

31 Immune System and Disease

KEY CONCEPTS

31.1 Pathogens and Human Illness

Germs cause many diseases in humans.

31.2 Immune System

The immune system consists of organs, cells, and molecules that fight infections.

31.3 Immune Responses

The immune system has many responses to pathogens and foreign cells.

31.4 Immunity and Technology

Living in a clean environment and building immunity help keep a person healthy.

31.5 Overreactions of the Immune System

An overactive immune system can make the body very unhealthy.

31.6 Diseases That Weaken the Immune System

When the immune system is weakened, the body cannot fight off diseases.

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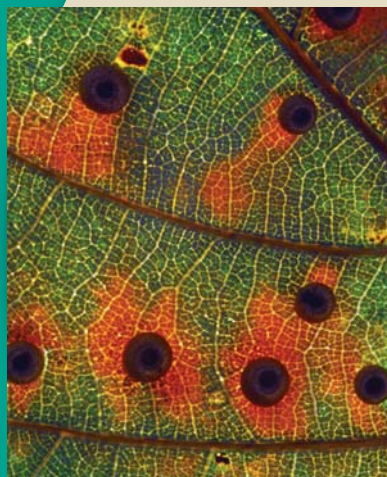
How do your cells fight off invaders?



colored SEM; magnification 4000×

Connecting CONCEPTS

You do not get sick every time disease-causing germs invade your body. Sometimes white blood cells, like the one in blue above, attack and destroy invaders without your feeling ill. Other times, you get sick because germs, such as the purple *E. coli* above, start winning. Fortunately, a healthy immune system can overpower many different types of germs—even when the germs temporarily gain the upper hand.



Plants Spots on a plant's leaves are evidence that the plant's immune system is fighting an infection. When a germ invades a plant, the infected cells release chemicals that kill the neighboring plant cells. With the surrounding cells dead, the germ is isolated and cannot infect the rest of the plant. Here, an English oak tree leaf has responded to a parasitic infection by causing its own cells around the infection sites to die (orange).

31.1

Pathogens and Human Illness

KEY CONCEPT Germs cause many diseases in humans.

▶ MAIN IDEAS

- Germ theory states that microscopic particles cause certain diseases.
- There are different types of pathogens.
- Pathogens can enter the body in different ways.

VOCABULARY

germ theory, p. 941
pathogen, p. 941
vector, p. 944

CALIFORNIA STANDARDS

10.d Students know there are important differences between bacteria and viruses with respect to their requirements for growth and replication, the body's primary defenses against bacterial and viral infections, and effective treatments of these infections.

Connect Diseases caused by germs, such as the *E. coli* bacteria on the previous page, can be fatal. From 1330 to 1352, the bacteria that caused the Black Death killed 43 million people worldwide, or 13 percent of the population at the time. In 1918, a viral disease called the Spanish flu killed between 20 and 50 million people worldwide, or as much as 3 percent of the population. Because diseases can have devastating effects, scientists become concerned whenever a new disease such as HIV, SARS, or avian flu appears.

▶ MAIN IDEA

Germ theory states that microscopic particles cause certain diseases.

A disease can be either infectious or noninfectious. Infectious diseases, such as flu and polio, can be passed from one person to another because infectious diseases are caused by germs. In contrast, cancer and heart disease are noninfectious diseases. These diseases are called noninfectious because a sick person cannot pass the disease to, or infect, a healthy person. Noninfectious diseases are not caused by germs; they result from a person's genetics or lifestyle.

FIGURE 31.1 History of Medicine

Most modern understanding about diseases occurred after Pasteur's **germ theory**.

B.C. 7000

Spirits Ancient societies drill holes in people's heads to release the evil spirits believed to cause disease.



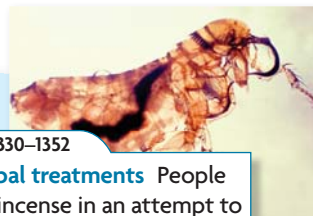
B.C. | A.D.

B.C. 460–B.C. 377

Humors Greek physician Hippocrates hypothesizes that fluids, called humors, cause disease.

A.D. 1330–1352

Herbal treatments People use incense in an attempt to cure those with the Black Death, caused by bacteria transmitted by rats' fleas.

