cell wall. The tail sheath contracts, and the tail core punches through the cell wall, injecting the phage's DNA. The phage works like a syringe, injecting its genes into the host cell's cytoplasm, where its DNA is found.


colored SEM; magnifications: large photo 25,000×; inset 38,000×

FIGURE 18.5 The SEM above shows bacteriophages attacking an *E. coli* bacterium. While injecting their genetic material into the bacterium, the protein coats remain outside the cell (inset). The unique structure of a bacteriophage is shown below.



Viruses that Infect Eukaryotes

Viruses that infect eukaryotes differ from bacteriophages in their methods of entering the host cell. For example, these viruses may enter the cells by endocytosis. Recall from Chapter 3 that endocytosis is an active method of bringing molecules into a cell by forming vesicles, or membrane-bound sacs, around the molecules. If the viruses are enveloped, they can also enter a host cell by fusing with the plasma membrane of the host cell and releasing the capsid into the cell's cytoplasm. HIV is a virus that enters cells in this way. Once inside the cell, eukaryotic viruses target the nucleus of the cell.

Summarize Describe how the structures of a bacteriophage are well-suited for their functions.

MAIN IDEA

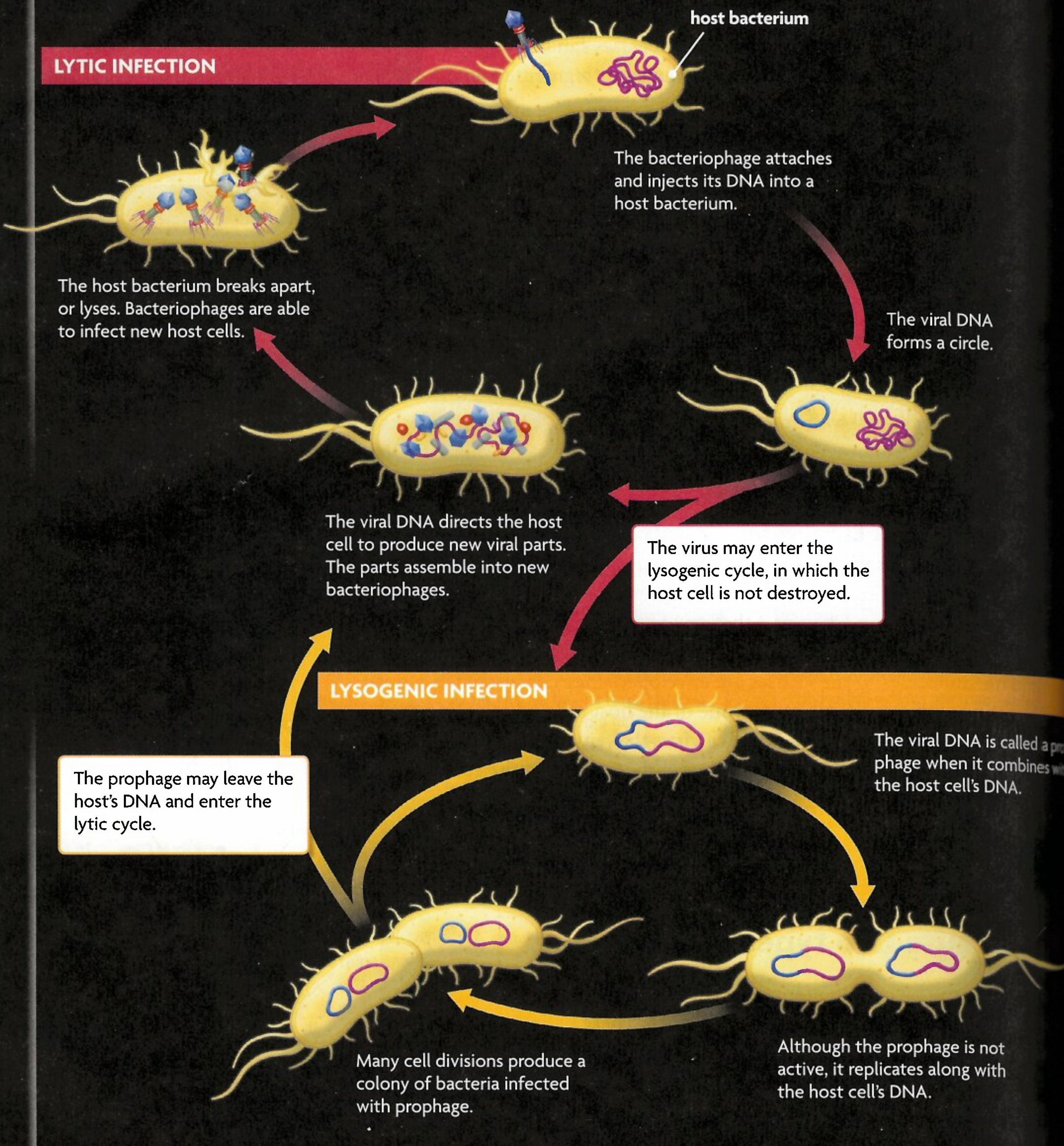
Viruses cause two types of infections.

The ways in which viruses enter and leave a cell may vary, but two basic pathways of infection are similar for all viruses. These pathways are shown for the most studied viruses, the bacteriophages, in **FIGURE 18.6.**

Once inside the host cell, phages follow one of two general paths in causing disease. In one path, the phage behaves like a bad houseguest. It takes over the household, eats all of the food in the refrigerator, and then blows up the house when it leaves. The other path of infection is somewhat more subtle. Instead of destroying the house, the phage becomes a permanent houseguest. Neither path is good for the host.

FIGURE 18.6 General Pathways of Viral Infection

A **lytic infection** results in the lysis, or breaking apart, of the host cell and release of new viral particles. A **lysogenic infection** does not destroy the host cell.



CRITICAL VIEWING Why are no capsids or tail sheaths made during a lysogenic infection?

Lytic Infection

A **lytic infection** (LIHT-ihk) is an infection pathway in which the host cell bursts, releasing the new viral offspring into the host's system, where each then infects another cell.

