

# Human Infectious Disease

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**M**icroorganisms (commonly called *microbes*) are found in all environments on Earth. They are found in the air, on food and plants, in and on animals, in the soil and water, and on just about every surface. Microbes range in size from microscopic single-celled organisms to parasitic worms that grow to several feet in length. Although microorganisms are everywhere, few of them cause disease in humans. Those that do usually are dealt with by our immune systems, discussed in the previous chapter. Even though the vast majority of microbes are harmless, some of those that cause disease can be quite deadly. Disease-causing microorganisms make us ill because they cause symptoms before our immune systems can respond. Making matters worse, some mi-

## THINKING CRITICALLY

You work out regularly at a local gym and jog three times a week with a friend. One day you and your friend see a story on the local TV news about an outbreak in your city of a bacterial disease called *listeriosis*. Discovered in some packages of a brand of luncheon meat sold in your local supermarket, the bacterium, if ingested, may cause serious complications including stillbirth in pregnant women late in pregnancy. It may also cause meningitis (infection of the connective tissue layers surrounding the brain) in the elderly. After hearing the story, your friend announces that he has a package of this luncheon meat in his refrigerator and, in fact, ate some of it two days ago.

Since he is a healthy 20-year-old and is not sick, he dismisses the story. He says the package must be fine, because he hasn't gotten sick. He announces that he is going to have some of the meat in a sandwich for lunch and invites you to join him for lunch. What advice would you give your friend?

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Microorganisms undergo mutations, creating new forms that are able to breach our immune system's defenses, causing disease, even death. Disease may occur in normal healthy individuals, but those with weakened immune systems are particularly vulnerable. As you learned in Chapter 14, poor nutrition may lead to a weakened immune system.

In this chapter, you will learn about the agents that cause infectious disease in humans. You will also learn about the stages of human diseases and discover how microorganisms cause disease. You will study the ways microbes are transmitted from one person to the next. In addition, you will learn about newly emerging infectious diseases and bioterrorism. Before we examine these topics, however, let's review what you learned about infectious agents—the viruses and bacteria—in the last chapter and expand your understanding of these organisms.

### Health Tip 15-1

Don't skip breakfast. Your mother's right, it is the most important meal of the day!

*Why?*

Breakfast breaks a huge fast caused by sleep, a time when no food enters the body. Body stores of nutrients like liver glycogen, a source of blood sugar, run low during sleep. When morning comes, it's best to replenish these supplies.

Breakfast supplies about 17% of one's daily caloric input at a crucial time. It also typically supplies about 25% of the recommended daily intake of dairy products. If you're eating right, that is, including fruits in your diet, breakfast will supply up to 28% of the recommended intake of fruit. It will provide 20% of the daily recommended grains and 28% of most vitamins and minerals. It's a quick meal with a big impact.

## 15-1 The Infectious Agents of Human Disease

When most of us hear the words *bacteria* and *virus*, we usually think of infections and the diseases they cause such as the flu or the common cold. In reality, most of these microorganisms are harmless to humans. Only a few actually cause disease. Microbes that cause disease are called **pathogens**. Microbes are considered **infectious** if they invade and grow in the tissues of the body. They are considered to be **contagious** if they can be readily transmitted from one organism to another—for example, from one person to another.

### Disease-Causing Agents

Many infectious diseases remain dangerous today.

History is full of accounts of infectious diseases that periodically flared up, creating huge epidemics. Infectious diseases, such as the plague, cholera, and smallpox, were once known as “slate-wipers” because they killed millions of people in Europe and other countries. Knowledge of impending epidemics often generated shock and terror in populations.

Until the 1850s, the fear of such diseases was complicated by ignorance because no one knew the cause of these diseases. To combat these diseases, people often dressed in strange costumes that were thought to ward off disease (Figure 15-1). Many strange potions and procedures, such as bloodletting, were used to cure people who had become ill. Unfortunately, few of these “cures” were effective, and some methods such as bloodletting often made a bad situation worse.

Before the turn of the twentieth century, the work of scientists such as Louis Pasteur, Robert Koch, and others had shown that certain microbes caused many of the devastating diseases of the time. In fact, the research of Pasteur and Koch culminated in the



**FIGURE 15-1 Beak Doctors** Some physicians during the time of plague believed that wearing a beak-like mask would protect them from the disease. Such physicians were called “Beak Doctors.”

## Scientific Discoveries that Changed the World

### 15-1 The Germ Theory of Infectious Disease Featuring the Work of Louis Pasteur and Robert Koch

Throughout history, infectious diseases such as plague, tuberculosis, typhoid fever, and diphtheria ravaged peoples and populations around the world. Neither royalty nor common folk were spared from the devastation. Fear was rampant during epidemics because no one knew how to cure people afflicted with the disease. Ways to eradicate such diseases were equally elusive.

Although cures for infectious diseases were not available in the nineteenth century, scientists were beginning to suspect infectious agents (“germs”) as the cause. The link between these diseases and infectious agents, however, was an idea that many in the 1800s found hard to believe because it did not fit with the perceptions at the time. Most scientists believed that infectious diseases, such as the plague and malaria, were spread by an altered chemical quality of the atmosphere or a poisoning of the air (the word malaria comes from *mala aria*, meaning “bad air”). These qualities of the air might arise from decaying or diseased bodies.

In the mid-1850s, evidence for germs (microorganisms) as the cause of infectious disease gained stronger footing thanks to the work of the French scientist Louis Pasteur. Pasteur was a chemist by training. In 1854, at the age of 32, he was appointed Professor of Chemistry at the University of Lille in northern France. In 1857, he was asked to unravel the mystery of why local French wines were turning sour. Pasteur observed that although

both good and soured wines contained tiny yeast cells, only the soured wines contained populations of barely visible rod-like organisms, known then and now as bacteria. His studies showed that yeast cells and bacteria are tiny, living factories in which important chemical changes take place. Pasteur’s work also drew attention to microorganisms as agents of change because bacteria appeared to make the wine “sick.” He surmised that, if microorganisms could sour wine, perhaps others could make people ill. In 1857, Pasteur published a short paper on wine souring by bacteria. In the paper, he implied that germs were related to human illness.

Other studies, discussed in **Scientific Discoveries 1-1**, furthered Pasteur’s understanding of microbes. He came to view microorganisms as entities that were everywhere. Some of these ubiquitous organisms, he concluded, might be agents of human disease. So sure was he of this fact that he formulated the germ theory of infectious disease. The germ theory holds that microorganisms are responsible for infectious diseases. Between 1865 and 1868, Pasteur showed that a mysterious disease of silkworms that was sweeping through France was caused by a protozoan that infected both the silkworms and the mulberry leaves fed to them. Pasteur showed that the disease could be controlled by separating the healthy silkworms from the diseased silkworms and their food. In quelling the spread of the silkworm disease, he strengthened the germ theory of infectious disease.

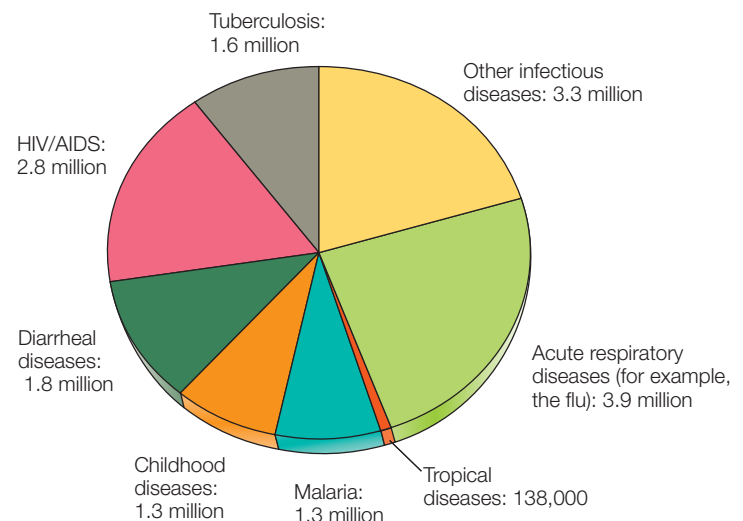
formulation of the **germ theory of disease** (as described in **Scientific Discoveries that Changed the World 15-1**). Thanks to their pioneering work, we now know the cause of most infectious diseases.

Once researchers and public officials understood the cause of infectious diseases, they set out to find ways to control or eliminate them. Over the years, better sanitation, improvements in water treatment, and the development of antibiotics and vaccines helped to control, even eliminate many infectious diseases. Despite these advances, however, infectious disease remains a major threat to human health worldwide. Moreover, some diseases still bring anxiety and alarm to the public. Just think about the fear that AIDS, the H1N1 virus, severe acute respiratory syndrome (SARS), and West Nile virus have caused in the United States and other countries. **Figure 15-2** shows the human impact of some of the most prolific deadly diseases that exist worldwide today.

### Viruses and Bacteria

Viruses and bacteria are among the most common infectious agents.

Many of the most common infections are caused by viruses and bacteria. As their name suggests, most microorganisms are tiny and cannot be seen without the aid of a microscope. To put their size into perspective, consider this analogy: If a virus were the size of a baseball, a typical bacterium would be the size of the pitcher’s mound. On this scale, one of your body’s cells that



**FIGURE 15-2 Infectious Disease Deaths Worldwide** This pie chart depicts the leading causes of infectious disease and the number of worldwide deaths, as reported by the World Health Organization. Tropical diseases include schistosomiasis and filariasis.

might be infected by the virus or bacterium would be the size of the entire ballpark.

**Viruses** are the simplest of all traditional infectious agents (**Figure 15-3**). As you may recall from Chapter 14, viruses contain genetic material—either DNA or RNA. The genetic information,

Pasteur made yet another important contribution to science and medicine in the 1870s. During this period, huge numbers of sheep and cattle in his home country were dying of anthrax, a deadly blood disease. Pasteur's research team showed that the disease was passed from animal to animal by infectious organisms, and he was confident that they could find a way of stopping the spread of anthrax by producing a vaccine.

Unfortunately, the work proved more difficult than he and his coworkers thought. Anthrax is highly infectious, and healthy animals have a strong chance of catching the disease simply by grazing over the burial site of anthrax victims. Still, he used the bacterium to produce an untested vaccine. Things came to a head in 1881 when a French veterinarian challenged Pasteur to test out his vaccine. Rather than appear unsure of his work, Pasteur accepted the challenge. His vaccine worked—his vaccinated sheep survived the injection of live anthrax spores. Again, Pasteur saved another French industry.

In 1885, Pasteur reached the zenith of his career when he successfully immunized a young boy against the dreaded disease rabies. Although he never saw the causative agent of rabies, Pasteur grew it in the brains of animals and injected the boy with bits of the brain tissue. Once again, success presented itself. Many monetary rewards followed, including a generous gift from the Russian government after Pasteur immunized 20 peasants against rabies. The funds helped establish the Pasteur Institute in Paris, one of the world's foremost scientific institutions. Pasteur presided over the institute until his death in 1895.

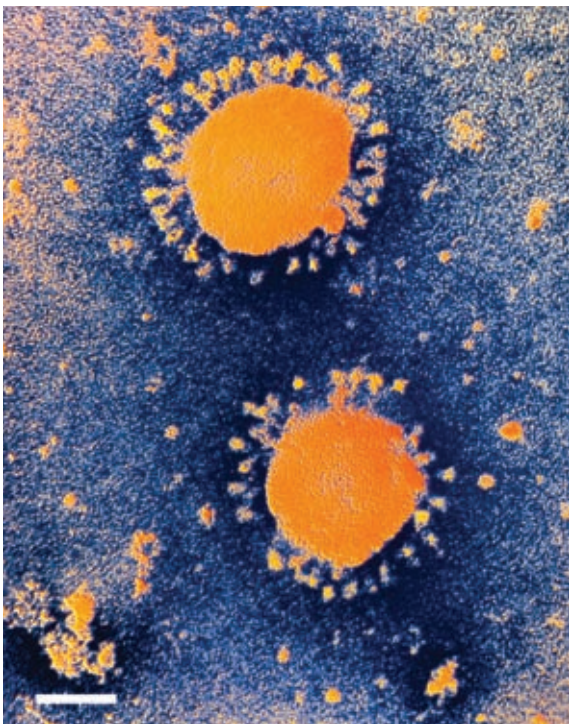
Pasteur's work stimulated others to investigate the nature of microorganisms and their association with disease. One of the most significant investigators was Robert Koch, a country doctor from East Prussia (now part of Germany). Koch's work provided the crucial evidence for complete acceptance of the germ theory.