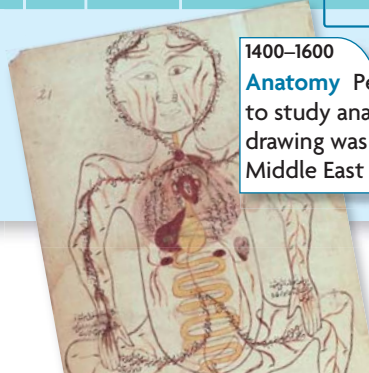


(LM; magnification 15×)

1400 | 1600

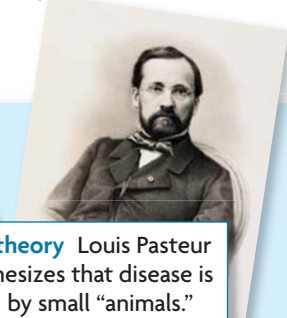
1400–1600

Anatomy People begin to study anatomy. This drawing was made in the Middle East in 1555.



1857

Germ theory Louis Pasteur hypothesizes that disease is caused by small "animals."



1865

Antiseptic technique Joseph Lister finds that cleaning his surgical tools reduces patients' infections.

On the other hand, infectious diseases can be passed from one person to another because infectious diseases are caused by germs.

Today, it seems obvious that some germs cause infectious disease, but this concept is only a little more than 100 years old. It was not until the 1850s that French scientist Louis Pasteur helped make the connection between microorganisms and disease. His theory, called the **germ theory** of disease, proposed that specific microorganisms caused diseases. These disease-causing agents are called **pathogens**. Pasteur hypothesized that if pathogens were eliminated from the body, a person would not get sick.

Pasteur's germ theory led to rapid advances in our understanding of disease, as shown in **FIGURE 31.1**. But at the time, germ theory was not immediately accepted. It took the work of two other scientists to bring about the complete acceptance of Pasteur's germ theory.

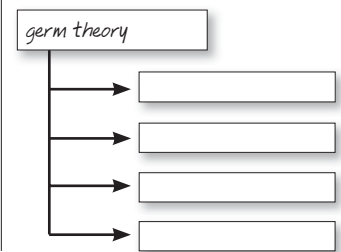
Between 1861 and 1865, about half of British surgeon Joseph Lister's patients died from infections after otherwise successful operations. After hearing Pasteur's germ theory, Lister began using a weak acid to clean his operating tools and his patients' wounds before surgery. The number of his patients who died from infection dropped dramatically to near zero.

Meanwhile, German scientist Robert Koch found that he could make a healthy animal sick by injecting it with pathogens from a sick animal. From his experiments, he concluded that four conditions must be met before one can say that a certain pathogen causes a disease. These conditions are called Koch's postulates.

- The pathogen thought to cause the disease must be present in every case in which the disease is found.
- The pathogen must be isolated and grown outside the body in a pure, uncontaminated culture.
- Healthy animals infected with the pure culture must develop the disease.
- The pathogen must be re-isolated and cultured from the newly sick animals and must be identical to the original pathogen.

TAKING NOTES

Use a main idea diagram to study germ theory of disease.



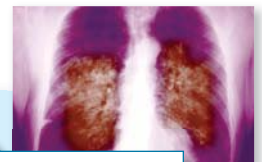
Contrast How is germ theory different from earlier theories about disease?



1883
Koch's postulates Robert Koch finds four conditions that prove a pathogen causes a disease.



1928
Antibiotics Sir Alexander Fleming discovers penicillin.

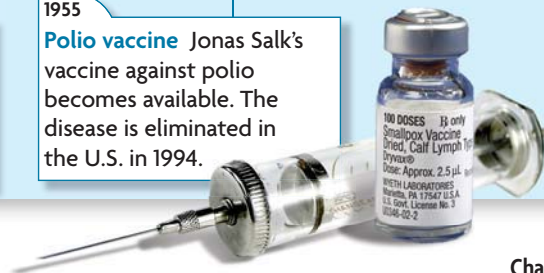


2002
New diseases First cases of SARS, a disease that affects the respiratory system, spring up in China.



1900s
Applying antiseptic technique Cities around the world start treating drinking water with chlorine, reducing the cases of cholera.

1955
Polio vaccine Jonas Salk's vaccine against polio becomes available. The disease is eliminated in the U.S. in 1994.



2005
Polio comeback Worldwide efforts increase to vaccinate people against polio, and the polio virus reemerges in fewer than ten people in the U.S.