- When the viral DNA enters the host cell, it takes over control of the host's own DNA, turning on the genes necessary to copy the viral genes.
- Under direction of the viral genes, the host's DNA undergoes transcription and translation, and produces capsids and enzymes. The enzymes then help in the copying of the virus's DNA.
- Using energy from the host cell, the capsids and viral DNA assemble into new virions. Viral enzymes dissolve the host cell membrane, releasing the new virus particles into the host's bloodstream or tissues—and destroying the host cell in the process.

Lysogenic Infection

In a **lysogenic infection** (LY-suh-JEHN-ihk), a phage combines its DNA into the host cell's DNA.

- After entering the host cell, the viral DNA combines with the host's DNA, forming a new set of genes called a prophage. A **prophage** is the phage DNA inserted into the host cell's DNA. In organisms other than bacteria, this stage is called a provirus.
- The prophage is copied and passed to daughter cells, with the host's own DNA, when the host cell undergoes mitosis. Although this process doesn't destroy the cell, it can change some of the cell's traits.
- After the cell has been copied, the prophage faces two possible paths. A trigger, such as stress, can activate the prophage, which then uses the cell to produce new viruses. Or the prophage can remain as a permanent gene.

Connect **Using the analogy of viral infections resembling houseguests, explain which describes a lytic and which describes a lysogenic infection.**

VOCABULARY

The term *lytic* comes from the Greek word *lutikos*, meaning "able to loosen." The word *lysis* is often used in biology to describe a cell breaking apart.

NSTA SCILINKS scilinks.org

For more information on viruses, visit scilinks.org.
Keycode: MLB018

18.2 ASSESSMENT

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REVIEWING MAIN IDEAS

1. Name and describe the main parts of a typical virus.
2. What are the differences between a **lytic infection** and a **lysogenic infection**? Include the effects of each type of infection on the cells of the host organism in your answer.

CRITICAL THINKING

3. **Apply** Researchers studying infection can often grow bacteria more easily than they can grow viruses. What conditions must scientists provide for viruses to multiply?
4. **Classify** A wart is caused by a virus that may lie dormant for years before any symptoms appear. Does this resemble a lytic or lysogenic infection? Explain.

Connecting CONCEPTS

5. **Evolution** If the virus is a foreign invader, how is it possible for the proteins of its **capsid** to match the receptors on the host cell's surface? Consider natural selection in your answer.

18.3 Viral Diseases

KEY CONCEPT Some viral diseases can be prevented with vaccines.

MAIN IDEAS

- Viruses cause many infectious diseases.
- Vaccines are made from weakened pathogens.

VOCABULARY

epidemic, p. 553
vaccine, p. 553
retrovirus, p. 553

REVIEW AT CLASSZONE.COM

Connect Why do we worry about catching a cold or the flu every winter? Cold weather itself does not cause us to get sick, but spending time close to other people can. For most people, winter means spending more time indoors. Cold and flu viruses then easily transfer to hands from doorknobs and other objects. That's why frequently washing your hands can help keep you healthy.

MAIN IDEA

Viruses cause many infectious diseases.

As you have read, viruses follow two pathways of infection once they encounter their target cells. But to enter the host's body in the first place, the virus must first pass a major obstacle.

First Defenses

In vertebrates, the first obstacle a virus must pass is the skin, but in other organisms it might be an outer skeleton or a tough cell wall. Viruses can penetrate the skin only through an opening such as a cut or scrape. Or they can take another route—the mucous membranes and body openings. It's no accident that some of the most common points of entry for infection are the mouth, nose, genital area, eyes, and ears.

Once inside the body, the virus finds its way to its target organ or tissue. However, the targeted cells don't just open the door to this unwanted guest. Body cells have receptors that guard against foreign intruders. These receptors act almost like locks. When the virus arrives at the host cell, it uses its own surface proteins as keys to trick the cell into allowing it to enter.

Connecting CONCEPTS

Cells Recall from **Chapter 3** that receptors are proteins that detect chemical signals and perform an action in response. In the case of a host-specific infection, these normally helpful receptors provide little protection to the cell.

Examples of Viral Infections

Viruses can cause symptoms that range from merely bothersome to life-threatening. Below are a few of the many human illnesses caused by viruses.

The common cold The most familiar viral disease is the common cold. More than 200 viruses are known to cause this seasonal nuisance. One such cold virus is shown in **FIGURE 18.7.** With so many viruses, it's not easy to find a cure. In fact, cold viruses can mutate as they move from one person to another. Although they're unpleasant to have, colds usually last only about one week.

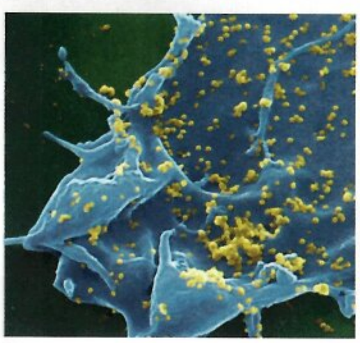

FIGURE 18.7 Cold virus particles (yellow) on the surface of a cell culture (blue). (colored SEM; magnification 10,000×)

fluenza Winter usually causes concern about the influenza, or "flu" virus—nd with good reason. The flu spreads quickly and can result in frequent local pidemics. An **epidemic** is a rapid outbreak of an infection that affects many eople. In the United States, up to 20 percent of the population is infected ith the flu each year.

At this time, only three influenza subtypes infect humans; other subtypes ay infect horses, pigs, whales, and seals. More than fifteen subtypes infect rds, and are all referred to as avian influenza, or bird flu. Sometimes a utation enables a virus to jump from one species to another, making the read of infection difficult to control. The high mutation rate of surface oteins on viral capsids makes it necessary for a new influenza vaccine to be ade every year. A **vaccine** (vak-SEEN) is a substance that stimulates the ody's own immune response against invasion by microbes.

ARS Severe acute respiratory syndrome (SARS) is another viral respiratory sease. It has symptoms similar to influenza, such as fever and coughing or fficulty in breathing. SARS is a relatively recent concern. It first appeared in ia in late 2002. By the following summer, it had spread to other countries. ARS continues to be monitored globally by the World Health Organization.

IV Human immunodeficiency virus, or HIV, is a retrovirus. *Retro-* means ackward," which describes how retroviruses work. Usually, DNA is used to ake an RNA copy in a cell, but a **retrovirus** is a virus that contains RNA and es an enzyme called reverse transcriptase to make a DNA copy. Double-randed DNA then enters the nucleus and combines with the host's genes as a sogenic infection. The viral DNA can remain dormant for years as a pro-rus, causing no symptoms to its human host.