In 1876, Koch observed the anthrax-causing bacteria with a microscope and identified the bacterium as that found in animals that had died from anthrax. Koch watched for hours as the rod-shaped bacteria multiplied, formed tangled threads, and finally reverted to highly resistant spores. He then took several spores on a sliver of wood and injected them into healthy mice. The symptoms of anthrax appeared within hours. Koch autopsied the animals, found their blood swarming with the same rod-shaped bacteria, and then re-isolated the bacteria. The cycle was now complete. The rod-shaped bacteria definitely caused anthrax. Koch established a set of criteria (called Koch's postulates) for proving that a specific microorganism caused a specific disease.

Koch's work on anthrax verified the germ theory of infectious disease. In 1881, he outlined his methods at an international medical congress, and several days later, Koch received a personal letter of congratulations from Pasteur.

Koch also reached the height of his influence in the 1880s. In 1883, he interrupted his work on tuberculosis to lead groups studying cholera in Egypt and India. In both countries, Koch isolated the infectious bacterium by following his previous methods. In 1891, he became Director of Berlin's Institute for Infectious Diseases. At various times, he studied malaria, plague, and sleeping sickness, but his work with tuberculosis ultimately gained him the 1905 Nobel Prize in Physiology or Medicine. He died of a stroke in 1910 at the age of 66.

By the end of the nineteenth century, the pioneering discoveries of Pasteur and Koch had created almost universal acceptance of the germ theory of infectious disease. With the passing of Pasteur and Koch, a new generation of international microbiologists stepped in to expand our understanding of microorganisms and infectious diseases.



**FIGURE 15-3 Coronaviruses** False color transmission electron micrograph of two human coronaviruses. In humans, coronavirus typically causes colds. The spikes can be seen clearly extending from the viral envelope. Viruses similar to these are responsible for severe acute respiratory syndrome (SARS). (Bar = 60 nm.)

containing genes, is surrounded by a protein coat, called the **capsid**. In some viruses, the capsid is covered by a membrane-like structure known as the **viral envelope** (see [Figure 14-1](#)).

As pointed out in Chapter 14, viruses are not cells, and they are not even considered living organisms because they lack the enzymes and cellular structures required for metabolism and growth. Because of this, viruses in the air or soil cannot replicate (make copies of themselves). To reproduce, they must invade living cells. Within these **host cells**, they find the chemicals and energy required to multiply.

All viruses go through similar life cycles. Consider, for example, the virus that causes chickenpox, one type of herpesvirus, which is shown in [Figure 15-4](#). To gain entry into a cell, the virus first attaches to protein receptors in the plasma membrane of target cells; in this case, it attaches to cells of the skin. The virus is then brought into the cell, often by phagocytosis, and its nucleic acid (DNA for the herpesvirus) is released into the cytoplasm. The virus' nucleic acid then takes control of the host cell's metabolic machinery, causing it to produce numerous copies of the virus' proteins. Once the components of new viruses are made, they are assembled into new viruses. In this process, an infected cell may produce hundreds of new viruses. After the viruses are assembled, they are released, usually when the cell bursts open. The host cell is typically destroyed in the process. [Table 15-1](#) includes several examples of common diseases caused by a variety of different viruses.

**TABLE 15-1 Human Diseases and Their Infectious Agent**

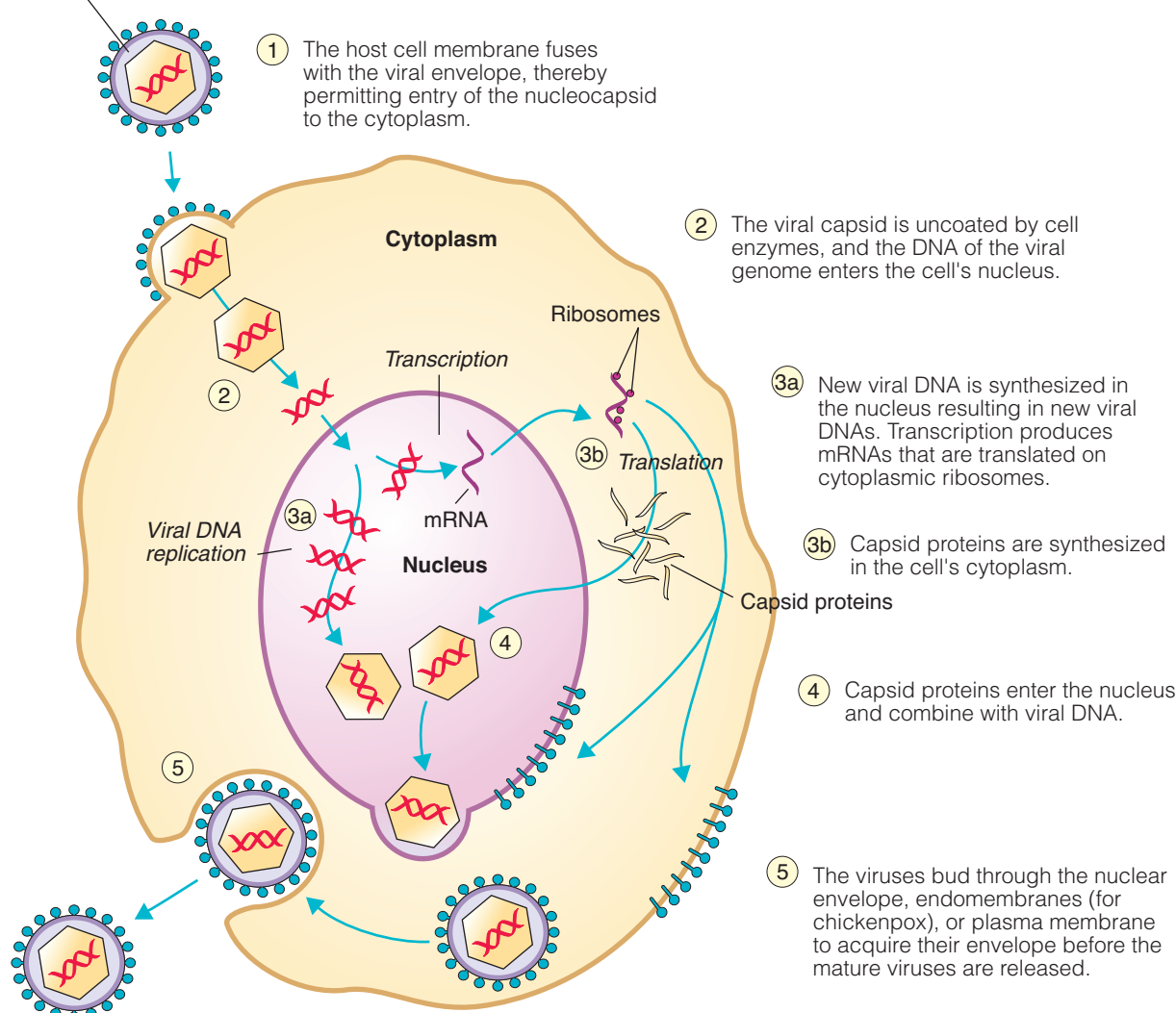
Disease	Infectious Agent					
	Virus	Bacterium	Fungus	Protozoan	Helminth	Other Agent
AIDS	✓					
Anthrax		✓				
Athlete's foot			✓			
Botulism		✓				
Chickenpox	✓					
Cholera		✓				
Common cold	✓					
Creutzfeldt-Jakob disease (variant)						✓
Cryptosporidiosis				✓		
Diarrhea	✓	✓		✓		
Diphtheria		✓				
Dengue fever	✓					
Ebola hemorrhagic fever	✓					
Filariasis					✓	
Genital herpes	✓					
Gonorrhea		✓				
Hantavirus pulmonary syndrome	✓					
Hepatitis	✓					
Histoplasmosis			✓			
Hookworm					✓	
Infectious mononucleosis	✓					
Influenza	✓					
Leprosy		✓				
Listeriosis		✓				
Lyme disease		✓				

**TABLE 15-1** Human Diseases and Their Infectious Agent—*continued*

Disease	Infectious Agent					
	Virus	Bacterium	Fungus	Protozoan	Helminth	Other Agent
Malaria				✓		
Measles	✓					
Monkeypox	✓					
Mumps	✓					
Oral thrush			✓			
Pinworm					✓	
Plague		✓				
Pneumonia	✓	✓	✓			
Rabies	✓					
Ringworm			✓			
Rubella	✓					
Salmonellosis		✓				
SARS	✓					
Schistosomiasis					✓	
Smallpox	✓					
Staph infections		✓				
Strep throat		✓				
Tetanus		✓				
Toxoplasmosis				✓		
Trichinosis					✓	
Tuberculosis		✓				
Typhoid fever		✓				
Valley fever			✓			
West Nile fever	✓					
Whooping cough (pertussis)		✓				

DNA-containing enveloped virus

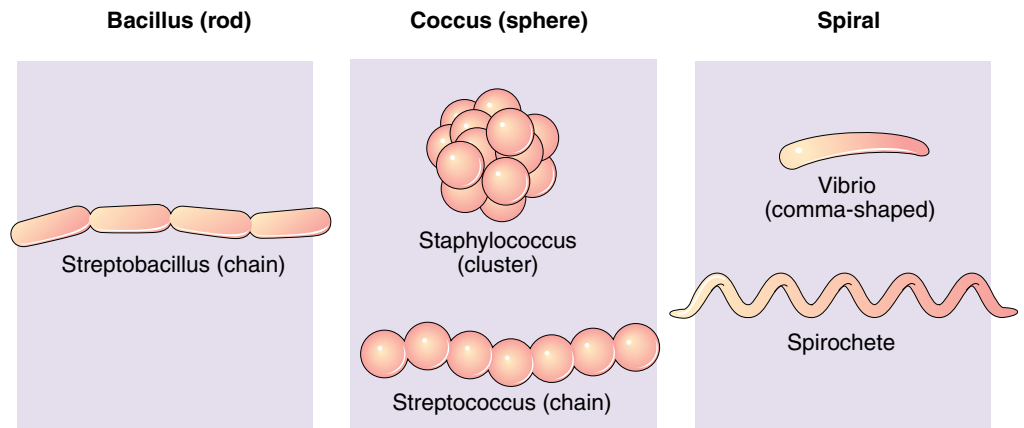
**FIGURE 15-4** Replication of a DNA Animal Virus The virus illustrated here is a herpesvirus (such as one that might cause chickenpox), and the host cell is from human skin.



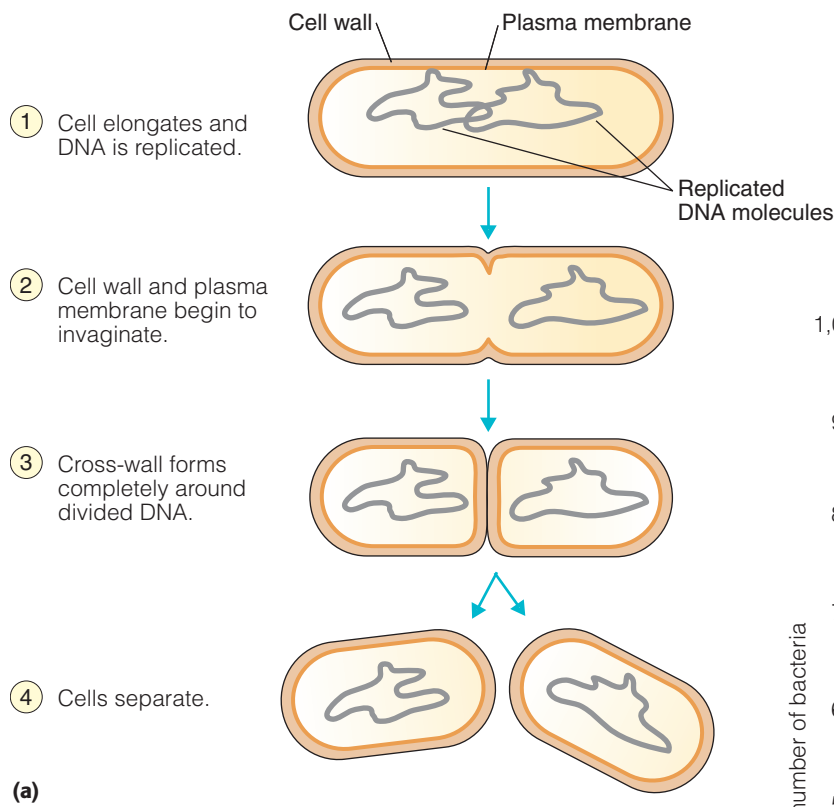
**Bacteria**, first described in Chapter 14, are single-celled organisms that usually are visible with a light microscope. Even so, they are so small that it would take a thousand of them laid end to end to span the diameter of a pencil eraser. Bacteria may be shaped like short rods, spheres, or spirals, depending on the species (Figure 15-5). Because bacteria are prokaryotes, they lack most of the organelles found in human cells. Nonetheless, most bacteria can reproduce and grow on their own—that is, they can reproduce without invading and taking over the metabolic functions of host cells as viruses do. During reproduction, bacteria replicate their DNA, then split into two identical cells, each with one copy of the DNA (Figure 15-6a). This process often occurs very rapidly, producing large populations of living cells in a very short time (Figure 15-6b).