▶ MAIN IDEA

There are different types of pathogens.

Traditionally, bacteria and larger pathogens were isolated by straining them through a ceramic filter with tiny pores. The disease-causing bacteria would remain on the filter, and the solution that passed through the pores was harmless.

Sometimes, however, there were no visible pathogens on the filter, and the solution caused disease. By 1898, scientists had hypothesized that some disease-causing agents must be smaller than bacteria. They called these agents filterable viruses. As better technology was developed, scientists discovered a huge variety of tiny new pathogens, which are outlined below and in

FIGURE 31.2.

- **Bacteria** are single-celled organisms. They can cause illness by releasing chemicals that are toxic to the host or by destroying healthy body cells. Food poisoning, which causes a person to become nauseous, is a sickness caused by bacteria-released toxins.
- **Viruses** are disease-causing strands of DNA or RNA that are surrounded by protein coats. Viruses are so small that they could not be seen until the invention of the electron microscope in the 1930s. These particles enter and take over a healthy cell, forcing it to stop its normal activities and produce more viruses. Viruses cause illnesses such as flus, colds, and AIDS. You will learn more about AIDS in Section 31.6.
- **Fungi** can be multicellular or single-celled organisms, such as those you read about in Chapter 19. The fungi that cause disease do so by piercing healthy cells and taking the cell's nutrients. Fungal infections usually occur in places that are warm and damp. Athlete's foot, for example, is a fungus that invades the skin cells between the toes.

Connecting CONCEPTS

Pathogens You can read more about microorganisms and viruses that cause disease in Chapters 18 and 19.

FIGURE 31.2 Common Infectious Diseases Worldwide

DISEASE	PATHOGEN TYPE	HOW IT SPREADS	AFFECTED BODY SYSTEMS	DEATHS ANNUALLY
HIV	virus	body fluids	immune	3,100,000
Pneumonia	virus, bacteria	airborne	respiratory	2,000,000
Tuberculosis	bacteria	airborne	respiratory, digestive	1,800,000
Malaria	protozoa	mosquito bite	digestive, circulatory, muscular	1,000,000
Hepatitis B	virus	contaminated food/water	digestive, immune	1,000,000
Measles	virus	airborne	respiratory, nervous	500,000
Influenza	virus	airborne, direct contact	respiratory	400,000

Source: World Health Organization

- **Protozoa** are single-celled organisms that prey on other cells. Like viruses, protozoa need healthy cells to complete their life cycles. Malaria is a blood disease that is caused by a protozoan. Chapter 19 includes a description of how the protozoan that causes malaria uses red blood cells to complete its life cycle.
- **Parasites** are organisms that grow and feed on a host. Some parasites kill the host, while others drain the body’s resources without killing the host. **FIGURE 31.3** shows a filaria, a parasitic worm found in tropical climates. Filaria will rarely kill its host, although some forms, such as heartworm, can be fatal in mammals. You can read more about parasitic worms in Chapter 23.

Although each of these pathogens is different, they all cause disease by attacking healthy cells. However, the way by which they attack varies.

Summarize What do all of these pathogens do that makes a person sick?

MAIN IDEA

Pathogens can enter the body in different ways.

Before a pathogen can make a person sick, it must get inside the body. Some pathogens can be transferred by direct or indirect contact. Pathogens that spread by direct contact are those that require an infected person or animal to physically touch a healthy person. Rabies, for example, is transferred when an infected animal bites a healthy animal. HIV is transmitted through an exchange of bodily fluids, such as during sexual intercourse or sharing of infected needles. It can also be transmitted from a mother to her child through the placenta or breast milk.



FIGURE 31.3 Filaria, such as this one, enter the body through contaminated food and can grow to be a meter long. (colored SEM; magnification 2500×)

QUICK LAB MODELING

How Pathogens Spread

Pathogens are disease-causing particles. In this lab, you will model how a pathogen spreads through a population.

PROBLEM From whom did the pathogen originate?

PROCEDURE

1. Obtain a cup filled with an unknown solution. Pour half your solution into a classmate’s cup. Then pour the same amount from your classmate’s cup back into your cup. Now your cup contains a mixture of the two solutions.
2. Repeat step 1 two more times with different classmates. Keep a record of with whom you exchanged solutions and in which order.
3. After you have exchanged solutions with three classmates, add three drops of “pathogen”-detecting solution to your cup. If your solution becomes pink, your cup contains the pathogen.