When the virus becomes active, it directs the formation of new viral parts. he new viruses leave, either by budding or bursting through cell membranes, nd infect new cells. This stage of the disease is a lytic infection that destroys hite blood cells of the host's immune system, as shown in **FIGURE 18.9.** The ss of white blood cells ultimately causes AIDS, acquired immune deficiency ndrome. Once a person's immune system is affected, he or she may be able to fight off even the common icroorganisms that humans counter every day. HIV's unusu-ly high mutation rate has made it a allenge to treat. The combined use several antiviral drugs—medica-ns that treat viral infection—has oved somewhat effective in slow-g the spread of the virus once a rson is infected.

lyze How do retroviruses work erently from other viruses?

FIGURE 18.8 Nurses in Canada walk outside an emergency SARS clinic, which was opened to deal with an outbreak.

Connecting CONCEPTS

HIV Certain types of white blood cells of the human immune system are targeted by HIV to cause AIDS. You will learn more about HIV transmission and how this virus targets the immune system in **Chapter 31.**

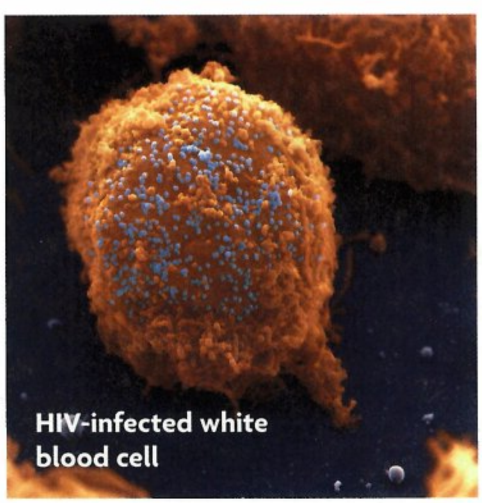

FIGURE 18.9 This scanning electron micrograph (SEM) shows the HIV virus as purple dots on an infected white blood cell. Destruction of white blood cells weakens the immune system and causes AIDS. (colored SEM; magnification: 3500×)

FIGURE 18.10 Viral Diseases

VIRAL INFECTION	SYMPTOMS OF DISEASE	TRANSMISSION OF DISEASE	U.S. VACCINE RECOMMENDATION
Chickenpox	rash, itchy skin, fever, fatigue	contact with rash, droplet inhalation	for children between 12 and 18 months
Hepatitis A	yellow skin, fatigue, abdominal pain	contact with contaminated feces	for people traveling to infected locations and protection during outbreaks
Mumps	painful swelling in salivary glands, fever	droplet inhalation	for children between 12 and 15 months and again at 4 to 6 years
Rabies	anxiety, paralysis, fear of water	bite from infected animal	for veterinarians and biologists in contact with wildlife
West Nile	fever, headache, body ache	bite from infected mosquito	no available vaccine

MAIN IDEA

Vaccines are made from weakened pathogens.

Chances are good that you have had vaccinations. In the United States, children are vaccinated at an early age against diseases such as measles, mumps, rubella (MMR), and chickenpox. Every year, millions of people are vaccinated against influenza. How does a simple shot provide protection against disease?

A vaccine is made from the same pathogen—disease-causing agent—that it is supposed to protect against. Vaccines consist of weakened versions of the virus, or parts of the virus, that will cause the body to produce a response. The immune system is triggered by the surface proteins of a pathogen. In the host's body, the vaccine works by preparing the host's immune system for a future attack. Vaccines can prevent some bacterial and some viral infections, including the viral diseases shown in **FIGURE 18.10.** Whereas bacterial diseases can also be treated with medicine once they occur, viral diseases are not easily treated. Vaccination is often the only way of controlling the spread of viral disease.

Vaccines cause a mild immune response. If the body is invaded again, it will be able to start an immune defense before the virus can cause damage.

Connecting CONCEPTS

Human Biology Vaccines help build up the immune system to prepare for exposure to a pathogen by recognizing its surface proteins. You will learn more about the immune system in Chapter 31.

Apply Before the chickenpox vaccination was available, children were often purposely exposed to the virus at a young age. What was the reason for doing this?

18.3 ASSESSMENT

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REVIEWING MAIN IDEAS

1. Name and describe two infectious viruses and a body's first defense against infection.
2. Briefly describe how a **vaccine** can prevent some viral infections.

CRITICAL THINKING

3. **Infer** If a vaccine is in short supply, why is it often recommended that older adults and children get vaccinated first?
4. **Apply** Why might getting a flu vaccination sometimes cause you to get a mild case of the flu?

Connecting CONCEPTS

5. **Human Biology** People infected with HIV, the virus that causes the disease AIDS, can become unable to fight off infections by organisms that normally do not harm people. Why is this so?

18.4 Bacteria and Archaea

KEY CONCEPT Bacteria and archaea are both single-celled prokaryotes.

MAIN IDEAS
- Prokaryotes are widespread on Earth.
- Bacteria and archaea are structurally similar but have different molecular characteristics.
- Bacteria have various strategies for survival.

VOCABULARY
- **obligate anaerobe,** p. 555
- **obligate aerobe,** p. 555
- **facultative aerobe,** p. 555
- **plasmid,** p. 556
- **flagellum,** p. 556
- **conjugation,** p. 558
- **endospore,** p. 558

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Connect Humans not only share the environment with prokaryotes—for many species, we *are* the environment. Up to 500 types of prokaryotes can live in the human mouth. In fact, you may have as many as 25 different types in your mouth right now. One milliliter of saliva can contain up to 40 million bacterial cells.

MAIN IDEA

Prokaryotes are widespread on Earth.

Prokaryotes, which include bacteria and archaea, are the most widespread and abundant organisms on Earth. Consider that humans are one species with about 6 billion individuals. In contrast, scientists estimate there are more than 1 billion (10^9) types of bacteria and more than 10^{30} individual prokaryotic cells on, above, and under Earth's surface. Bacteria and archaea are an important part of every community they inhabit. These tiny organisms live in just about every habitat on Earth, including the air we breathe. Prokaryotes have been found living inside rocks, in deserts, and in polar ice caps. One gram of soil may contain as many as 5 billion bacterial cells from up to 10,000 types of bacteria.