As noted earlier, very few bacteria are harmful to humans. In fact, less than

1% of the bacteria known to science cause disease. Some bacteria that live in our bodies are beneficial. For example, a number of bacterial species live on our skin surface and protect us from potentially infectious pathogens. Likewise, many species of



**FIGURE 15-5** Variations in Bacterial Shape and Cell Arrangements



harmless bacteria live in our intestines and help us digest food, provide us with nutrients, and protect us against pathogens.

Pathogenic bacteria, on the other hand, can infect the body, causing illness, even death. Illness results from some combination of their rapid growth, their production of poisonous chemicals known as *toxins*, and our immune system's response to the infection. *Listeria*, the bacterium that causes human listeriosis, mentioned in the critical thinking exercise at the beginning of the chapter, is such an example (Figure 15-6). Table 15-1 lists several other common diseases caused by bacteria.

### Eukaryotic Pathogens and Parasites

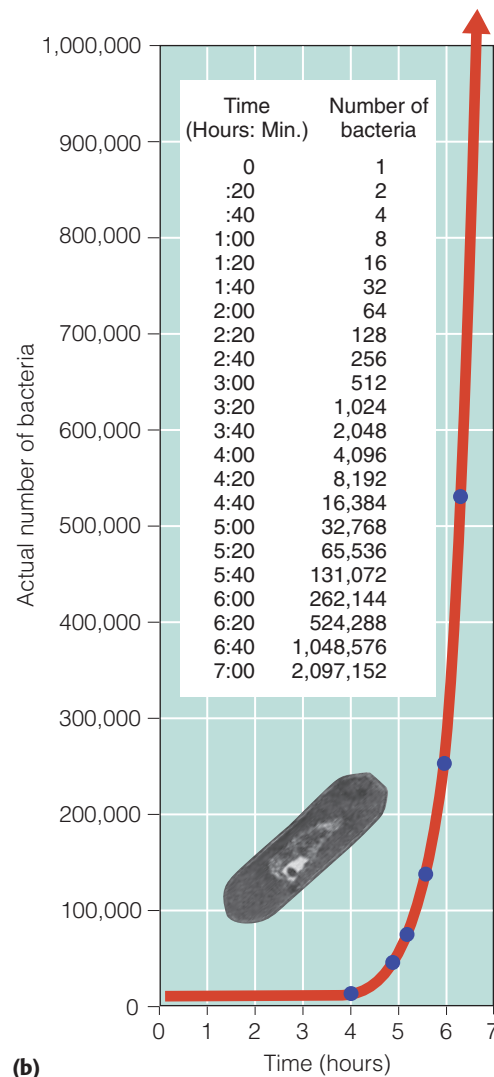
Fungi, protozoa, and helminthes also cause disease.

Not all infectious diseases are caused by bacteria and viruses. Several eukaryotic microbes such as fungi, certain protozoa, and helminthes can cause infections and some very serious diseases in humans (Table 15-1).

**Fungi** consist of the yeasts, molds, and a group you are probably most familiar with—mushrooms. Yeasts are single-celled organisms. Molds are multicellular and often are visible on spoiled foods, such as cheese or bread, or on overripe fruit. Mushrooms also are multicellular. Although they are not infectious organisms, some species of mushroom can produce toxic chemicals that can be deadly if consumed.

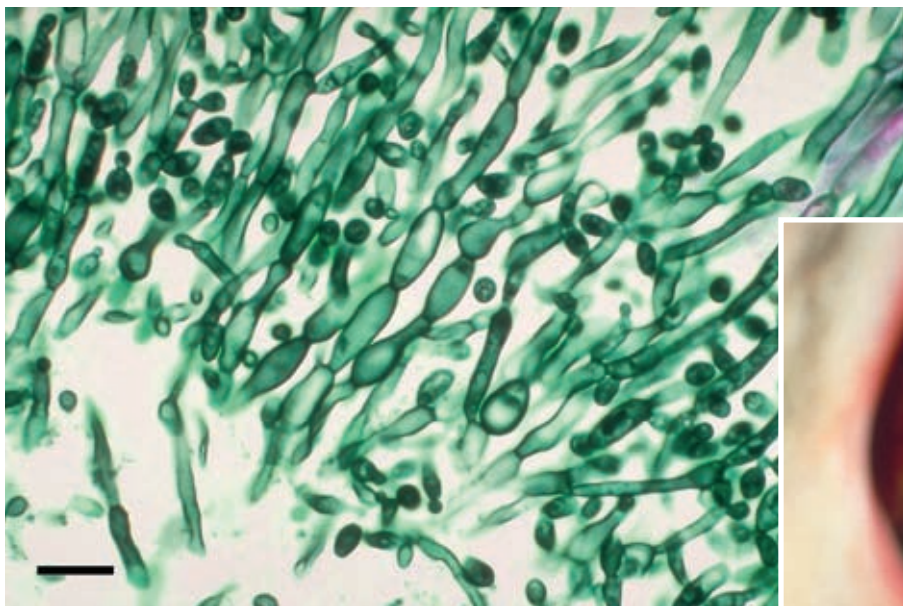
Fungi live in the air, water, and soil, and on plants. Some can live in our bodies, usually without causing illness. Some species of fungi are beneficial. For example, the antibiotic penicillin is produced by a fungus. This drug kills many species of infectious bacteria. Several species of yeast are also important

**FIGURE 15-6 Bacterial Cell Division** (a) As a result of DNA replication and cell division, two cells are formed, each genetically identical to the parent cell. (b) The number of bacteria progresses from 1 cell to 2 million cells in a mere 7 hours. The J-shaped growth curve gets steeper and steeper as the hours pass. Only a depletion of food, buildup of waste, or some other limitation will halt the progress of the curve. The photomicrograph is of a *Listeria* cell dividing.



in making foods such as bread and cheese. Yeasts also are used in the production of beer and wine.

A few fungi cause human illness and disease. For example, athlete's foot is caused by one species of fungi that grows in the skin. A yeast-like fungus known as *Candida* (Figure 15-7) can infect the mouth, causing oral thrush in infants, in people taking antibiotics, and in people with weakened immune systems. *Candida* is also responsible for most types of infection-induced diaper rash and is the organism responsible for "yeast infections" in the vaginas of adult women. Certain species of *Candida* can also grow inside the blood and tissues of the body. Fungal pathogens can produce respiratory diseases, such as valley fever in the American Southwest and histoplasmosis in the Ohio and Mississippi River valleys.



(a)

**FIGURE 15-7** The Agent of Oral Thrush (a) A photomicrograph of stained *Candida albicans* cells (bar = 40  $\mu$ m). (b) Oral thrush.



(b)

**Protozoa** also are single-celled eukaryotic organisms. Many protozoans inhabit the intestinal tracts of humans. Although most protozoans are harmless, some are pathogenic. Pathogenic protozoans spend part of their life outside of humans, living in soil, water, or insects, or infecting other animals. If they infect the human body, they often live off body fluids, surviving as parasites. A **parasite** is an organism that lives within the body of another, often causing some level of damage.

Protozoa invade the human body through contaminated food or water. One such parasite, *Cryptosporidium parvum*, invaded the Milwaukee city water supply in 1993 and was responsible for the largest waterborne disease outbreak in U.S. history, causing illness in more than 400,000 people. Other protozoa are transmitted through sexual contact. Still others are carried by vectors, organisms such as mosquitoes and ticks that transmit the protozoa from one person to the next. Malaria is an example. Malaria is perhaps the most prevalent and deadly of all protozoan diseases in the world, killing more than 1 million people (mostly children in tropical countries) each year. The malaria-causing protozoan, called *Plasmodium*, is transmitted from person to person by mosquitoes (Figure 15-8). For example, a mosquito sucks blood from one individual infected with *Plasmodium*. When that same mosquito attacks another person, it may transfer some of the protozoa to the uninfected person.

**Helminths** are parasitic worms. (The term *helminth* comes from the Greek for “worm.”) Most helminths are visible to the naked eye. Nonetheless, they are designated as “microorganisms” because they can cause infectious disease.

The most common helminths are flatworms and roundworms. When adult helminths or their microscopic eggs enter

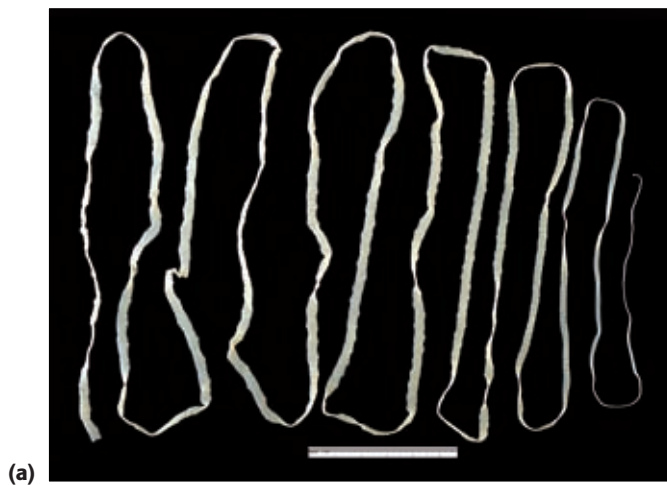
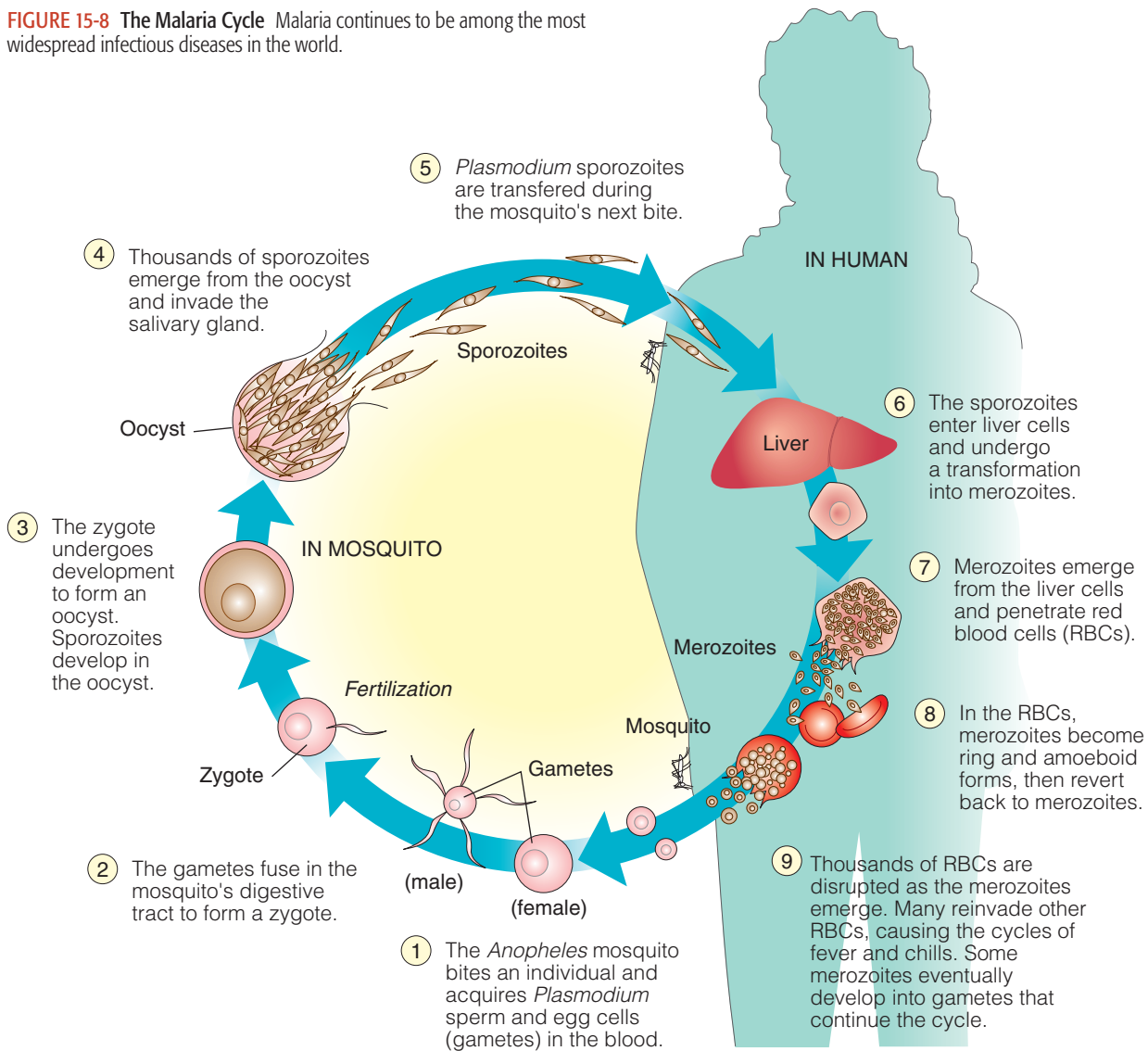
the body, they live parasitically off the body’s nutrients within the intestinal tract, lungs, liver, skin, or brain, depending on the species. **Flatworms** range in length from 6 inches to more than 25 feet! One of the most prevalent flatworms, *Schistosoma*, is responsible for a disease known as *schistosomiasis*, which affects more than 250 million people worldwide. Victims suffer from fever, muscle pain, diarrhea, coughing, vomiting, and a burning sensation during urination. **Tapeworms** are one type of flatworms made up of hundreds of segments, each of which is capable of breaking off and developing into a new tapeworm (Figure 15-9a).