ANALYZE AND CONCLUDE

1. **Analyze** If your cup contained the pathogen, can you identify its origin? If your cup did not contain the pathogen, is it possible that any of the other solutions poured into your cup contained the pathogen?
2. **Analyze** Only one person in your class began with the pathogen in his or her cup. How can you determine whose cup had it?

MATERIALS

- 8-oz cup
- 100 mL unknown solution
- eyedropper
- 3 drops “pathogen”-detecting solution



CALIFORNIA STANDARDS

IE1.d Formulate explanations by using logic and evidence.

IE1.g Recognize the usefulness and limitations of models and theories as scientific representations of reality.

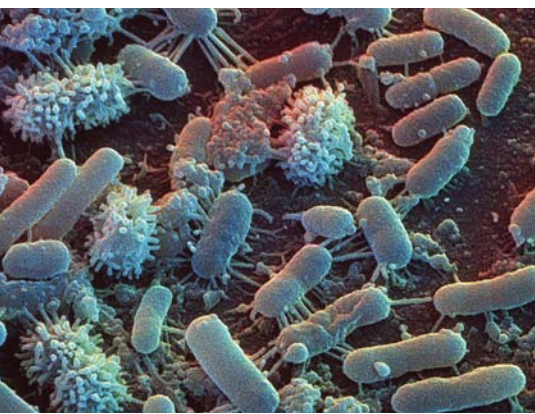


FIGURE 31.4 Sometimes even surfaces that we think are clean are covered with pathogens. Here you can see different types of pathogens clinging to a kitchen sponge. (colored SEM; magnification 6000×)

Pathogens that are spread by indirect contact can survive on nonliving surfaces, such as tables, door knobs, or kitchen sponges—as shown in **FIGURE 31.4**. Some parasitic worm larvae live in the soil and can burrow through the skin of a victim's bare foot. Once inside the body, the larvae travel into the victim's intestines. Species that remain in the intestines throughout their life cycle can cause discomfort, nausea, and diarrhea.

Other pathogens are spread through the air. When you cough or sneeze, you release droplets into the air around you. When you are sick, these droplets might contain pathogens. Other airborne pathogens are lightweight and hearty enough that they can survive in the air on dry particles. Respiratory diseases such as tuberculosis and SARS are examples of airborne diseases.

Still other pathogens are spread by vectors. A **vector** is anything that carries a pathogen and transmits it into healthy cells. Insects are examples of vectors. Insects can transmit bacteria, viruses, and protozoa. The Black Death, which killed millions of people in the 1300s, is caused by a bacterium that lives in the stomach of a rat's flea. People got sick with the Black Death when they were bitten by a contaminated flea. Mosquitoes can also pass diseases between animals. The protozoan that causes malaria, for example, completes a part of its life cycle in the gut of a mosquito. Mosquitoes can also transmit diseases between species. West Nile virus originally affected birds, but when an infected mosquito bites a person with a weak immune system, the virus can cause the person's brain to swell. However, insects cannot transmit pathogens, such as HIV, that die when the insect digests the infected human blood cells.

Pathogens can also be transmitted through food. Some diseases are caused by pathogens that were alive when the food-animal lived. Mad cow disease, which causes neurological problems in humans, is caused by an abnormal protein that is found in some beef cattle. Salmonella, which causes vomiting, is found in the intestines of some pigs and other animals. Most parasitic worm eggs enter the body through the mouth, as when a person eats contaminated food. Other diseases, such as various types of food poisoning, are caused by bacteria or fungi that decompose food.

Infer Why are some diseases only spread by insect bites?

31.1 ASSESSMENT



REVIEWING MAIN IDEAS

1. What conditions must be met before a specific **pathogen** is proved to cause a disease?
2. Name five general types of pathogens. **10.d**
3. What are some ways in which pathogens spread?

CRITICAL THINKING

4. **Contrast** How do bacteria and viruses differ in the ways they affect cells in the body? **10.d**
5. **Synthesize** How did the work of Lister and Koch support Pasteur's **germ theory** of disease?

