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

ILLINOIS STANDARDS

12.11.11 Understand how prokaryotic cells, eukaryotic cells (whether of animals or plants and whether unicellular or multicellular), and viruses differ in complexity and structure. . . .

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.

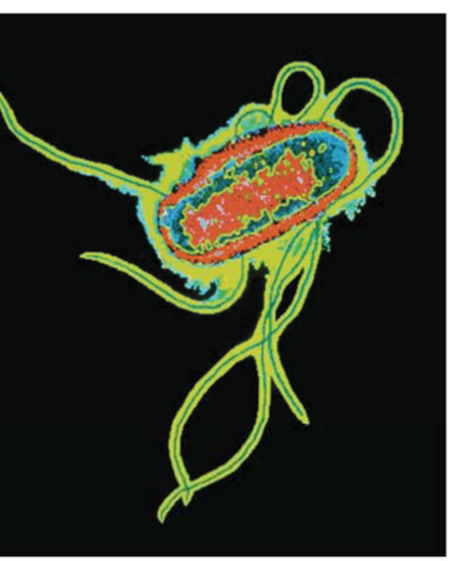
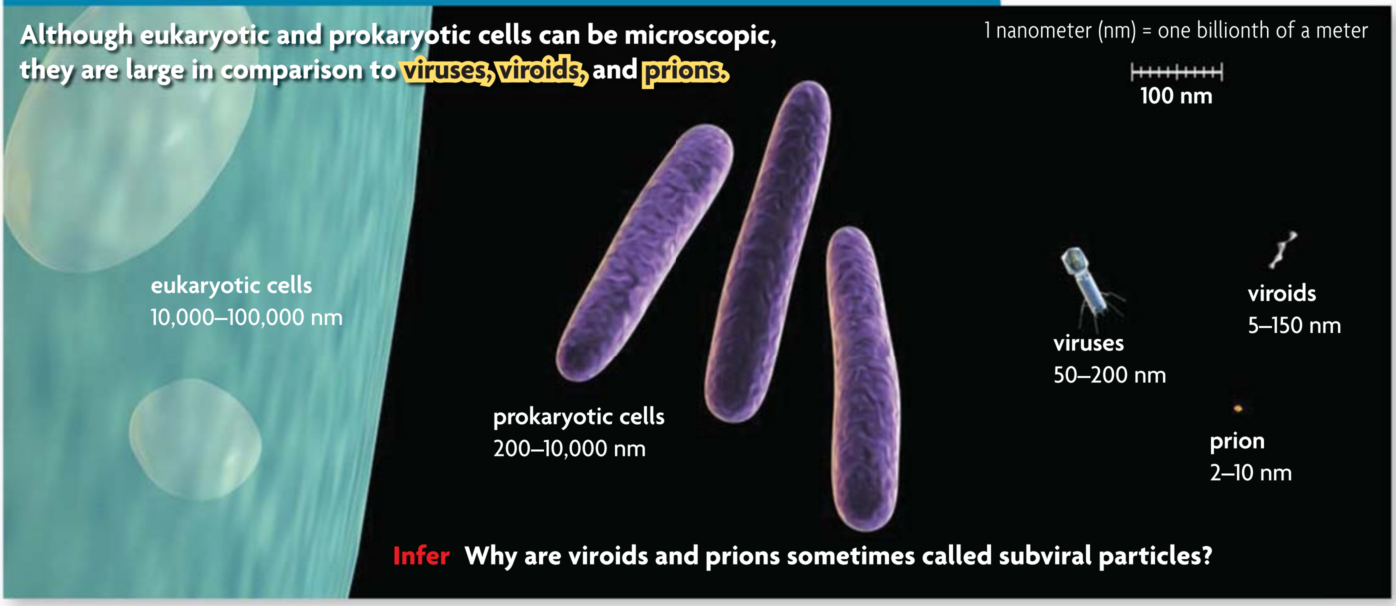


FIGURE 18.1 Prokaryotes, such as this *Escherichia coli* bacterium, are single cells that have all of the characteristics of living things. (colored TEM; magnification 6000×)

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 of biological classification?**

18.1 ASSESSMENT

ONLINE QUIZ ClassZone.com

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.

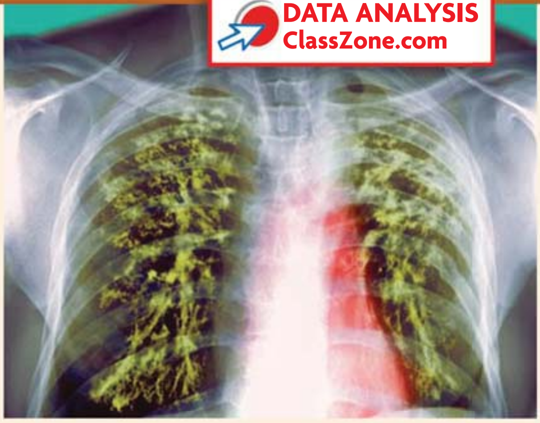
Connecting CONCEPTS

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?