Another type of helminth is the roundworm. **Roundworms** damage their hosts by forming large masses of worms in blood vessels, lymphatic vessels, or the intestines. The roundworm responsible for the disease filariasis, for example, blocks lymphatic vessels after many years of infection. The lymphatic vessels swell and become distorted with fluid. The condition is called *elephantiasis* (Figure 15-9b).

The most common roundworm disease in the U.S. is pinworm disease. Surprisingly, an estimated 30% of children and 16% of adults serve as hosts. Among the other roundworm diseases are trichinosis in pork and hookworm disease. Hookworm infects hundreds of thousands worldwide, causing a dry cough, mild fever due to the presence of worms in the lung, and abdominal pain due to the presence of worms in the intestine.

Besides these “traditional” microbial pathogens, other infectious agents exist. The most newsworthy nontraditional infectious agent is the prion. **Prions** are responsible for several diseases, including mad cow disease, and are described in [Health Note 15-1](#).

**FIGURE 15-8 The Malaria Cycle** Malaria continues to be among the most widespread infectious diseases in the world.



**FIGURE 15-9 Helminths** (a) An unmagnified view of the tapeworm *Taenia saginata*. This flatworm is long and ribbon-like and consists of hundreds of visible segments. *T. saginata* infects the human intestinal tract. (b) Elephantiasis of the leg caused by the roundworm *Wuchereria bancrofti*. The parasite breeds in the tissues of the lymphatic vessels and damages them. As fluid accumulates, the legs swell and become distorted.

## healthnote

## 15-1 Prions: Virus-Like Infectious Agents

**W**hen viruses were discovered, scientists believed they had found the smallest infectious particles. In recent years, however, that perception has changed. Scientists have discovered an apparently new class of disease agents—virus-like agents called **prions** (PREE-on). What are prions, how were they discovered, and what diseases do they cause?

To understand prions, we begin with a story of a mysterious illness that cropped up in 1986 in Great Britain. During that year, farmers found that some of their cattle were losing weight and losing control over their muscles. Many became aggressive. All of them eventually died. This disease was dubbed *mad cow disease*. Scientists thought that the disease was caused by a virus.

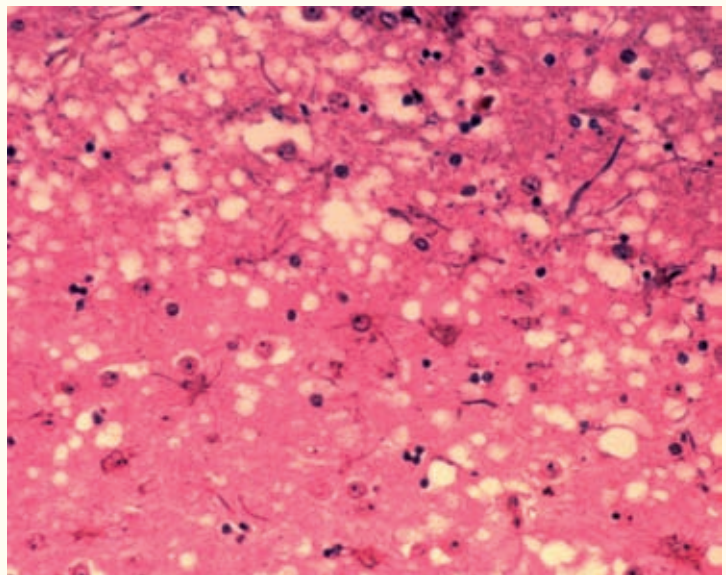
In the early 1990s, several young people died of a human brain disorder that resembled mad cow disease. Symptoms included dementia, weakened muscles, and loss of balance. After many studies, health officials hypothesized that the human disease was caused by eating beef that had been processed from cattle that had been afflicted with mad cow disease. They postulated that the disease agent was transmitted from cattle to humans.

Since then, the disease has produced an economic disaster to the beef export industry in Britain and caused a political crisis throughout the European Union and beyond. In January 2001, over 1,000 cattle in Texas were suspected of being the first in North America to suffer from mad cow disease. Luckily, tests conducted by the U.S. Food and Drug Administration (FDA) indicated that there was no mad cow disease present and no cause for alarm. In May 2003, however, the first mad cow was discovered in Alberta, Canada. In December, 2003, one case of mad cow disease was reported in the state of Washington.

Mad cow disease, also known as bovine spongiform encephalopathy (BSE), is a fatal brain disorder. Infected animals develop sponge-like holes in their brains (spongiform) where brain cells have been destroyed in large numbers (Figure 1).

Similar neurological degenerative diseases also have been discovered in other animals and humans. These include scrapie in sheep and goats, wasting disease in elk and deer, and *Creutzfeldt-Jakob* disease in humans. All are examples of a group of rare diseases called *transmissible spongiform encephalopathies* (TSEs) because, like BSE, they can be transmitted to other animals of the same species and possibly to other animal species, including humans.

At first, many scientists believed the disease agent responsible for these diseases was a new type of virus. However, to date, no virus or nucleic acid characteristic of a virus has been discovered in any of the



**FIGURE 1** A photomicrograph showing the vacuolar degeneration of gray matter characteristic of human and animal prion diseases.

## 15-2 The Course of a Human Disease

Up to this point, we have been using the terms *infection* and *disease*. What exactly is meant by them?

To a microbiologist and a doctor, the term **infection** is used to refer to a state of being infected by a microorganism or the process of being infected. A **disease** is a change from the healthy state of the body. An infectious disease results from an infection that has not been initially repelled by the immune system or halted by medical intervention, for example, by antibacterial or antiviral drugs. An infectious disease occurs when body cells are damaged or destroyed because of an infectious agent or by a product they produce.

### Pathogens and Disease

Pathogens differ in their ability to cause disease.

The ability of a pathogenic organism to cause disease depends on its pathogenicity. **Pathogenicity** refers to the ability of a microorganism or virus to gain entry into the host's tissues and then bring about a physiological or anatomical change that results in poor health. Pathogens vary greatly in their pathogenicity. For example, the bacteria responsible for cholera, plague, and typhoid fever cause serious human diseases in nearly all

animals. In the early 1980s, Stanley Prusiner and colleagues made a very interesting discovery while studying scrapie. Scrapie is the TSE that causes infected sheep to scrape their bodies raw on fences or other surfaces. Prusiner and colleagues isolated an unusual protein from scrapie-infected tissue that they thought represented the infectious agent. Prusiner called the infectious particle a *prion*. Based on more research and study, Prusiner and colleagues proposed the protein-only hypothesis. This hypothesis says that prions are composed solely of protein and contain no nucleic acid.

Because the gene (called PrP) that codes for the prion protein is primarily expressed in the brain, it was proposed that there are two types of prion proteins: (1) normal prion proteins that are found in all uninfected brain cells where they have a specific but still unidentified role and (2) abnormal prions, which are similar to the normal prions in many ways except in their shape.

Abnormal prions are found in infected cells and are the suspected infectious agents of diseases like mad cow disease. With the wrong shape, the abnormal proteins cannot carry out their specific role and eventually brain cell function falters; cell death soon follows. Based on his work with prions, Prusiner won the Nobel Prize in Physiology or Medicine in 1997. Nevertheless, some scientists believe a virus is somehow involved because the prion hypothesis “challenges” the basic belief of DNA and inheritance.

If the protein-only hypothesis is correct, how can an infectious agent without a shred of nucleic acid spread and cause disease? Many researchers believe that prion diseases are spread by the infectious abnormal prion binding to normal prion proteins, causing the latter to change shape. In a domino-like scenario, they hypothesize that the newly converted prion proteins cause other normal prion proteins to become abnormal. According to the hypothesis, all this occurs without any need for nucleic acid to replicate. The altered proteins are extremely stable, and thus accumulate in infected tissues causing damage and cell death.

The 1990s outbreak of mad cow disease supports this idea. Scientists originally thought BSE made its way into cattle through feed that contained bone meal made from the carcasses of scrapie-infected sheep. However, in October 2000, the British BSE inquiry concluded that BSE is a new disease, possibly arising from a mutation in one cow’s genes. The inquiry concluded that the remains of this one cow were used in cattle feed, thus starting the infection of Britain’s cattle herds.

Many people then ate beef or beef byproducts that were unknowingly contaminated either directly from nervous tissue or from instruments that had contacted nervous tissue that contained the abnormal prions. These abnormal proteins eventually crossed into the human nervous system. Once the infectious agent enters the brain, it can lie dormant for several years (even as long as 10 to 15 years). Once activated, the disease usually runs its course in less than 1 year.

Scientists do not understand how abnormal prion proteins produce the clinical symptoms of the disease. It is known that infected nerve cells attempt to get rid of abnormal prions by clumping them together into plaques for cellular digestion. Because the nerve cells cannot digest the abnormal prions properly, however, they accumulate in the cells. When the cells die, the abnormal prions are released and then they infect other nerve cells. Over time, large holes develop in the brain where groups of nerve cells have died. Death of the animal occurs from the numerous nerve cell deaths that led to loss of brain function.

To protect the U.S. beef industry, the federal government has banned the importation of live cattle and animal parts from BSE-afflicted countries. However, with the December 2003 discovery of a cow with BSE in Washington state, the U.S. Department of Agriculture has implemented new protective measures. These include condemning animals having signs of neurological illness and holding from slaughter any cows suspected of having BSE until test results are known. In addition, “downer cattle”—those unable to walk on their own—cannot be used for human food or animal feed.



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individuals infected by them. Other pathogens, however, only cause disease when a host’s defenses are suppressed. These organisms are said to be **opportunistic**. They invade the body and cause disease only when the right circumstances or opportunities are present. Many of the pathogens that infect AIDS patients, as well as the bacterium *Listeria* that is responsible for listeriosis, are examples of opportunistic organisms.

The degree of pathogenicity expressed by a pathogen is called **virulence**. The bacterium responsible for typhoid fever is considered highly virulent because it causes the disease in virtually everyone who comes in contact with it. *Listeria* is considered moderately virulent because it causes disease in some individuals. Finally, avirulent organisms are those that rarely, if ever, cause disease. This group includes all of the nonpathogenic microorganisms.

## The Signs and Symptoms of Human Disease

A pathogen produces a predictable set of signs and symptoms.

Pathogens usually follow a disease cycle from their invasion until the expression of symptoms. First, the pathogen must invade the body at a specific entry point. The entry point depends on the microbe (Table 15-2). For example, the bacterium responsible for tetanus, *Clostridium tetani*, is found in soil. The bacterial spores usually enter the body via puncture wounds, for example, when one steps on a rusty nail. (The spores cling to the rough edges of the nail—the rust itself is of no consequence.) The injected bacterial spores germinate in the wound where there is little, if any, oxygen. The bacteria then spread to the nerves that control voluntary muscles and cause painful muscle stiffness.

TABLE 15-2 Common Routes of Transmission and Some Disease Examples		
Entry Site	Transmission Route	Disease Example
Respiratory	Aerosol droplets Mouth to hand/object to nose	Influenza, tuberculosis, common cold, strep throat
Salivary	Kissing Animal bite	Infectious mononucleosis Rabies
Gastrointestinal	Stool to hand to mouth Stool to water/food to mouth	Hepatitis A Salmonellosis
Skin	Skin discharge to air to respiratory tract Skin puncture	Chickenpox Tetanus
Blood	Transfusion or needle prick Insect bite	Hepatitis B, AIDS Malaria
Urogenital	Urethral or cervical secretions Urine to hand to catheter	Gonorrhea, herpes Urinary tract infections
From animal	Animal bite Arthropod (flea, tick)	Rabies Plague, Lyme disease

Interestingly, though, tetanus will not develop if the bacterial spores are consumed with food because the spores cannot germinate in the human intestinal tract. This is why one can eat a freshly picked radish without fear of developing tetanus. Other pathogens enter the body as the result of a cut or abrasion of the skin, while many viruses, such as those that cause the flu, enter via the respiratory tract by the mouth, nose, or eyes.