Prokaryotes can be grouped based on their need for oxygen. Prokaryotes that cannot live in the presence of oxygen are called obligate anaerobes. An **obligate anaerobe** (AHB-lih-giht AN-uh-ROHB) is actually poisoned by oxygen. As you have learned, archaea are prokaryotes that can live in extreme environments. The archaea that produce methane gas are obligate anaerobes. They live in marshes, at the bottom of lakes, and in the digestive tracts of herbivores such as deer, sheep, and cows, as shown in **FIGURE 18.11.** These microorganisms release nutrients from plants that animals are unable to digest on their own.

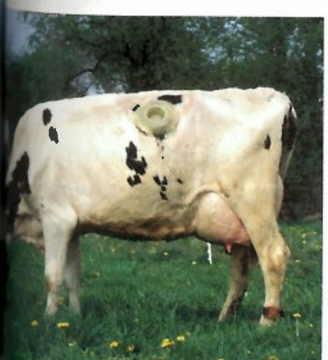


FIGURE 18.11 A "window" made into a cow's rumen, the first of its four stomachs, allows scientists to study digestion. Anaerobic bacteria live mutualistically within a cow's stomach. The bacteria have shelter and nutrients, and break down plant material for the cow to digest.

In contrast, some prokaryotes need the presence of oxygen in their environment. Organisms that need oxygen in their environment are called **obligate aerobes** (AHB-lih-giht AIR-OHBZ). This group includes several familiar pathogens, such as those that cause the diseases tuberculosis and leprosy. There are also prokaryotes that can survive whether oxygen is present in the environment or not. This type of prokaryote is called a **facultative aerobe** (FAK-uhl-TAY-tihv AIR-OHB).

Evaluate **Bacteria are often associated with illness. Why is this a misconception?**

MAIN IDEA

Bacteria and archaea are structurally similar but have different molecular characteristics.

Connecting CONCEPTS

Classification Recall from **Chapter 17** that archaea and bacteria are in separate kingdoms and in separate domains as well. Both their kingdoms and their domains have the same names, Archaea and Bacteria.

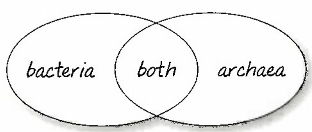
Members of domain Bacteria and domain Archaea comprise all of Earth's prokaryotes. Domain Bacteria is the more diverse and widespread of the two domains, while many archaea are found in Earth's extreme environments. Some archaea are even able to grow at temperatures greater than 100°C (212°F). Bacteria and archaea have many structural similarities but important genetic and biochemical differences.

Structural Comparisons

Even under the microscope, archaea look very similar to bacteria. For example, both archaea and bacteria are small, single-celled organisms that have cell walls and plasma membranes. Archaea come in many shapes, while the three most common forms of bacteria are shown in **FIGURE 18.12**. Bacteria are often named based upon their shapes. Rod-shaped bacteria are called *bacilli.* Spiral-shaped bacteria are called *spirilla* or *spirochetes,* and spherical bacteria are called *cocci.*

TAKING NOTES

Create a Venn diagram to compare bacteria and archaea using information from this section.



Prokaryotes do not have any membrane-bound organelles, such as a nucleus containing double-stranded DNA. Instead, their DNA is in the form of a circle and is surrounded by cytoplasm. Prokaryotes may also have plasmids. A **plasmid** is a small piece of genetic material that can replicate separately from the prokaryote's main chromosome.

Most prokaryotes can move on their own. Many bacteria and archaea move by gliding or using flagella. A **flagellum** (fluh-JEHL-uhm) is a long, whiplike structure outside of a cell that is used for movement. The flagella of prokaryotes are attached to the plasma membrane and cell wall. They may be at one end of an organism, or they may have different arrangements over the entire cell. Although similar in appearance, the flagella of bacteria and archaea are structurally different from each other. In addition, their flagella are both structurally different from the flagella of eukaryotes. You will learn more about the flagella of eukaryotes in Chapter 19.

Many prokaryotes also contain structures called pili that are thinner, shorter, and often more numerous than flagella. Pili help prokaryotes stick to surfaces and to other prokaryotes. A typical prokaryote is shown in **FIGURE 18.13**.

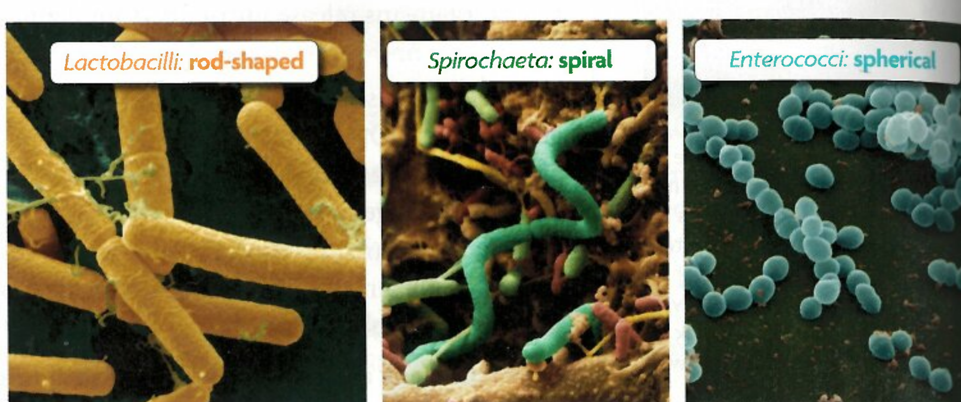
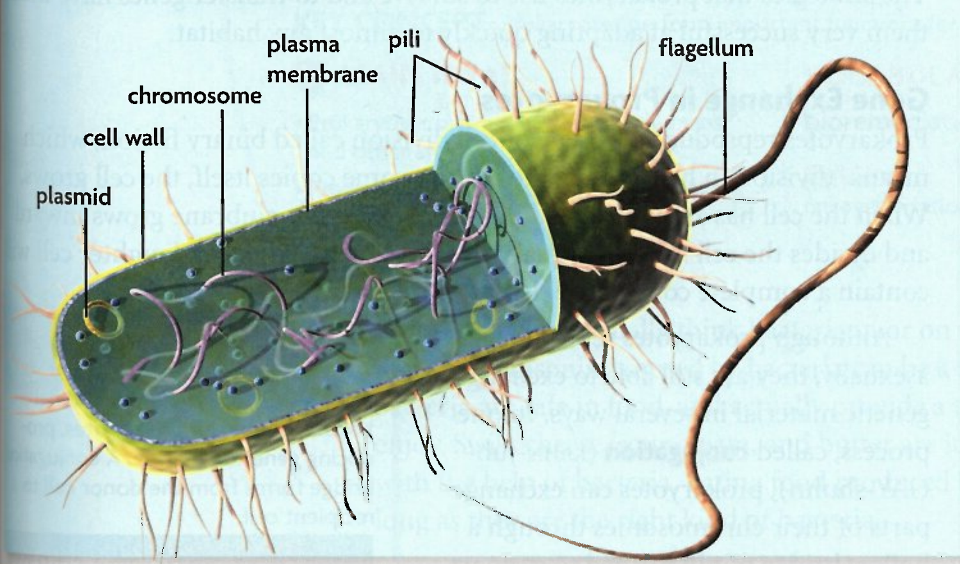