DATA ANALYSIS ClassZone.com

Trends in Infectious Disease

Collecting data on the spread of infectious disease in a population is an important part of monitoring trends and determining a course of treatment. Different methods of displaying data, such as bar graphs or line graphs, often convey different information. Recall from page 497 in Chapter 16 the difference between discrete and continuous data.



Lungs infected by tuberculosis

TABLE 1. STATES WITH MOST TB CASES IN 2005

State	Number of cases
California	2900
Texas	1535
New York	1294
Florida	1094
Illinois	596
Georgia	510
New Jersey	485
Virginia	355
North Carolina	329
Pennsylvania	325

TABLE 2. RATE OF TB FOR U.S. RESIDENTS

Year	TB Cases per 100,000 Persons
1955	46.6
1960	30.7
1965	25.2
1970	18.1
1975	15.7
1980	12.2
1985	9.3
1990	10.3
1995	8.7
2000	5.8
2005	4.8

Source: Centers for Disease Control and Prevention

CHOOSE DATA REPRESENTATION

The tables above show two sets of data describing tuberculosis (TB) infection in the United States.

1. **Connect** For each of the tables above, identify whether the data are continuous or discrete.
2. **Graph Data** Determine which type of graph would best represent each set of data and construct the graph for each set.
3. **Analyze** What trend did your graph show in rates of tuberculosis cases in the United States between the years 1955 and 2005?
4. **Analyze** Which table gives a more complete picture of TB infection in the United States? Explain.
5. **Predict** What trend do you expect the rate of TB cases to show in 2010?

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

ILLINOIS STANDARDS

12.11.11 Understand how prokaryotic cells, eukaryotic cells (whether of animals or plants and whether unicellular or multicellular), and viruses differ in complexity and structure. . . .

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.

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.

FIGURE 18.3 These pictures compare a healthy leaf and a leaf infected by tobacco mosaic virus (TMV). TMV was the first virus identified by scientists.

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.

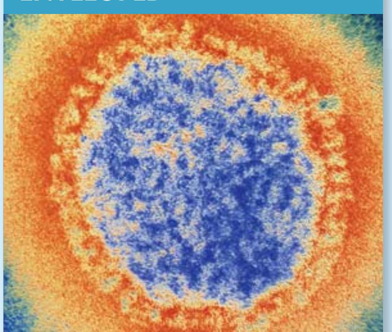
Viruses can only reproduce after they have infected host cells. Viruses are simply packaged sets of genes that move from one host cell to another. Unlike bacteria and other living parasites, a virus has no structures to maintain—no membranes or organelles needing ATP, oxygen, or glucose. All it carries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

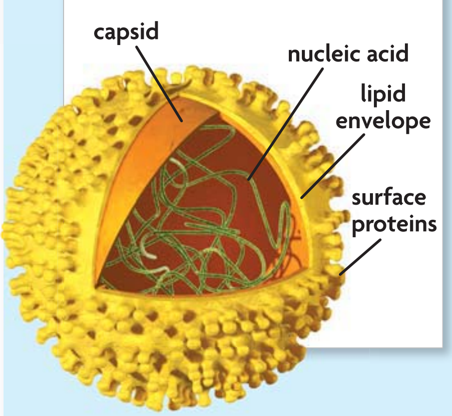
FIGURE 18.4 Viral Shapes

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

ENVELOPED

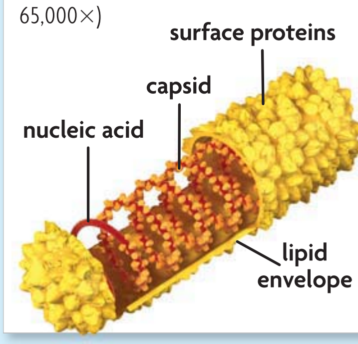


Enveloped viruses, such as this influenza virus, often have spikes. The envelope is shown in orange. (colored TEM; magnification 255,000×)

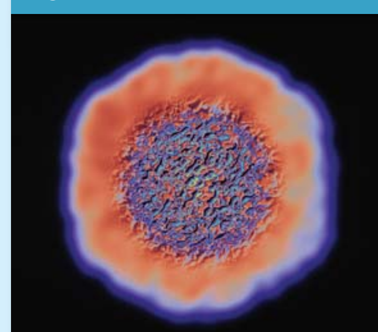


HELICAL

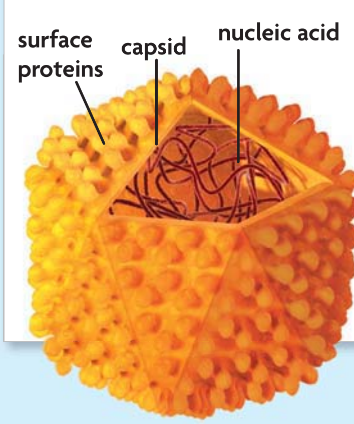
Some viruses have a long, narrow, coiled shape called a helix. The rabies virus is an example of a helical virus that also has an envelope. (colored TEM; magnification 65,000×)