Connecting CONCEPTS

6. **Viruses** Viruses infect healthy cells by injecting their genetic material into them. How are viruses similar to **vectors**? If the virus is the vector, what is the pathogen? **10.d**

31.2

Immune System

KEY CONCEPT The immune system consists of organs, cells, and molecules that fight infections.

▶ MAIN IDEAS

- Many body systems protect you from pathogens.
- Cells and proteins fight the body's infections.
- Immunity prevents a person from getting sick from a pathogen.

VOCABULARY

- immune system**, p. 945
 - phagocyte**, p. 946
 - T cell**, p. 946
 - B cell**, p. 946
 - antibody**, p. 947
 - interferon**, p. 947
 - passive immunity**, p. 948
 - active immunity**, p. 948
- Review**
pathogen, lymphocyte

CALIFORNIA STANDARDS

10.a Students know the role of the skin in providing nonspecific defenses against infection.

10.b Students know the role of antibodies in the body's response to infection.

10.f* Students know the roles of phagocytes, B-lymphocytes, and T-lymphocytes in the immune system.

Connecting CONCEPTS

Hypotonic You learned in Chapter 3 that when the environment has more solutes than a cell, water will diffuse out of the cell and the cell could die.

FIGURE 31.5 Cilia that line the throat (yellow) capture foreign particles. (colored SEM; magnification 7500×)

Connect Think of your body as a heavily guarded castle. When pathogens come to invade, they must first break down the outer wall or find a way around it. If the intruders get past the physical barriers, they must face your body's fighters in hand-to-hand combat. When the invaders gain the upper hand, you become sick. When the body's defenses are winning the war, you remain healthy.

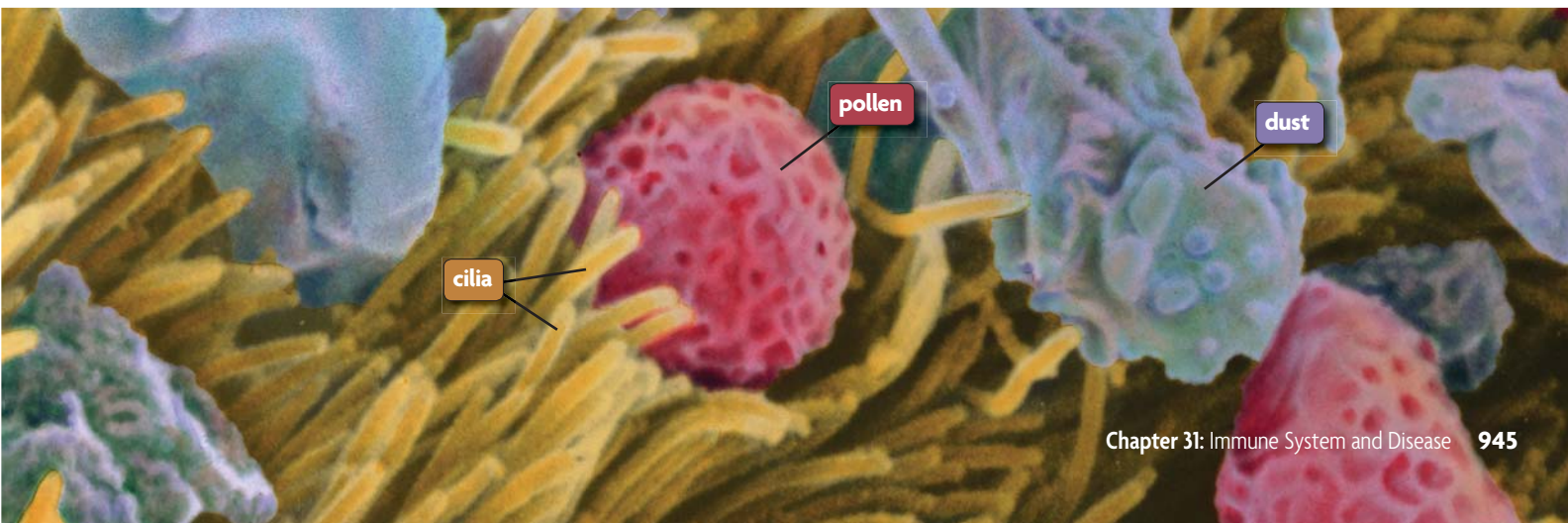
▶ MAIN IDEA

Many body systems protect you from pathogens.