FIGURE 18.12 The most common shapes of bacteria are rods, spirals, and spheres. Many bacteria are named after these shapes. Some examples are shown at right. (colored SEMs; magnifications: *lactobacilli* magnification unknown; *spirochaeta* 5000×; *enterococci* 7000×)

FIGURE 18.13 Prokaryote Structure

This diagram shows the typical structure of a prokaryote. Archaea and bacteria look very similar, although they have important molecular differences.



Molecular Comparisons

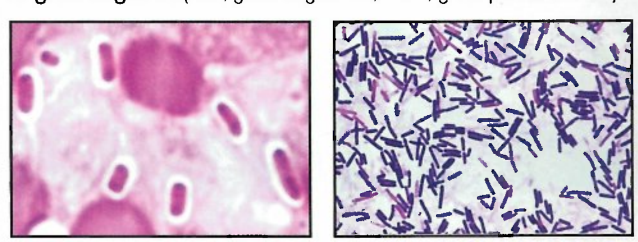
It was not until molecular analysis techniques were available that the many differences between bacteria and archaea became clear. Despite their similarities in function and appearance, bacteria and archaea are not closely related. Molecular evidence suggests that archaea have at least as much in common with eukaryotes as they do with bacteria. For example, archaea cell walls and membranes are chemically different from those of bacteria. The membranes of archaea contain lipids that are not found in any other type of organism on Earth, and bacteria have a polymer called peptidoglycan (PEHP-tih-doh-GLY-cuhn) in their cell walls, which archaea do not.

The amount of peptidoglycan in their cell walls is an important characteristic of bacteria. Bacteria are often classified into one of two groups based on this difference, as shown in **FIGURE 18.14**. A staining method called a Gram stain is used to tell the two groups apart. The Gram stain is important for diagnosing infectious bacterial diseases, and it sometimes helps determine the type of medicine a doctor chooses to fight infection. Because of their cell wall differences, archaea are often not affected by medicine used to treat bacterial infection.

Contrast Archaea were first named archaeabacteria, a term that you may still find in some books and articles. What are two differences between archaea and bacteria?

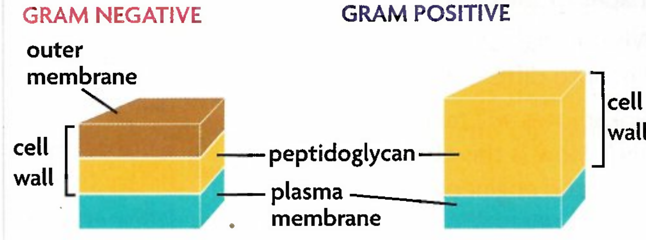
FIGURE 18.14 GRAM STAINING

A staining technique called a Gram stain is used to identify types of bacteria. This stain identifies the amount of a polymer, called peptidoglycan, that is present. The result is either gram positive or gram negative. (LMs; gram-negative 2,500×; gram-positive 550×)



Gram-negative bacteria have a thin layer of peptidoglycan and stain red.

Gram-positive bacteria have a thicker peptidoglycan layer and stain purple.



MAIN IDEA

Bacteria have various strategies for survival.

The strategies that prokaryotes use to survive and to transfer genes have made them very successful at adapting quickly to almost any habitat.

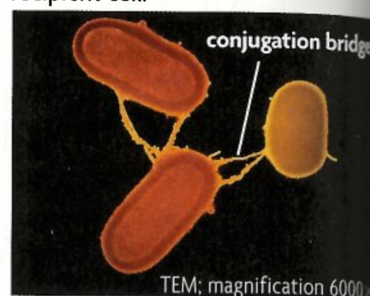
Gene Exchange in Prokaryotes

Prokaryotes reproduce by a type of cell division called binary fission, which means "division in half." While the chromosome copies itself, the cell grows. When the cell has about doubled in size, its plasma membrane grows inward and divides the cell into two equal-sized daughter cells. Each daughter cell will contain a complete copy of the parent cell's genes.

Although prokaryotes reproduce asexually, they are still able to exchange genetic material in several ways. In one process, called **conjugation** (KAHN-juh-GAY-shuhn), prokaryotes can exchange parts of their chromosomes through a hollow bridge of pili formed to connect two or more cells.

VISUAL VOCAB

In **conjugation,** genetic material transfers between prokaryotes, producing genetic variation. A conjugation bridge forms from the donor cell to a recipient cell.



Surviving Harsh Conditions

During conditions unfavorable for survival, some bacteria can produce an **endospore,** a specialized cell with a thick, protective wall. To form an endospore, the bacterium copies its chromosome and produces a wall around the copy. This thick wall around the bacterial DNA helps it survive harsh conditions such as drying out, temperature change, and disinfectants. Endospores can last for centuries. Some have even been found in Egyptian mummies!

Connect **Why are disinfectants alone not enough to kill all types of bacteria?**

18.4 ASSESSMENT

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REVIEWING MAIN IDEAS

1. What are the three most common shapes of bacteria?
2. Why are bacteria and archaea classified into different domains?
3. Prokaryotes will take up foreign DNA. How is this characteristic used in genetic engineering?