POLYHEDRAL



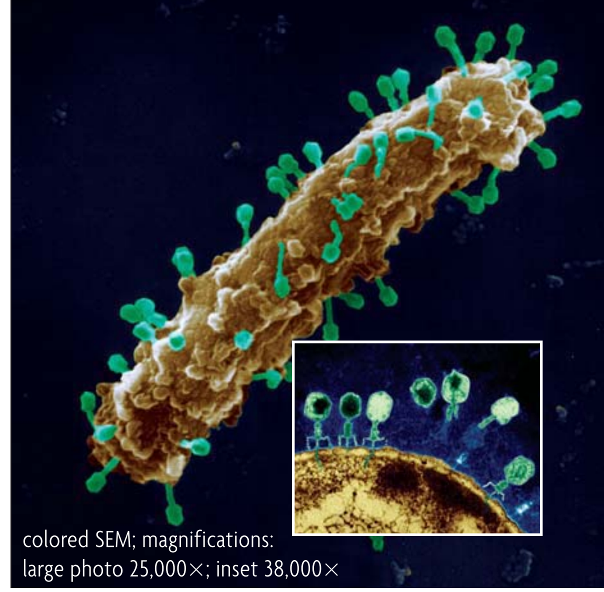
Polyhedral viruses are many-sided, like the one shown here that causes foot-and-mouth disease in animals. (computer illustration)



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.

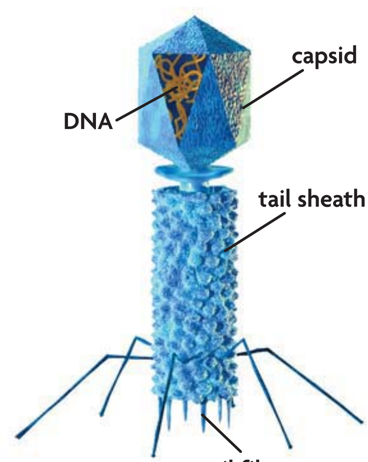
In contrast to prokaryotes and eukaryotes, in which DNA is always the main genetic material, a virus can have either DNA or RNA but never both. The genetic material of viruses can be single-stranded or double-stranded, and linear, circular, or segmented.



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 prey on 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.

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 prey on 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.

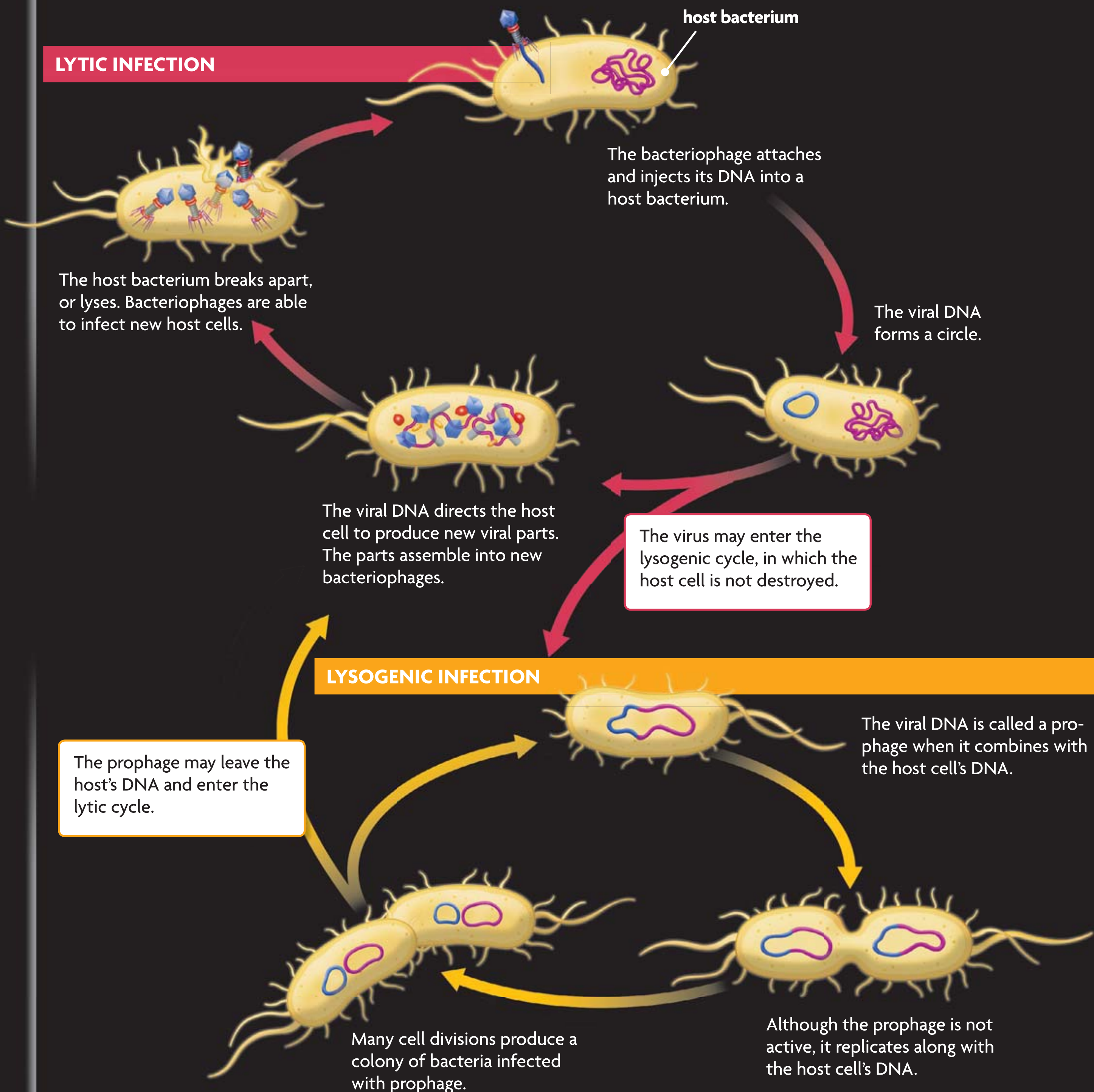
The ways in which viruses enter and leave a cell may vary, but two basic pathways of infection are similar for all viruses. These pathways are shown for the most studied viruses, the bacteriophages, in **FIGURE 18.6.**