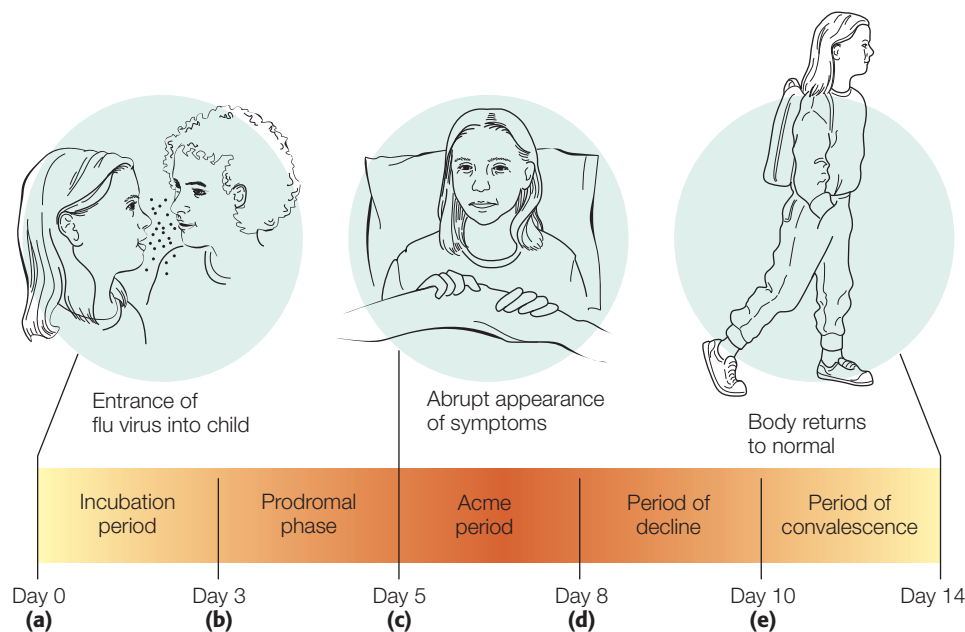
Once a pathogen invades a healthy body, the immune system springs into action. As you learned in Chapter 14, the immune system attacks infectious agents through antibodies or directly via T cells. The body also combats infectious agents via nonspecific mechanisms. For example, coughing and sneezing help to eliminate many viruses from the respiratory system, while fever raises the body temperature and slows viral replication.

Every disease organism that infects humans changes the body from the healthy state to a diseased state by altering body structures and functions. Such changes are referred to as signs and symptoms. **Signs** are changes in body function that a physician can detect and measure. A mild fever and swelling of lymph nodes are examples. Most infectious diseases, however, are also accompanied by one or more **symptoms**. These are changes in the body that a patient experiences but an observer (physician) cannot see—for example, a tired feeling or a headache.

Some disease organisms produce a specific group of signs and symptoms and are therefore referred to as a **syndrome**. AIDS is an example. AIDS, as you learned in A Closer Look following Chapter 14, is a viral disease that produces a characteristic set of signs, such as diarrhea, loss of certain white blood cells, weight loss, and pneumonia, as well as symptoms such as discomfort and fatigue.

## The Course of a Disease

A disease typically follows a series of five stages.



**FIGURE 15-10** The Course of Disease, as Typified by the Flu (a) A child is exposed to the flu viruses in respiratory droplets, and the incubation period begins. (b) At the end of this period, the child experiences fever, headache, and tiredness as the prodromal phase ensues. (c) The acme period begins with the appearance of specific flu symptoms, such as cough, muscle pain, and shaking chills. (d) Sweating and normal skin color return as the period of decline takes place. (e) With the period of convalescence, the body returns to normal.

If the immune system's first and second lines of defense fail to prevent a pathogen from entering the body, victims go through a series of disease stages (Figure 15-10). Consider the flu.

Each fall and winter season, an estimated 10% to 20% of the U.S. population gets the flu (influenza). This disease begins with an **incubation period**, a length of time between a person's exposure to the flu virus and the appearance of the first symptoms. The incubation period for the flu virus is short, usually 2 to 3 days. Other diseases, such as the measles, have longer incubation periods of 1 to 2 weeks. Still others, such as leprosy, have prolonged incubation periods of 3 to 6 years. The incubation period is determined by such factors as the number of organisms that enter the body, their rate of replication, and the level of host resistance.

The second phase of a disease is a time of mild signs or symptoms and is called the

**prodromal phase.** For many diseases, this period is characterized by fairly general symptoms such as fever, headache, and tiredness. They indicate that a competition between pathogen and host has begun.

During this phase, diseases often are characterized as subclinical or clinical. A **subclinical disease** is accompanied by few obvious symptoms. Many people, for example, have experienced subclinical cases of mumps or infectious mononucleosis. A **clinical disease** is one in which the symptoms are apparent (such as occurs with a common cold). Symptoms may be anywhere from mild to severe, depending on the pathogen.

The **acme period** or **climax** is the third stage in disease progression. This is the critical stage of the disease. Very specific signs and symptoms appear during this phase. During a bad case of the flu, for instance, signs and symptoms include a severe cough and muscle pain in the chest, back, and legs. Many patients experience high fever and shaking chills (chills are a result of the difference in temperature between the superficial and deep areas of the body). Individuals suffering from the flu are most contagious during this period.

Complications can arise during this phase, depending on the specific form of the disease and the state of the host. While many people contract the flu each year in the United

States, approximately 115,000 of them require hospitalization because of complications—for example, because of a fever lasting more than five days (which is usually a sign of bacterial or viral pneumonia that has developed because the individual is in a weakened state). In many elderly individuals or people who are in poor health, complications such as this can lead to death if treatment is not sought early on. In fact, each year, influenza kills more than 35,000 Americans. Most people who are in good health at the time of a flu infection survive.

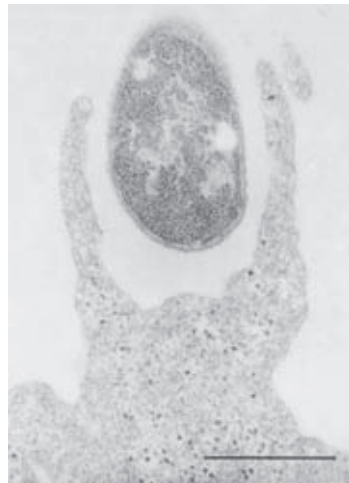
As the signs and symptoms of a disease subside, victims enter a **period of decline**. Sweating is common during this phase of the disease, as the body releases excessive amounts of heat. The recovery period varies in length. For individuals ill with the flu, it is often quite rapid. For other infectious diseases, however, recovery may take a long time.

The disease sequence concludes after the body passes through a **period of convalescence**, during which time the body's systems return to normal. Interestingly, during the period of decline—and even convalescence—individuals can transmit the disease to others. During this period, pathogens exit the body. Bacteria responsible for gastrointestinal illness may pass through the feces, while flu viruses can be released by coughing and sneezing.

## 15-3 How Pathogens Cause Disease

In this section, we will examine some of the factors that determine whether a microorganism can cause disease in an individual. We will focus most of our attention on the properties of microorganisms that enable them to overcome a host's immune defense.

Infection is dependent on the pathogen's ability to adhere to cells in specific tissues. The bacterium that causes the sexually transmitted disease known as *gonorrhea*, for example, only adheres to the lining of the urogenital tract. Many human viruses, including the flu virus, have protein structures called *spikes* that protrude from their capsids or envelopes. The spikes attach to specific host cells. Once a pathogen binds to a cell membrane, it is usually engulfed by the cell by phagocytosis (Figure 15-11).



**FIGURE 15-11 Tissue Invasion** A bacterium is being engulfed by an epithelial cell (bars = 1 mm).

### Enzymes and Toxins

Pathogenicity and virulence depend on key metabolic characteristics of a pathogen.

The ability of many pathogens to penetrate tissues and cause damage depends on their release of enzymes or toxins. Certain enzymes, for instance, help pathogens resist body defenses and thus increase the virulence of a microbe. These enzymes may interfere with certain cellular functions or alter barriers that are meant to thwart invasion. Microbial enzymes, such as coagulase, for example, produce blood clots that encompass clusters of pathogens, protecting them from immune system attack. Other bacterial enzymes target and destroy cells of the immune system. The bacterium *Staphylococcus* produces enzymes that digest the “cellular cement” that holds cells of tissues together. This enables the bacteria to penetrate deep into body tissues. These bacteria are responsible for a variety of illnesses including pneumonia, food poisoning, and skin infections.

Several human diseases involve the formation of biofilms (impenetrable colonies) in tissues that are very difficult for the immune system or even medical intervention to eliminate. **Health Note 15-2** describes biofilms.

Some bacteria cause disease by producing toxins. **Toxins** are microbial poisons. They fall into two categories: exotoxins and endotoxins.

**Exotoxins** are protein molecules, often enzymes, that are manufactured by bacteria in body tissues. When released from the bacteria, the toxins may be transported throughout the body.

## healthnote

## 15-2 Infectious Disease and Biofilms

In your reading of this chapter, you may have the impression that pathogens act as independent agents to cause disease. In a few cases, that might be true. However, for the most part, pathogens do not act as individuals; rather, they survive in complex communities called **biofilms**. A biofilm consists of an immobilized population of bacteria (or other microorganisms) caught in a sticky web of tangled polysaccharide fibers that adheres to various surfaces.

Biofilms develop on virtually all surfaces in contact with a watery environment. This includes the surfaces of aquatic plants or animals, water pipes, and stones. Contact with a fluid environment ensures a plentiful supply of nutrients, and as the bacteria grow, they secrete sticky polysaccharides.

Researchers have found that biofilms are highly organized structures. They contain water channels that serve to deliver nutrients to the bacteria and remove wastes. The bacteria share these passageways, interact metabolically, and benefit from each other's metabolic by-products. They also form communities that store nutrients and resist predators such as protozoa and viruses. Some scientists estimate that in nature, 99% of all microbial activities occur in biofilms.

Usually, only minute amounts of an exotoxin are needed to cause disease. The exotoxin that causes botulism is among the most lethal toxins known. One pint of the pure toxin would be sufficient to destroy the entire human population of around 6.8 billion people.

Exotoxins destroy cellular structures or inhibit essential metabolic functions. Thus, the disease symptoms vary depending on the exotoxin involved. [Table 15-3](#) highlights several examples.

**Endotoxins** are a lipid portion of the cell wall of many bacteria. They usually are released only upon disintegration (death) of the bacterial cell. When released, endotoxins cause

Bacteria in biofilms act very differently than individual cells and are extremely difficult to treat. In biofilm, for example, the bacteria often are impervious to drugs such as antibiotics, disinfectants, and antiseptics, which are designed to attack individual cells ([Figure 1](#)). Pathogens in biofilms may resist the immune system's attempts to eliminate them and therefore can be extremely virulent. For example, white blood cells have difficulty reaching the pathogens in this slimy conglomeration of armor-like material.

Health officials at the Centers for Disease Control and Prevention (CDC) estimate that more than 65% of human infections involve biofilms. If you or someone you know has had a middle ear infection, the cause was a bacterial biofilm. Dental plaque is a type of biofilm as well. Brushing and flossing teeth and seeing a dentist regularly are essential to reduce and control this biofilm. Eye doctors are also concerned about the formation of biofilms on contact lenses, which can produce serious eye infections. Proper cleaning and storage of contact lenses is important to prevent biofilm formation.

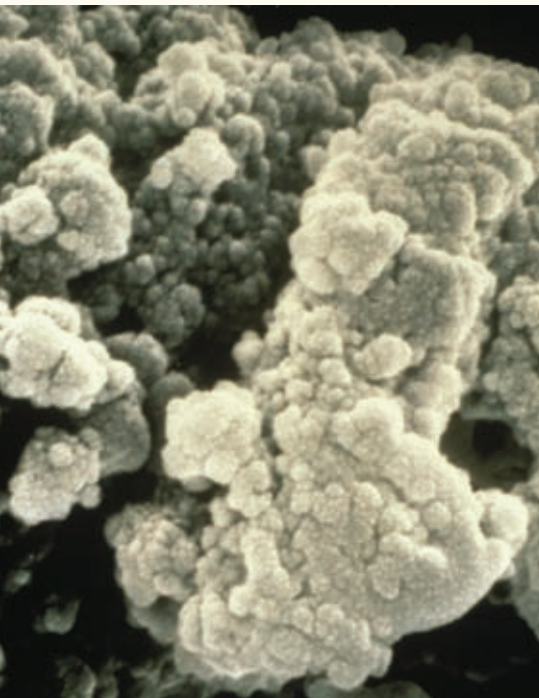
Biofilms can also form on catheters and medical devices such as artificial hearts. Biofilms in urinary catheters often provide starting points for urinary tract infections, as bacteria creep up the catheters. Once in body tissue, the bacteria sequestered in the slimy conglomerates are shielded from attack by the body's immune system, and they are difficult to kill with antibiotics. In males, biofilms also have been implicated in

chills, fever, weakness and aches, and general malaise. Endotoxins may also damage the circulatory system, causing a massive increase in the permeability of the blood vessels. This, in turn, causes blood to leak into the intercellular spaces, where it is useless. Tissues swell, the blood pressure drops, and the patient may lapse into a coma.