CRITICAL THINKING

4. **Infer** Scientists estimate that only 1 percent of prokaryotes can be grown in the lab. What does this suggest about our knowledge of bacteria and archaea?
5. **Synthesize** Prokaryotes multiply by binary fission, which simply divides a cell in two. Why are mutations and **conjugation** important for natural selection in prokaryotes?

Connecting CONCEPTS

6. **Health** Bacteria in your mouth convert foods containing sugar and starch into acids that can then cause cavities in your teeth. These bacteria will be present even if you brush your teeth, floss, or use mouthwash. So why are these hygiene habits so important?

18.5 Beneficial Roles of Prokaryotes

KEY CONCEPT Prokaryotes perform important functions for organisms and ecosystems.

MAIN IDEAS

- Prokaryotes provide nutrients to humans and other animals.
- Prokaryotes play important roles in ecosystems.

VOCABULARY

bioremediation, p. 561

Review

nitrogen fixation

REVIEW AT CLASSZONE.COM

Connect People usually think bacteria in or on food are harmful, and it is true that food poisoning caused by bacteria can be a serious problem. However, some bacteria are safe in food, and actually provide a taste or texture that many people enjoy. Swiss cheese, sour cream, and butter are just a few products that are made with the help of bacteria. Eating food produced by bacteria is not dangerous, as long as they are the right kind of bacteria!

MAIN IDEA

Prokaryotes provide nutrients to humans and other animals.

Prokaryotes, such as the bacteria shown in **FIGURE 18.15**, are a key part of animal digestive systems. A balanced community of prokaryotes in our bodies is important for our health. Prokaryotes have a beneficial relationship, or mutualistic symbiosis, with the host animal and break down food while getting a place to live. They also make vitamins and other compounds, and keep away harmful microbes by filling niches that might otherwise be filled by disease-causing bacteria. In turn, the host animal provides the bacteria with food and a home with a stable pH and temperature.

FIGURE 18.15 These bacteria, found in human intestines, are beneficial to our health. They produce B vitamins and keep out harmful microbes. (colored SEM; magnification: 6300×)

Humans can get nutrients from prokaryotes in other ways as well. Many foods that humans enjoy are fermented by bacteria. Bacteria help ferment, or chemically break down, many dairy products people eat every day, such as yogurt and cheeses. Pickles, soy sauce, sauerkraut, and vinegar also depend on fermentation by prokaryotes to produce their flavors.

***Connecting* CONCEPTS**

Ecology Recall from **Chapter 14** that *symbiosis* is the close association of two or more species. A *niche* is a specific role an organism plays in its environment.

Summarize **What are two ways in which prokaryotes that live within our bodies are helpful to us?**

QUICK LAB **OBSERVING**

Examining Bacteria in Yogurt

Some types of bacteria can ferment milk, producing lactic acid in the process. Yogurt is a product of fermentation. It is acidic and stays fresh longer than milk, and it is also digested more easily. In this exercise, you will prepare a microscope slide of yogurt.

PROBLEM What types of bacteria can you observe in yogurt?

PROCEDURE

1. Using a toothpick, place a dab of yogurt on a microscope slide. **Caution:** Do not eat in the laboratory.
2. Mix the yogurt in a drop of water and carefully add a coverslip.
3. Examine the slide with a compound microscope.
4. Record your observations by drawing a picture of what you see through the microscope.

MATERIALS

- toothpick
- dab of yogurt
- microscope slide
- drop of water
- coverslip
- microscope

ANALYZE AND CONCLUDE

1. **Identify** Recall the terms *bacillus, coccus,* and *spirilla* from the previous section. Which type or types of bacteria did you observe in your slides?
2. **Analyze** Many people do not produce lactase, which is an enzyme that breaks down the milk sugar lactose. As a result, lactose-intolerant people have trouble digesting dairy products. Why might they have fewer problems eating yogurt?

MAIN IDEA

Prokaryotes play important roles in ecosystems.

Even though you can't easily see them, prokaryotes play important roles in every ecosystem they occupy. Some, such as cyanobacteria, produce oxygen through photosynthesis. Others help recycle carbon, nitrogen, hydrogen, and sulfur through the ecosystem. The absence of prokaryotes in the environment can disrupt an ecosystem, since other organisms rely on them for survival.

Photosynthesizing prokaryotes include purple and green photosynthetic bacteria and cyanobacteria. Whereas purple and green bacteria use light to make carbohydrates, they do not produce oxygen. Cyanobacteria, however, are similar to plants in how they produce oxygen as a byproduct of photosynthesis. Cyanobacteria are named for their greenish blue (cyan) color. Recall from Chapter 12 that cyanobacteria played an important part on early Earth, supporting the life forms we are familiar with today. Fossil evidence suggests there was very little oxygen on Earth prior to the appearance of cyanobacteria.

Some colonies of photosynthesizing cyanobacteria, as well as other bacteria, are also able to fix nitrogen. Although much of the atmosphere is made up of nitrogen gas (N_2), this is not in a form that plants or animals can use to make amino acids or proteins.

Recall from Chapter 13 that nitrogen fixation is the process f converting atmospheric nitrogen into ammonia (NH_3) and ther nitrogen compounds that plants can then use. Prokary-tes supply usable nitrogen to ecosystems ranging from asslands and forests to the arctic tundra.

Some types of nitrogen-fixing bacteria are free-living, while hers live along with other organisms. Legumes, a group of lants including peas, beans, alfalfa, and clover, have a mutual-tic relationship with nitrogen-fixing bacteria. These bacteria e in the plant's nodules, small rounded lumps that form the ots, as shown in **FIGURE 18.16.** The bacteria provide usable itrogen to the plant by capturing nitrogen gas from air apped in the soil. They combine the nitrogen with hydrogen produce ammonia. In return, the plant supplies food and elter to the bacteria.