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.

Animated BIOLOGY Examine the two ways in which viruses infect host cells at ClassZone.com.

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.

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.

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.

NSTA SCILINKS scilinks.org

For more information on viruses, visit scilinks.org.

Keycode: MLB018

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

18.2 ASSESSMENT

ONLINE QUIZ ClassZone.com

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.

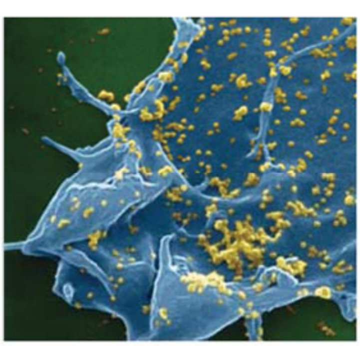


FIGURE 18.7 Cold virus particles (yellow) on the surface of a cell culture (blue). (colored SEM; magnification 10,000×)

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

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

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

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

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

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.**

When the virus becomes active, it directs the formation of new viral parts. The new viruses leave, either by budding or bursting through cell membranes, and infect new cells. This stage of the disease is a lytic infection that destroys white blood cells of the host's immune system, as shown in **FIGURE 18.9.** The loss of white blood cells ultimately causes AIDS, acquired immune deficiency syndrome. Once a person's immune system is affected, he or she may be unable to fight off even the common microorganisms that humans encounter every day. HIV's unusually high mutation rate has made it a challenge to treat. The combined use of several antiviral drugs—medications that treat viral infection—has proved somewhat effective in slowing the spread of the virus once a person is infected.

Analyze How do retroviruses work differently from other viruses?

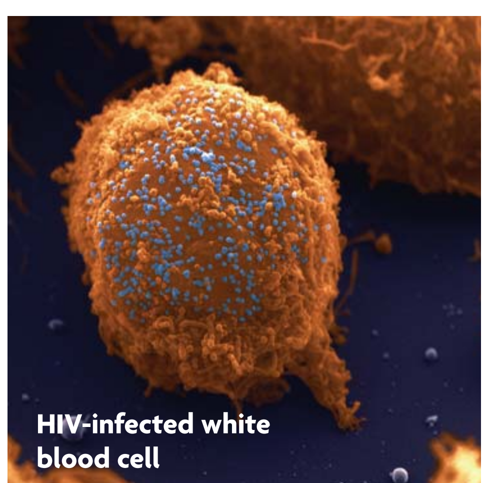


FIGURE 18.9 This scanning electron micrograph (SEM) shows the HIV virus as purple dots on an infected white blood cell. Destruction of white blood cells weakens the immune system and causes AIDS. (colored SEM; magnification: 3500×)

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.

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?

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.

18.3 ASSESSMENT

ONLINE QUIZ
ClassZone.com

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?