The **immune system** is the body system that fights off infection and pathogens. Just as a castle has several lines of defense, so does your body's immune system. The immune system relies on physical barriers to keep pathogens out. However, when pathogens get past the physical barriers, the warrior cells of the immune system travel through the lymphatic and circulatory systems to reach the site of infection.

Your skin is your body's first line of defense. Like a castle's outer wall, the skin surrounds and protects your insides. The skin physically blocks invading pathogens. The skin also secretes oil and sweat, which make the skin hypotonic and acidic. Many pathogens cannot survive in this kind of environment.

Just as a castle's walls have doors and windows, your skin also has openings. For example, your eyes, nose, ears, mouth, and excretory organs are open to the environment, and so they need extra protection. Mucous membranes in these organs use hairlike cilia that are covered with a sticky liquid to trap pathogens before they move into the body, as shown in **FIGURE 31.5**.



Even with skin and mucous membranes to protect you, some pathogens still get into the body. Once pathogens are inside, the immune system relies on the circulatory system to send chemical signals to coordinate an attack and to transport specialized cells to the infection.

Summarize Name some of the tissues that help to prevent and fight infection.

▶ MAIN IDEA

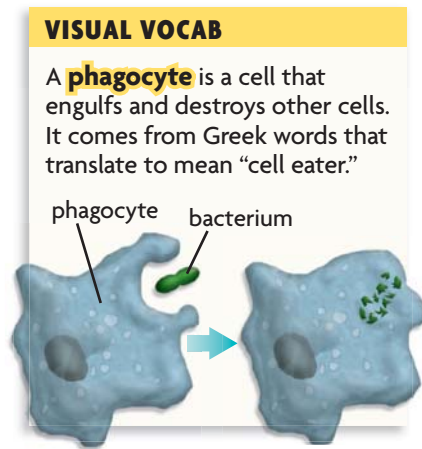
Cells and proteins fight the body's infections.

Once pathogens get past all of your outer defenses, the cells of your immune system spring into action. Just as a castle has many fighters and weapons, your immune system has many types of white blood cells and proteins.

White Blood Cells

White blood cells find and kill pathogens that have gotten past the body's external barriers. The six main types of white blood cells and their roles in fighting infection are summarized in **FIGURE 31.6**.

When a pathogen enters the body, basophils in the blood stream or mast cells found in other tissues release chemical signals. These signals attract other white blood cells to the site of the infection. If the pathogen is a parasite, eosinophils come and spray the parasite with poison. If the pathogen is a virus, bacterium, or fungus, neutrophils and macrophages go to work. These cells are phagocytes. A **phagocyte** (FAG-uh-SYT) is a cell that destroys pathogens by surrounding and engulfing them.



After phagocytes, lymphocytes reach the infection. Lymphocytes are white blood cells that initiate the specific immune responses, which you will read about in Section 31.3. There are two types of lymphocytes: T-lymphocytes and B-lymphocytes, also called T cells and B cells. **T cells** destroy body cells that are infected with pathogens. **B cells** produce proteins that inactivate pathogens that have not yet infected a body cell.

Connecting CONCEPTS

Lymphocytes Recall from **Chapter 30** that lymphocytes are cells of the lymphatic system that attack disease-causing particles.

FIGURE 31.6 White Blood Cells

NAME	FUNCTION
Basophil	makes chemicals that cause inflammation in the bloodstream
Mast cell	makes chemicals that cause inflammation in other body tissues
Neutrophil	engulfs pathogens and foreign invaders; phagocyte
Macrophage	engulfs dead or damaged body cells and some bacteria; phagocyte
Lymphocyte	destroys infected body cells or produces proteins that inactivate pathogens
Eosinophil	injects poisonous packets into parasites, such as protozoa