Like exotoxins, endotoxins add to the virulence of pathogens and enhance their ability to cause disease. However, they are required in larger doses than are exotoxins. Typhoid fever and some urinary tract infections are the result of endotoxin production.

**TABLE 15-3** Diseases Caused by Exotoxins

Disease	Bacterium	Signs or Symptoms; Mechanism of Action
Botulism	<i>Clostridium botulinum</i>	Muscle paralysis; inhibits the release of acetylcholine at the synaptic junction
Whooping cough (pertussis)	<i>Bordetella pertussis</i>	Spasmodic and recurrent coughing, ending with a loud inspiratory whoop with choking on mucus; paralyzes ciliated cells and impairs mucus movement
Cholera	<i>Vibrio cholerae</i>	Severe diarrhea; causes massive loss of water from the intestines, which can produce a rapid drop in blood pressure
Diphtheria	<i>Corynebacterium diphtheriae</i>	Thick membrane coating the upper respiratory mucous membranes. Fever, sore throat, cough; interferes with protein synthesis in the cytoplasm of epithelial cells of the upper respiratory tract; respiratory blockage
Anthrax	<i>Bacillus anthracis</i>	Inflammation, hemorrhage, shock (inhalational anthrax); three exotoxins generate an accumulation of fluid and killing of host cells



**FIGURE 1 Biofilms** Biofilms are communities of microorganisms. Some biofilms can cause infectious diseases, such as these *Pseudomonas* bacteria that have formed a biofilm on the lungs of a cystic fibrosis patient.

prostate gland infections, which are accompanied by chronic pain and sexual dysfunction. Finding a way to penetrate this polysaccharide barrier is important in order to stem the tide of urinary tract infections.

Besides being involved in human disease, biofilms can cause problems in industry. Biofilms, for example, can corrode water pipes. When they contaminate computer chips, biofilms act as conductors and thereby interfere with electronic signals. Indeed, one researcher has called biofilms the “venereal disease of industry.”



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## 15-4 How Infectious Diseases Are Transmitted

For a disease to spread, pathogens must be transmitted to other hosts. In some cases, an infectious disease spreads only within a given region. If this occurs and the level of infection is relatively low, microbiologists and health officials consider it an **endemic disease**. Plague in the American Southwest is an example of an endemic disease. If, on the other hand, the disease breaks out in explosive proportions within a population, it is considered an **epidemic**. Influenza often causes epidemics. A more contained occurrence is considered an **outbreak**. An abnormally high number of measles cases in one U.S. city would

be classified as an outbreak, whereas it would be classified as an epidemic if it occurred in several states. A **pandemic disease** (or **pandemic**) occurs worldwide. The most recent example of a pandemic would be AIDS, although other pandemics have occurred (Table 15-4).

So, how are the microbial agents that can cause outbreaks, epidemics, and pandemics spread? Although diseases can be transmitted in many ways, all modes of transmission fall into two broad categories: direct and indirect transmission methods.

### Direct Transmission Methods

Direct transmission may occur through direct physical contact.

**Direct transmission** occurs in a variety of ways. The most common involves person-to-person contact, during which time bacteria, viruses, or other infectious agents are transferred from people who have the disease to uninfected individuals. Direct physical contact usually occurs during hand-shaking, kissing, or exchanging body fluids—for example, from sexual intercourse or blood transfusions (Figure 15-12). Infectious mononucleosis, a disease common among college students, typically is transmitted by kissing. Gonorrhea and genital herpes are transmitted directly during sexual contact. Hepatitis B is transmitted by blood transfusions.

Infectious diseases can also spread from a mother to her unborn child through the placenta or via the vagina during

TABLE 15-4 Some of the Major Historical Pandemics and Resulting Human Deaths	
Pandemic	Estimated Deaths
Bubonic plague/“Black death” (6th, 14th, 17th centuries)	137 million
Smallpox (1900–1977)	300–500 million
Influenza	
“Spanish flu” (1918–1919)	20–50 million
“Asian flu” (1957–1958)	1–4 million
“Hong Kong flu” (1968–1969)	1–4 million
AIDS (1981–2004)	23 million

childbirth. The AIDS virus is an example of an infectious agent that can be passed from mother to her fetus during childbirth. Disease can also be transmitted after birth through breast milk.

Diseases can also spread from animals to people. A pet cat or dog, for example, can carry disease-causing microbes such as rabies. Rabies can be transmitted to a pet by a bite from another animal (raccoons, bats, cattle, rabbits, skunks, and foxes) that has rabies. A bite from the infected cat or dog can then spread the viral disease to a human.

Toxoplasmosis, which is sometimes called *litter box disease*, results from contact with a protozoan parasite in cat feces. Although the infected animal lacks signs and symptoms, initial symptoms in a human after contact are similar to those of the flu (swollen lymph glands, fatigue, fever, and headache). To be safe, women who are pregnant and have a cat should allow someone else to clean the litter box because the disease can cause miscarriage, premature births, and mental retardation.

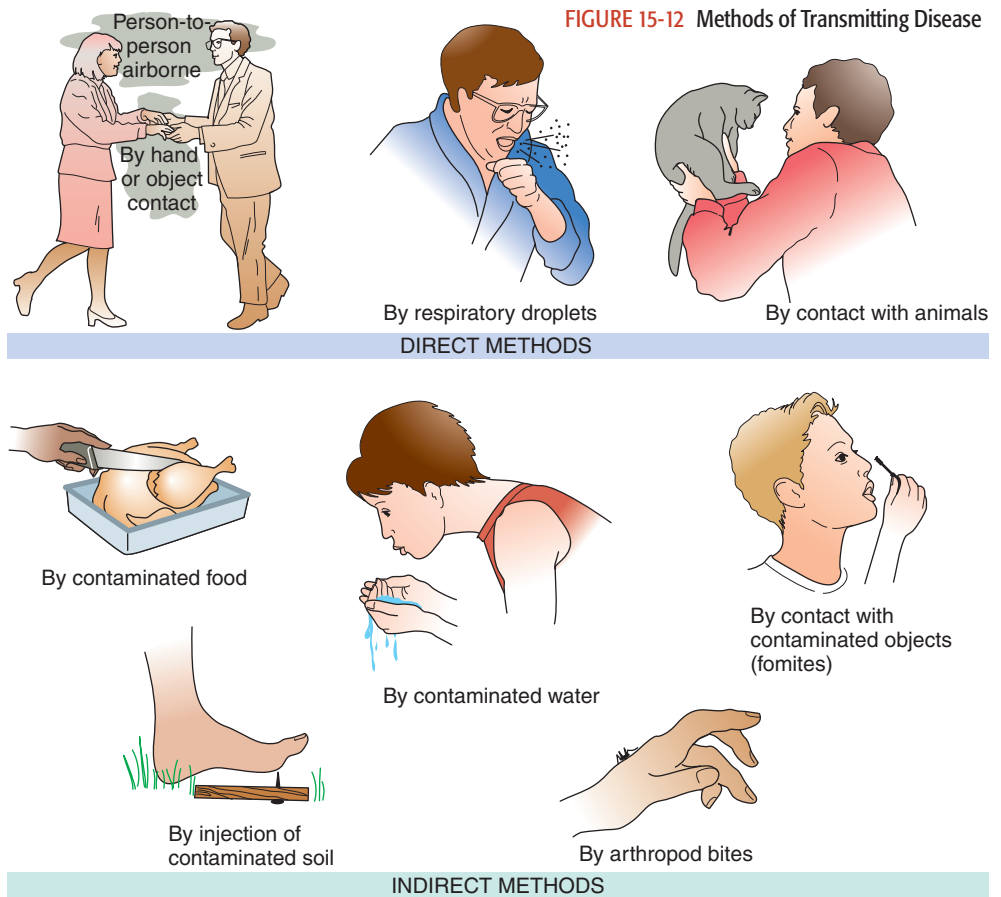
Infectious diseases also are transmitted by less common pets such as reptiles and birds. All reptiles, especially turtles and iguanas, can carry the bacterium *Salmonella*. If transmitted to humans, the bacterium can cause gastroenteritis, an inflammation of the stomach and intestine, which results in diarrhea and vomiting.

Infectious disease also can be spread directly by respiratory droplets and airborne particles. For example, when you cough or sneeze, you expel droplets into the air around you. If you have a cold, the flu, or another contagious respiratory illness, these droplets contain the infectious agent. Respiratory droplets travel only about 3 feet because they are too large to stay suspended in the air for a long period. However, if a droplet contacts the eyes, nose, or mouth of someone else, that individual may become infected and may experience signs and symptoms of the disease. Crowded places, especially indoor environments—including classrooms, airports, and airplanes—can increase the chances of respiratory droplet contact, which may explain the increase in such respiratory infections in the winter months when more people congregate in enclosed places.

## Indirect Transmission

Diseases can also be transmitted by indirect contact.

Disease-causing organisms may also be transmitted indirectly (see Figure 15-12). **Indirect transmission** occurs when a person comes in contact with pathogens on inanimate objects, such as handkerchiefs, doorknobs, or faucet handles. For example, if you touch a doorknob that has been touched by someone who had the flu, you may pick up the viruses he or she left behind. If you then touch your eyes, mouth, or nose before washing



your hands, you may become infected. Skin punctures by contaminated objects also can spread a disease-causing organism, as mentioned earlier for tetanus.

Some pathogens travel through the air on much smaller airborne particles, known as **aerosols**. Aerosols consist of moisture droplets and fine dust particles. They can remain suspended in the air for extended periods and can travel in air currents. Aerosols containing pathogens such as viruses or bacteria may be inhaled, causing disease in the host. Tuberculosis and SARS are examples of diseases that usually spread through the air as respiratory droplets and aerosols.

Arthropods, such as mosquitoes, flies, fleas, lice, and ticks, are also responsible for the indirect transmission of disease. Such carriers are called **vectors**. Some mosquitoes, for example, may carry the malaria parasite or the West Nile virus. A bite from a mosquito carrying West Nile virus can transfer the virus into the blood and lead to West Nile fever. Deer ticks can carry the bacterium responsible for Lyme disease. Fleas may carry the plague bacterium. Even common houseflies may carry diseases. Thus, when a housefly lands on your dinner plate, it may transfer pathogens to the food. If a sufficient dose is transmitted, eating the contaminated food may make you sick.

Finally, some infectious agents can spread through the food we eat and the water we drink. Poor food processing or food preparation can introduce pathogens into meats and other foods. The food then serves as the vehicle by which the pathogens are spread. Toxin-producing strains of *E. coli* often make the news because improper food-processing procedures have accidentally introduced the bacterium into a food product, often hamburger. In 1998, the U.S. Department of Agriculture recalled

25 million pounds of raw hamburger contaminated with a toxin-producing strain called *E. coli* O157:H7. If contaminated raw foods are not cooked to the proper temperature needed to kill the bacteria, chances are people will become ill and, in extreme cases, even die. In 2006, two outbreaks of *E. coli* occurred in the United States, resulting in numerous deaths. The bacteria were found on spinach in the first outbreak, and lettuce in the

second, and were present as a result of contaminated irrigation water. In June 2009, two people died and 28 became ill on the East Coast from *E. coli*-contaminated beef, and in November 2009, 65 people fell sick in 29 states from eating chocolate-chip cookie dough tainted with the bacterium. *Salmonella* in peanut products killed at least six people and sickened hundreds in January 2009.

## 15-5 Emerging Infectious Diseases and Bioterrorism

In the latter half of the twentieth century, many infectious diseases that once ravaged human populations seemed to be under control. After millions upon millions of deaths, humans had finally triumphed over infectious disease. Our success stemmed from the use of antibiotics, the development of vaccines, a vigilant public health system, better sanitation, and water purification. In fact, in 1980, the virus that causes smallpox was eradicated from the face of the Earth through a massive global vaccination effort.

Over the last several decades, however, a number of new infectious diseases, such as AIDS and SARS, have emerged (Figure 15-13). We have also witnessed a resurgence of some infectious diseases, such as tuberculosis and dengue fever, that health officials thought were under control. Why are new infectious diseases emerging and other infectious diseases reemerging?