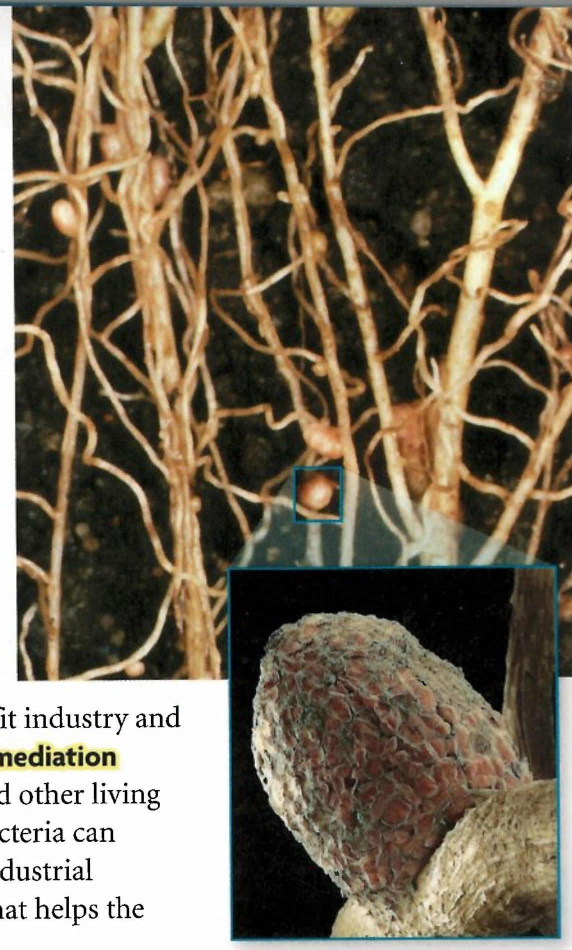

FIGURE 18.16 Root nodules of this white clover contain nitrogen-fixing bacteria. The symbiotic bacteria convert nitrogen from the atmosphere (N_2) into a form usable by the clover. In return, the plant produces carbohydrates through photosynthesis that the bacteria can consume. (inset colored SEM; magnification 90×)

Scientists have found many ways to use prokaryotes to benefit industry and e environment. One important use of prokaryotes is in **bioremediation** (BY-oh-rih-MEE-dee-AY-shuhn), a process that uses microbes and other living ings to break down pollutants. For example, some types of bacteria can gest oil, which is helpful for cleaning up oil spills and other industrial cidents. Workers spray oil-polluted beaches with a fertilizer that helps the acteria grow.

Bacteria can digest almost any product that humans can make, including oisons. Therefore, they play an important role in recycling and composting. hen you hear the term *biodegradable,* it often refers to the ability of bacteria break down a material. Some of the only materials made by humans that annot be biodegraded are certain types of plastics.

pply When there is a toxic chemical spill, sometimes workers will spray bacteria er the contaminated area. Why might they do this?

8.5 ASSESSMENT

ONLINE QUIZ
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EVIEWING ▶ MAIN IDEAS

1. Describe two ways bacteria provide nutrients to humans.
2. What are two roles prokaryotes play in the cycling of elements in an ecosytem?

CRITICAL THINKING

3. **Connect** Think of an example in which the use of **bioremediation** either has improved the environment or has the potential to do so.
4. **Synthesize** How do prokaryotes lend stability to an ecosystem?

Connecting CONCEPTS

5. **Ecology** Prokaryotes in cow intestines produce more methane if the cow is fed a diet high in grains rather than grass. Some scientists propose that overfeeding grain to cows contributes to global warming. How did these scientists arrive at this hypothesis, and how could it be tested?

8.6 Bacterial Diseases and Antibiotics

KEY CONCEPT Understanding bacteria is necessary to prevent and treat disease.

MAIN IDEAS

- Some bacteria cause disease.
- Antibiotics are used to fight bacterial disease.
- Bacteria can evolve resistance to antibiotics.

VOCABULARY

toxin, p. 563
antibiotic, p. 564

Review
homeostasis

REVIEW AT CLASSZONE.COM

Connect In the early 1900s, most deaths in the United States were caused by infectious diseases, such as bacterial pneumonia and tuberculosis. Thanks to new medicines, infectious diseases were among the least common causes of death by the century's end. In recent years, however, many diseases are making a comeback due to a new problem—antibiotic resistance.

MAIN IDEA

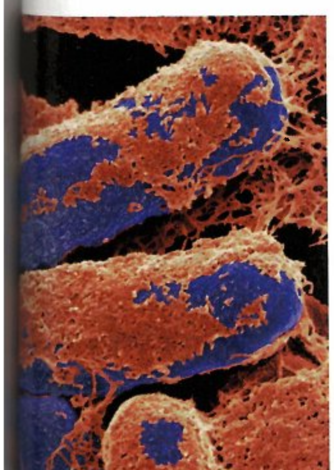
Some bacteria cause disease.

Some bacteria cause disease in plants and animals by disrupting the host organism's homeostasis, or the stability of its internal environment. Bacteria can cause illness to a host in two basic ways: by invading tissues and attacking cells or by making poisons, or toxins, that can be carried by blood to sites throughout the body. A **toxin** is a poison released by an organism.

The disease tuberculosis (TB) is an example of bacteria invading the host's tissues, and using the tissues for nutrients. *Mycobacterium tuberculosis* bacteria multiply in the lungs, killing white blood cells that respond to the invasion. The host's reaction to an invasion by bacteria may itself cause serious problems. In the case of TB, the host responds to the infection by releasing enzymes that cause swelling. That swelling, in turn, damages the host's lungs.

TB is a good example of the changing ecological balance between host and pathogen in an infectious disease. A host is not usually aware of pathogens that its immune system defeats. It is when the host's immune system fails that the host becomes aware of the pathogen's presence. Most healthy people can defeat a potential TB infection, especially if there are not many bacteria present.

Bacteria, such as *Staphylococcus aureus* and *Clostridium botulinum,* shown in **FIGURE 18.17,** can also make their hosts sick through food poisoning. *S. aureus,* which normally lives in nasal passages, can be transferred to food when food handlers don't wash their hands after they blow their nose. This transfer can result in serious food poisoning, known as staph poisoning. Even high temperatures cannot destroy a toxin produced by *S. aureus.* The most common source of food poisoning by *S. aureus,* however, is from foods that were contaminated after they were cooked. If contaminated food is not refrigerated, bacteria can multiply and produce a large amount of toxin.