DATA ANALYSIS

IDENTIFYING EXPERIMENTAL DESIGN FLAWS

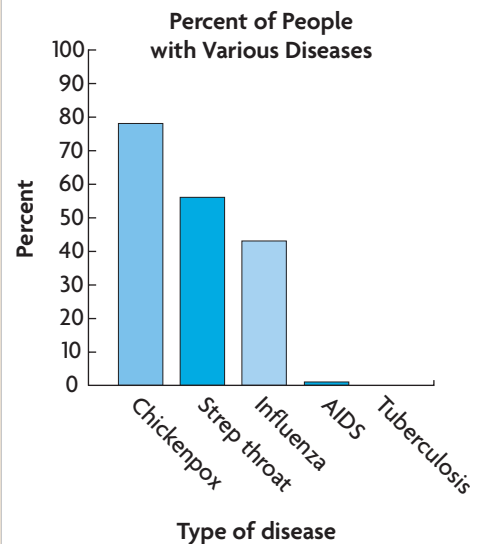
Sometimes scientific investigations can be flawed as a result of how the experiments were designed. Such design problems could include having a sample that is not representative of the population or one that is too small. This can result in the collection of invalid data, incorrect conclusions, and the release of misleading information.

To study how common certain diseases are in the United States, a student interviews 100 people as they exit a small Midwestern hospital. The student asks them if they have ever had any of five specific infectious diseases. He calculates the percent of people who responded “yes” to each question and puts the data in the graph to the right.

Based on his data, the student concludes that chickenpox is the most contagious disease of the five diseases studied. He also concludes that people in the United States no longer get tuberculosis.

- 1. Evaluate** What problems exist with the sample population in this investigation?
- 2. Analyze** Are the conclusions drawn from this data accurate? Why or why not?
- 3. Evaluate** How could this investigation be redesigned to produce valid results?

GRAPH 1. STUDENT DATA



CALIFORNIA STANDARDS

IE.1.d Formulate explanations by using logic and evidence.

Proteins

The immune system uses three types of proteins to fight off invading pathogens: complement proteins, antibodies, and interferons.

- Complement proteins are made by white blood cells and by certain organs. Some complement proteins weaken a pathogen’s cell membrane, allowing water to enter the cell and cause it to burst. Others attract phagocytes to the infected area. Still others cause microbes to stick to the walls of blood vessels, where they can more easily be found and destroyed by circulating phagocytes.
- **Antibodies** are proteins made by B cells. Antibodies destroy pathogens in one of three ways. Antibodies might make the pathogen ineffective by binding to the pathogen’s membrane proteins. As **FIGURE 31.7** shows, antibodies might also cause pathogens to clump, making them easier for phagocytes to engulf and destroy. Other antibodies activate complement proteins that weaken the pathogen’s cell membrane.
- **Interferons** (ihn-tuhr-FEER-AHNZ) are proteins produced by body cells that are infected by a virus. Cells release interferons, which stimulate uninfected body cells to produce enzymes that will prevent viruses from entering and infecting them. If viruses cannot enter healthy cells, they cannot reproduce. Other interferons stimulate an inflammation response.

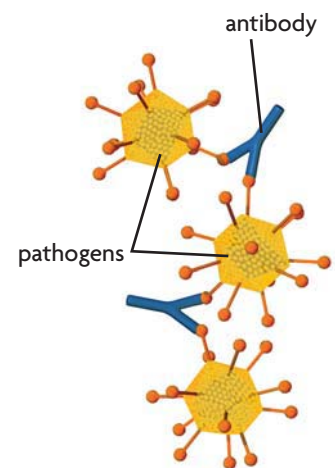


FIGURE 31.7 Antibodies help the immune system. Some types of antibodies cause pathogens to clump, making them easier to engulf and destroy.

Compare and Contrast What are some differences between the ways white blood cells and proteins fight infections?

 **MAIN IDEA**

Immunity prevents a person from getting sick from a pathogen.

If you are immune to a pathogen, it means that you will not get sick when that pathogen invades your body. There are two types of immunity—passive and active.

Passive Immunity

Passive immunity is immunity that occurs without the body's undergoing an immune response. Passive immunity is transferred between generations through DNA and between mother and child.

Some viruses can be spread between different species. A pathogen that infects a bird might infect a person as well. However, some viruses only make members of a specific species sick. Genetic immunity is immunity that a species has because a pathogen is not specialized to harming that species. Infants have another type of immunity. Inherited immunity occurs when pathogen-fighting antibodies in a mother's immune system are passed to the unborn baby through the umbilical cord or the mother's milk.

Active Immunity

Active immunity is immunity that your body produces in response to a specific pathogen that has infected or is infecting your body. Acquired immunity is a type of active immunity that occurs after your immune system reacts to a pathogen invasion. Acquired immunity keeps you from becoming sick by a particular pathogen more than once. We will look more closely at how the immune system produces acquired immunity in the next section.