### Emerging and Reemerging Infectious Diseases

Several infectious diseases once thought to be under control are reemerging, and new infectious diseases are emerging for a variety of reasons.

**Emerging infectious diseases** are those that have recently surfaced in a population. Among the more newsworthy have been AIDS, hantavirus pulmonary syndrome, Lyme disease, Ebola hemorrhagic fever, mad cow disease, SARS, West Nile fever (in the Americas), and the H1N1 virus.

The most recent, the H1N1 virus, is a type of influenza A virus and is the most common cause of influenza (the flu) in human beings. In 2010, the virus spread quickly throughout the world. Victims suffered from chills, fevers, sore throat, muscle pain, severe headaches, coughing, and general discomfort—as is common in the flu. However, this new strain also caused many deaths worldwide, especially among children. Vaccines against the virus were made available, starting fairly late in 2010. Where did the virus come from?

The H1N1 virus, dubbed the swine virus, came from pigs. Although some strains of the H1N1 virus are found only in human beings, others are endemic in pigs and birds. Those found in pigs create swine influenza; those in birds cause avian influenza.

Scientists found that the 2009 global flu pandemic was due to a new strain in humans that originated in pigs, and then spread to humans, hence the name swine flu. Interestingly, pigs are an intermediary in viral transmission. That is, many viruses can be transmitted from chickens to pigs to humans, but not directly from chickens to humans.

Although swine influenza is quite common among pigs, the transmission to humans does not occur very often. Even then, swine influenza that is transmitted to humans does not always lead to human influenza. Those who are most likely to contract a swine influenza are individuals who raise and process pigs. If cooked properly, the meat poses very little, if any, risk of infection.

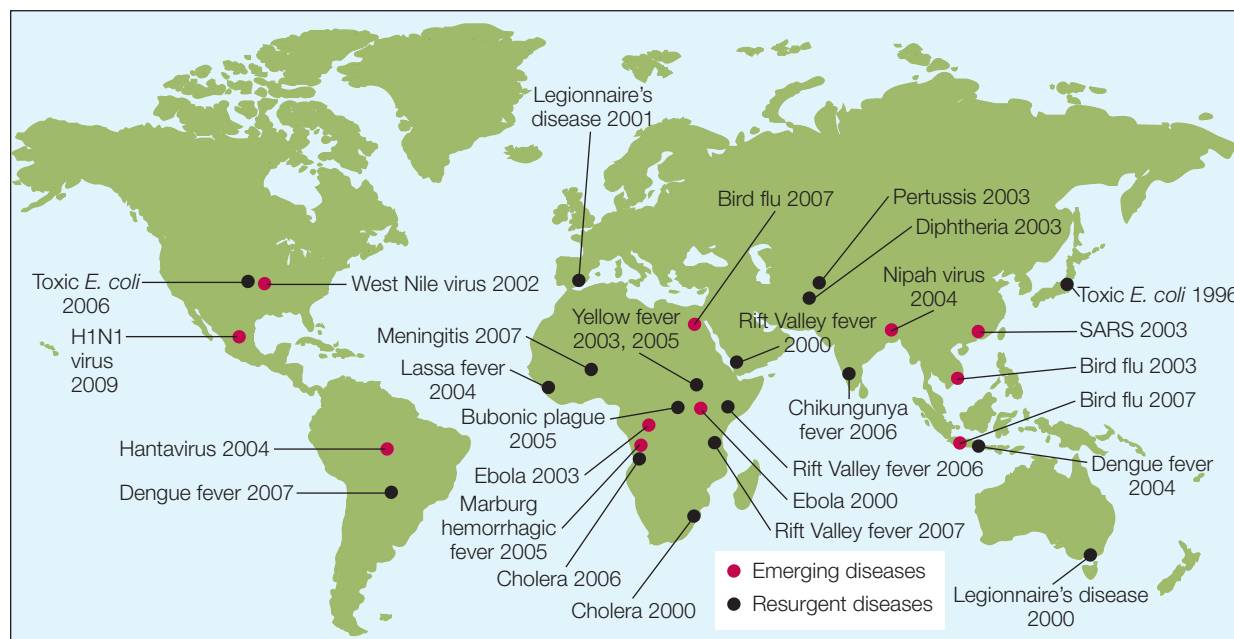


FIGURE 15-13 Emerging and Reemerging Diseases in the last two decades.

One of the major reasons for the appearance of new diseases is the expanding world population. As populations grow and expand into previously uninhabited areas, humans are exposed to insects and other animals that harbor infectious agents. Human contact with infected animals may result in a direct transmission of pathogens. Such a scenario probably explains how HIV “jumped” to humans from chimpanzees, which suffer a similar disease, and how the Ebola virus results in sporadic outbreaks of hemorrhagic fever in parts of Africa.

Another reason for the appearance of new diseases is the increased worldwide transport of animals—especially animals for the pet trade. The SARS virus probably was transmitted to humans as a result of animal transport in Asia. In fact, the trade in exotic animals into the United States caused the 2003 outbreak of monkeypox.

Increased international travel also can spread diseases to new geographical areas. It is believed that the West Nile virus that emerged in New York City in 1999 came from an individual or animal that was infected in the Middle East, where the virus is endemic. The virus has now spread throughout the entire United States.

Finally, changes in food handling or processing can also be the cause for an emergent disease. As [Health Note 15-2](#) explains, prions, which are responsible for mad cow disease, spread from “infected” beef carcasses that were used to make cattle feed.

**Reemerging infectious diseases** are ones that have existed in the past but are now showing a resurgence in frequency or geographic range. Some of the more prominent reemerging diseases are cholera, tuberculosis, and dengue fever. One reason diseases are reemerging is antibiotic resistance, described in Chapter 14. Antibiotic-resistant strains of the bacterium that cause tuberculosis, for example, have evolved over time. Because they are resistant to many of the antibiotics used to treat the disease, the disease is spreading. Yet another cause for the reemergence of pathogenic organisms is that large segments of the human population, notably AIDS victims, suffer from lowered immunity to infectious disease, allowing many formerly rare diseases to reappear.

Diseases are also reemerging because of lax public health programs. In the 1980s, the collapse of the Soviet Union and subsequent economic depression that hit many of the newly formed countries resulted in a decline in public health programs. This left many members of the population unvaccinated and thus susceptible to infectious disease. In one case, diphtheria vaccinations disappeared in parts of the former Soviet Union. Within a 3-year period, diphtheria became epidemic in those areas.

The emergence of new diseases and the reemergence of others once thought to be under control may also be due to

climate change (Chapter 23). Scientific studies have shown that warming in several regions has resulted in the spread of vector borne infectious diseases such as dengue fever into neighboring areas, which were previously too cool to support the vectors. Although the magnitude of such infections is yet to be determined, global warming may become a prime factor in the emergence and reemergence of infectious disease in the decades ahead. Because additional emerging or reemerging infectious diseases are inevitable in the future, public health systems around the world need to be vigilant and join together to combat emerging infectious diseases and prevent their spread.

## Bioterrorism

Bioterrorism is an attempt to use infectious disease agents to frighten and inflict pain and suffering in populations.

As you have seen, infectious disease in the human population results from the presence of infectious disease agents and many human factors, such as increasing population density, increased travel, and settlement of previously uninhabited areas. Infectious agents are also being used by terrorists to cause fear or inflict pain and suffering—and even death—in large populations. This threat is called **bioterrorism**. The anthrax attacks that occurred in the eastern United States in October 2001 demonstrate the potential for such agents to cause fear and anxiety.

Potential bioterrorists could rely on a large number of infectious agents, including pathogenic bacteria, fungi, viruses, and bacterial toxins. The potential impact of the biological agents depends on their virulence and the ease with which they can be disseminated. The pathogens of most concern, called the *Category A Select Agents*, are those that can be spread via aerosols ([Figure 15-14](#)). This group includes anthrax and smallpox. Category A also includes bacterial toxins, poisonous



(a)



(b)

**FIGURE 15-14 Bioterrorism** (a) Combating the threat of bioterrorism often requires special equipment and protection because many organisms seen as possible bioweapons are spread through the air. (b) This photo, taken in 1967, shows a smallpox patient.

substances that can be added to food or water supplies, such as the toxin that causes botulism.

Biological weapons offer rogue nations and terrorist groups several advantages over conventional weapons of mass destruction and terror. Perhaps most important, biological weapons are much cheaper to produce than chemical and nuclear weapons. In addition, they provide a weapon every bit as dangerous and deadly as the nuclear weapons of the more developed nations.

In May 2000, Ken Alibek, a scientist who once worked in the Soviet bioweapons program before defecting to the United States, testified before the U.S. House Armed Services Committee that the best defense against biological weapons is to develop appropriate medical defenses such as vaccines. These could minimize the impact of bioterrorism agents, rendering them useless.

The threat of biological weapons in the United States is being addressed, in part, by careful monitoring of sudden and unusual disease outbreaks. That way, health officials hopefully can react quickly to stop them from spreading. Extensive research is being carried out to determine the effectiveness of various antibiotic treatments. Research is also being carried out on the best ways to develop effective vaccines.

Vaccination of the general public probably offers the best defense against bioterrorism. As of 2003, the United States had stockpiled sufficient smallpox vaccine to vaccinate the entire population if a smallpox bioterrorist event occurred. Vaccines for other agents are being developed. In addition, scientists are trying to develop instruments that detect microbiological weapons before they can cause disease.

## 15-6 Health and Homeostasis—Staying Healthy

In this chapter, we have described several human diseases that result from microbial pathogens in our environment. Just how susceptible are we to contracting an infectious disease? The answer depends on many factors, including our age, our health status, and where we live. In the tropical regions of the world, for example, where malaria and cholera are endemic, a person is much more likely to contract these diseases. In the United States, these diseases pose little or no threat.

In general, a person's risk of contracting one of the emerging diseases, such as SARS and West Nile fever, is relatively low—especially if he or she is in good health. It is much more likely that illnesses will result from pathogens found in the home or neighborhood. That is, you are much more likely to get sick from contaminated surfaces in your kitchen than from the bite of an infected mosquito.

As an example, one of the most common food borne illnesses is salmonellosis, caused by *Salmonella* bacteria found in contaminated foods. Salmonellosis is caused by eating meat that wasn't cooked long enough or that was cooked at a lower-than-optimal temperature. It is also caused by consuming food that has been improperly stored after cooking.

Salmonellosis is characterized by diarrhea, fever, and abdominal cramps. Nearly 40,000 cases are reported annually in the United States. However, the Centers for Disease Control and Prevention (CDC) estimate that the actual number of salmonella illnesses each year is greater than 1 million. That's because most mild cases are not reported to physicians. Careful attention to food preparation—such as making sure eggs and meats such as poultry are thoroughly cooked and food preparation surfaces are cleaned with soap and hot water first—can reduce the risk of food borne pathogens.

Although it can be difficult to avoid surfaces that have been contaminated with flu or cold viruses, some simple steps can help minimize the chances of infection. Washing one's hands frequently with ordinary soap (no need to use antibacterial soaps), for example, is one of the easiest and most effective means of preventing the spread of infectious disease. As a precaution, you should wash your hands thoroughly before prepar-

ing or eating food, after coughing or sneezing, after changing a diaper, and after using the toilet. When soap and water are not readily available, use a hand-sanitizing gel.

Do not handle an animal that looks ill or appears to have an infection, and do not share a drinking glass or eating utensils with someone who is sick. It is important to also stay up to date on infectious diseases that might have the greatest impact in your area, such as West Nile fever.

Certain medicines can keep you from contracting an infectious disease. For example, if you are traveling in an area where malaria is common, you may want to ask your doctor for an antiparasitic medication. In areas where you will encounter mosquitoes, ticks, and other biting insects that carry disease, doctors recommend the use of insect sprays containing the repellent DEET.

### Health Tip 15-2

Don't waste your money on antibacterial soaps.

*Why?*

Antibacterial soaps and other cleaning products that contain antibacterial agents don't protect us like manufacturers would have you believe. One recent study showed that they don't lower the incidence of colds or flus in households that use them.

Antibacterial compounds in these products may be contributing to higher levels of asthma and allergies, as explained in Chapter 14. Moreover, the antibacterial compounds are ending up in our waterways and in sewage sludge, much of which is applied to farmland. Although researchers are currently trying to determine what effect, if any, they might have, these antibacterial compounds could affect beneficial bacteria in the soil and could end up in the food supply.