[FIG]URE 18.17 *Clostridium [bo]tulinum* causes a serious [ill]ness called botulism. Food [co]ntamination by this bacterium [of]ten comes from improper home [ca]nning. (magnification unknown)

FIGURE 18.18 Common Bacterial Infections

INFECTION	BACTERIUM	SYMPTOMS	CAUSES
Acne	*Propionibacterium*	chronic cysts, blackheads	increased oil production in skin
Anthrax	*Bacillus anthracis*	fever, trouble breathing	inhaling endospores
Lyme disease	*Borrelia burgdorferi*	rash, aching, fever, swelling of joints	bite from infected tick
Tetanus	*Clostridium tetani*	severe muscle spasms, fever, lockjaw	wound contaminated with soil
Tooth decay	*Streptococcus mutans*	tooth cavities	large populations of bacteria in mouth

FIGURE 18.19 *Streptococcus* bacteria are commonly found on skin. They are fairly harmless unless they come in contact with tissues they do not normally colonize, such as muscle or fat. This can occur through open wounds.

Staph food poisoning can make you pretty sick, but botulism can kill you. *C. botulinum* produces a deadly toxin. Botulism is usually caused by the eating of improperly canned foods that were contaminated with endospores before being sealed. Bulging cans are a sign that *C. botulinum* may be present.

Normally harmless bacteria can be destructive when introduced to a part of the host that is not adapted to them. Disease can result if these bacteria get into tissues they do not usually colonize through a cut, scrape, or surgical incision. You can see one result of typically harmless *Streptococci*, which we have normally in our mouths and noses—and often on our skin—becoming pathogenic in **FIGURE 18.19.** These are also the bacteria that can cause what is commonly known as strep throat.

Apply **Potato salad left out at a picnic is sometimes a source of food poisoning. Which bacterium mentioned above is the most likely culprit? Explain.**

MAIN IDEA

Antibiotics are used to fight bacterial disease.

If you've ever had a cold, your doctor may have told you that the only cure was to let the cold "run its course." If you had strep throat, however, the doctor would prescribe a powerful antibiotic. Why do you get antibiotics for strep throat but not for the common cold?

Colds and strep throat are treated differently because they are caused by different pathogens. Viruses cause colds, while the bacterium *Streptococcus* causes strep throat. Many types of **antibiotics**—or chemicals that kill or slow the growth of bacteria—work by stopping bacteria from making cell walls.

Antibiotics are produced naturally by some species of bacteria and fungi. They can be used as medicine for humans and other animals without damaging their cells, since animal cells do not have cell walls. Because viruses also lack cell walls, antibiotics do not work on viral infections.

Antibiotics can be effective when used properly, but they should not be the first line of defense against bacterial infection; prevention should. Overuse of antibiotics can completely wipe out the community of intestinal microbes, resulting in illness.

Infer **Why don't antibiotics affect our bodies' own cells?**

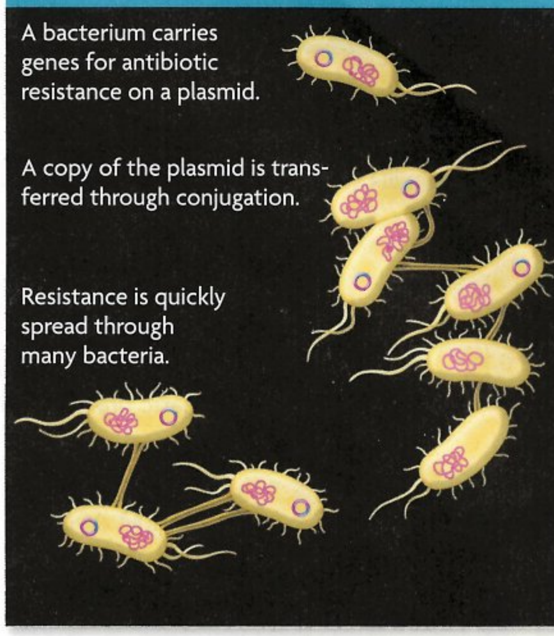
Connecting CONCEPTS

Immune System Although antibiotics do not work on viruses, vaccines may work on both viruses and bacteria. This is because vaccines trigger the immune system. You will learn more about how the immune system works in **Chapter 31.**

MAIN IDEA

Bacteria can evolve resistance to antibiotics.

FIGURE 18.20 ANTIBIOTIC RESISTANCE



Although antibiotics should certainly be used when needed, the inappropriate and incomplete use of antibiotics has produced a serious public health issue—multidrug-resistant bacteria. Resistance occurs as a result of natural selection, as individuals who are more resistant are more likely to survive and reproduce. This has led to the evolution of multidrug-resistant strains of "superbugs" that are almost impossible to treat. As you can see in **FIGURE 18.20**, bacteria can acquire genes for resistance through plasmid exchange. This has happened with many bacteria with a wide range of commonly used antibiotics. This problem has arisen due to various factors.

Overuse The potential problem with antibiotics is that they may create a selective pressure that favors the very bacteria they are intended to destroy. Using antibiotics when bacteria are not causing an illness may make some bacteria resistant.

Underuse Failure to take the entire course of antibiotics prescribed for a bacterial infection is one of the main factors leading to drug resistance. If your doctor prescribed a ten-day course of an antibiotic, you must finish the entire prescription. Otherwise, you may not have destroyed all of the bacteria—only the weakest ones.

Misuse A large portion of the antibiotics distributed in the United States are fed to livestock. Antibiotics are often misused in agriculture to increase the animals' rate of growth. However, when antibiotics are added to the food of healthy animals, bacteria within the food—including pathogens—can become resistant to multiple antibiotics.

Connect **How can you use "superbugs" as an example of natural selection?**

18.6 ASSESSMENT

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REVIEWING ▶ MAIN IDEAS

1. What are two ways in which bacteria can cause disease?
2. How can **antibiotics** stop bacterial infections?
3. What is antibiotic resistance, and how does it occur?

CRITICAL THINKING

4. **Apply** Why are antibiotics not effective against viruses?
5. **Synthesize** Evolution is often thought of as taking thousands, or even millions, of years to occur. What are two reasons that antibiotic resistance has been able to evolve in bacteria so quickly?

Connecting CONCEPTS

6. **Ecology** Pesticide resistance occurs in much the same way as antibiotic resistance. How could we apply what we have learned about antibiotic resistance to how pesticides are used in the environment?