Some infectious diseases, such as the common cold, usually do not require a visit to the doctor. However, if you think you have encountered a serious infectious disease, contact your doctor. He or she can perform the necessary tests to determine if you are infected, the seriousness of the infection, and how best to treat it. Even if you only have a virus, physicians may prescribe antibiotics if you develop a secondary bacterial infection. Remember, however, that although antibiotics may be a short-term answer for some bacterial diseases, long-term or indiscriminate use of antibiotics may result in the appearance of more resistant, harder-to-treat strains of bacteria.

Vaccination is the best line of defense for many infectious diseases. Over time, the list of vaccine-preventable diseases has continued to expand. Currently, there are more than a dozen vaccines available. These include vaccines for childhood diseases such as chickenpox, measles, mumps, and rubella. The newest is a vaccine against a virus (human papilloma virus) that can lead to cervical cancer in women. In addition, many vaccines or boosters are available for adults to prevent illnesses such as tetanus and diphtheria. Yearly flu shots usually provide a high degree of protection for you, your family, and the population in general. They are especially recommended for youngsters and adults over 50 who are more likely to die from the flu.

## SUMMARY

### The Infectious Agents of Human Disease

1. Microorganisms are found in nearly every environment on Earth. Microbes range from submicroscopic viruses to macroscopic parasitic worms. Although they are found everywhere, only a very small percentage of the microbes found in our environment is capable of causing human disease.
2. Pathogens are the microbes capable of causing disease. If they can be transmitted from one organism to another, they are considered contagious; if they invade and cause disease, they are considered infectious.
3. Our present-day understanding of pathogens as the cause of human infectious disease arose largely from the work of Louis Pasteur and Robert Koch, who formulated the germ theory of disease in the late 1800s.
4. Viruses are composed of genetic information (DNA or RNA) and a protein capsid. The capsid may be surrounded by a viral envelope.
5. Viral replication requires the virus to (1) adhere to the appropriate host cells; (2) be brought into the cell; (3) replicate its genetic information and manufacture capsid proteins; (4) assemble genetic information and capsids into new virus particles; and (5) be released from the host cell.
6. Most bacteria, which can be seen with a light microscope, are composed of rods, spheres, or spirals. They reproduce by replicating the DNA and then splitting to form two separate cells. Such reproduction can occur at a very rapid rate.
7. Eukaryotic microorganisms also can cause infectious disease. Fungi can cause athlete's foot, oral thrush, and serious respiratory infections. Protozoa are responsible for water-

borne diseases. Malaria, one of the major infectious disease killers, takes the lives of more people worldwide than any other protozoan disease. The helminths consist of flatworms that cause diseases such as schistosomiasis and roundworms that cause pinworm disease and others.

### The Course of a Human Disease

8. The ability of a pathogen to enter the body and cause disease is called *pathogenicity*. It varies from one pathogen to another. Some pathogens are opportunistic, only causing disease when the host's immune system is suppressed or unable to mount a defense. Virulence describes the degree of pathogenicity.
9. Most pathogens produce a set of signs and symptoms that are characteristic of the disease. Signs are what the physician can detect (mild fever and tissue swelling) and symptoms are what the patient feels (headache and sore throat). A syndrome is a specific set of signs and symptoms characteristic of some diseases, such as AIDS.
10. Most diseases go through a five-stage course, including: (1) the incubation period, (2) the prodromal phase, (3) the acme period, (4) the period of decline, and (5) the period of convalescence. Some convalescent patients may still be carriers for the disease from which they are recovering.

### How Pathogens Cause Disease

11. Most pathogens must adhere to specific cells or tissues for an infection to progress. Adhesive proteins may be found on many bacteria and virus cell surfaces.
12. Many bacterial pathogens depend on enzymes to increase their virulence. Enzymes

may protect the pathogen from destruction by the immune system, destroy immune cells, or facilitate the penetration of deeper host tissues.

13. Several bacterial pathogens produce toxins that also increase virulence. Exotoxins are products of cell metabolism that can destroy host cell structures or interfere with their metabolism. Their effects vary depending on the specific toxin ingested.
14. Endotoxins are parts of the cell wall in some bacteria. Their effects require a higher dose of toxin than exotoxins. The signs and symptoms are similar for all endotoxins.

### How Infectious Diseases Are Transmitted

15. Infectious diseases can be endemic, that is, they remain localized within a small number of individuals. Infectious agents can also create epidemics, explosive increases in the numbers of diseased individuals. An explosive but localized increase in numbers of infected individuals is called an outbreak. A disease that produces explosive numbers of ill individuals worldwide results in a pandemic.
16. Diseases can be transmitted by direct contact of pathogens between an infected individual and another person, for example, from a mother to her unborn child.
17. Animals can carry human diseases, such as rabies and toxoplasmosis, and transmit them directly to humans. Direct contact transmission also occurs through respiratory droplets that can carry an infectious disease a few feet in the air.
18. Indirect contact is also responsible for the transmission of disease. Inanimate objects, for example, can become contaminated with disease agents. Contact with such objects

can result in the transmission of the disease to another individual.

19. Aerosols, consisting of moisture droplets and dust contaminated with pathogens, can carry disease farther than respiratory droplets.
20. Arthropods, such as mosquitoes, fleas, and ticks, can carry infectious diseases. Infectious disease also can be spread through food or water.

#### Emerging Infectious Diseases and Bioterrorism

21. Emerging infectious diseases are those that have appeared in a population for the very first time, such as AIDS in the 1980s and SARS in 2003. Causes for such emergence include a growing world population that has become exposed to insects and animals harboring such infectious diseases; the worldwide transport of animals and exotic

animals that harbor infectious disease; and the increased numbers of individuals who travel internationally.

22. Reemerging infectious diseases are those that were under control but now are increasing in incidence. The increase in antibiotic resistance, a lack of a strong public health system, reductions in vaccinations, and global warming are all responsible for the increasing numbers of such diseases.
23. Bioterrorism is a strategy used by terrorist organizations and rogue states to cause fear, inflict harm, or cause death in a population using pathogens or other harmful biological agents. Pathogens that can be dispersed relatively easily, such as the smallpox virus or anthrax bacteria, or bacterial toxins that can be placed in water supplies are some of the most dangerous agents. Minimizing

such threats requires strong medical defenses (vaccines) and improved methods of detection.

#### Health and Homeostasis—Staying Healthy

24. The chance of contracting an emerging infectious disease is not high for individuals who have good, healthy immune systems. It is much more likely that an individual will contract an infection or illness from pathogens in his or her kitchen. Therefore, staying healthy means practicing those methods that eliminate and reduce the chances for disease transmission: keeping one's kitchen and bathroom clean, washing one's hands often, and making sure all vaccinations are up to date.

### THINKING CRITICALLY ANALYSIS

*This analysis corresponds to the Thinking Critically scenario presented at the beginning of this chapter.*

There are several important points concerning your friend's decision to keep and eat the "potentially contaminated" luncheon meat. First, the disease is an example of an outbreak; it appears to be limited (at the time of the newscast) to a few individuals in the town. Second, because your friend is in apparently good health, he is not at great risk. Remember that poor health makes an individual more susceptible to many potentially harmful microbes.

Another point to remember is that if the packaged meat is contaminated with *Listeria*, this disease is not contagious. A person with the disease cannot transmit

it directly to anyone else. However, the meat does represent a mechanism for indirect transmission. You should advise your friend not to eat it or offer it to anyone. If he objects, you should note that it is possible that the luncheon meat is contaminated with *Listeria*, but that the number of bacteria at the time he ate his first sandwich might have been low. Leaving the meat in the refrigerator longer provides time for the bacteria to grow and produce significant numbers (a dose) that could be dangerous if ingested at a later date.

Tell your friend no thanks for the lunch invitation! And advise him not to eat it or offer it to anyone else. It's best if he disposed of it immediately.

### KEY TERMS AND CONCEPTS

Acme period, p. 313  
 Aerosol, p. 316  
 Bacterium, p. 306  
 Biofilm, p. 314  
 Bioterrorism, p. 318  
 Capsid, p. 303  
 Clinical disease, p. 313  
 Contagious, p. 301  
 Direct transmission, p. 315  
 Disease, p. 310  
 Emerging infectious disease, p. 317  
 Endemic, p. 315  
 Endotoxin, p. 314  
 Epidemic, p. 315  
 Exotoxin, p. 313  
 Flatworm, p. 308

Fungus, p. 307  
 Germ theory of disease, p. 302  
 Helminths, p. 308  
 Host, p. 303  
 Incubation period, p. 312  
 Indirect transmission, p. 316  
 Infection, p. 310  
 Infectious, p. 301  
 Microorganism, p. 300  
 Opportunistic, p. 311  
 Outbreak, p. 315  
 Pandemic, p. 315  
 Parasite, p. 308  
 Pathogen, p. 301  
 Pathogenicity, p. 310  
 Period of convalescence, p. 313

Period of decline, p. 313  
 Prion, p. 308  
 Prodromal phase, p. 313  
 Protozoan, p. 308  
 Reemerging infectious diseases, p. 318  
 Roundworm, p. 308  
 Sign, p. 312  
 Subclinical disease, p. 313  
 Symptom, p. 312  
 Syndrome, p. 312  
 Tapeworm, p. 308  
 Toxin, p. 313  
 Vector, p. 316  
 Viral envelope, p. 303  
 Virulence, p. 311  
 Virus, p. 302

## CONCEPT REVIEW

- List and briefly describe the five steps that must take place for a virus to infect a cell, replicate its kind, and spread to other cells. p. 303.
- Identify several diseases caused by fungi, protozoa, and helminths. Have you had any of them, or do you know anyone who has? pp. 304–305.
- Define the terms *pathogenicity* and *virulence*. pp. 310–311.
- List and describe the five stages in the course of an infectious disease. When is an individual likely to spread the disease? pp. 312–313.
- How are infectious diseases transmitted? Give examples of each major type. pp. 315–317.
- What is a vector? Describe the importance of vectors in disease transmission. p. 316.
- Describe the difference between an epidemic and an outbreak. p. 315.
- How do enzymes help pathogens overcome host defenses? pp. 313–314.
- What are exotoxins and endotoxins? pp. 313–314.
- Identify and explain the reasons for the emergence of “new” infectious diseases and the reemergence of infectious diseases once thought to be under control. pp. 317–318.
- Make a list of the five most likely areas in your home where illness and disease could arise. Why did you select these areas? pp. 315–317.
- Define bioterrorism and identify a viral disease and two bacterial diseases that are considered potential bioterror agents. Why are these agents of particular concern? p. 318.

## SELF-QUIZ: TESTING YOUR KNOWLEDGE

- Microbes that cause disease are called \_\_\_\_\_. They are \_\_\_\_\_ diseases if they can be transmitted easily between humans. p. 301.
- Two scientists, \_\_\_\_\_ and \_\_\_\_\_, were responsible for proposing and developing the germ theory of disease. p. 302.
- The viral genetic information is surrounded by a protein coat, called a/an \_\_\_\_\_, which in turn may be surrounded by a/an \_\_\_\_\_. p. 303.
- In order to replicate, a virus must infect a/an \_\_\_\_\_ cell. p. 303.
- The three variations in bacterial shape are \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_. p. 306.
- Among the eukaryotic pathogens, yeast-like infections are caused by \_\_\_\_\_, the \_\_\_\_\_ often are parasites of the intestinal tract, and the \_\_\_\_\_ are parasitic worms. pp. 307–309.
- A \_\_\_\_\_ is a change from the healthy state of the body, which depends on the \_\_\_\_\_ of the infecting organism. p. 310.
- Those pathogens that only cause disease when the host’s immune system is suppressed are called \_\_\_\_\_. p. 311.
- The term \_\_\_\_\_ is used to describe those changes in body function that a patient experiences while \_\_\_\_\_ is used to identify those changes that can be detected and measured by a physician. p. 311.
- The period between a person’s exposure to a pathogen and the appearance of the first symptoms is called the \_\_\_\_\_ period, while the \_\_\_\_\_ period is the stage characterized by the development of very specific symptoms characteristic of the disease. p. 312.
- The two different types of bacterial toxins can be recognized by the fact that the \_\_\_\_\_ are produced usually only after the death or disintegration of bacterial cells while the \_\_\_\_\_ are produced by live bacteria in the host tissues. pp. 313–314.
- The occurrence of rabies in several dozen residents in a city would be considered a/an \_\_\_\_\_ because the disease had not spread throughout the state or neighboring states. p. 315.
- Being exposed to the flu virus from touching a contaminated door knob would be an example of \_\_\_\_\_ transmission while being exposed to the virus from respiratory droplets in the air would be an example of \_\_\_\_\_ transmission. pp. 315–316.
- Examples of recently emerging infectious diseases would include \_\_\_\_\_ and \_\_\_\_\_; reemerging infectious diseases are represented by \_\_\_\_\_ and \_\_\_\_\_. pp. 317–318.
- The best defense against the potential use of a bioterrorism agent is through \_\_\_\_\_ of the population. p. 318.



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