Sometimes people get the same colds or flus over and over again throughout their lifetimes. This occurs because the viruses that cause these sicknesses mutate very quickly. Each time a different strain of virus invades, your immune system has to start from the beginning again. On the other hand, your immune system destroys repeat invaders before you get sick.

Contrast How do passive and active immunity differ?



To find out more about the immune system, go to scilinks.org.
Keycode: MLB031

31.2 ASSESSMENT



REVIEWING MAIN IDEAS

1. How does the **immune system** work with other body systems to prevent and fight disease? **10.a**
2. How do **phagocytes** help to fight infections? **10.f***
3. Which of the two types of immunity requires white blood cells? Explain. **10.f***

CRITICAL THINKING

4. **Contrast** How do complement proteins differ from **antibodies**? **10.b**
5. **Predict** If a person had a disease that prevented lymphocytes from maturing, how would the immune system's response to infection change? **10.f***

Connecting CONCEPTS

6. **Protein Synthesis** How might a person's immune system be affected if a portion of the DNA that codes for **interferons** has mutated?

MATERIALS

- slide of normal lymph tissue
- slide of diseased lymph tissue
- slide of normal lung tissue
- slide of diseased lung tissue (lung cancer or pneumonia)
- slide of normal red blood cells
- slide of anemic red blood cells
- slide of healthy stomach tissue
- slide of ulcer cells
- slide of normal liver
- slide of cinetosis of the liver
- microscope

PROCESS SKILLS

- **Observing**
- **Analyzing**



IE.1.a Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

Observing Normal and Diseased Tissue

In this lab, you will examine different cells and tissues under the microscope and compare the appearance of normal tissue with that of diseased tissue.

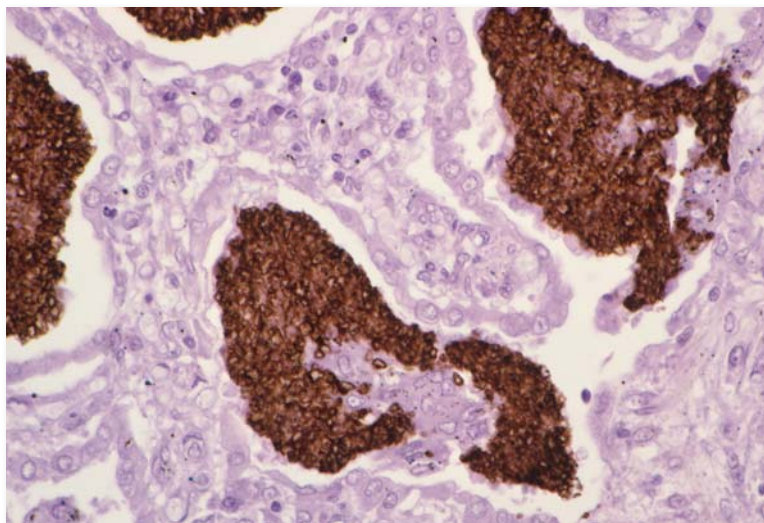
PROBLEM How do diseased tissues differ from normal ones?

PROCEDURE

1. Choose three slides of different healthy tissues and three slides of the same types of tissues with disease.
2. Examine a slide of normal tissue under low power and high power on the microscope. Draw the cells that you see.
3. Examine a slide of the same kind of tissue, but diseased, under low power and high power on the microscope. Draw the cells that you see.
4. Repeat steps 2 and 3 with each of the remaining slides that contain the different types of tissues.

ANALYZE AND CONCLUDE

1. **Contrast** How do each of the diseased tissues you observed differ from the normal tissues?
2. **Compare** What do the diseased tissues have in common with one another?
3. **Infer** Using what you know about pathogens, why do you think a tissue's appearance changes when it is infected?
4. **Infer** Using what you know about the function of each tissue, how do you think each of the diseased tissues is affected by the pathogen?



Many different viruses, bacteria, and fungi can cause pneumonia, a disease characterized by inflammation of the lungs. In this photograph, fungi (brown) have filled the aveolar spaces of the lungs (purple). (colored LM; magnification: 300 \times)

31.3

Immune Responses

KEY CONCEPT The immune system has many responses to pathogens and foreign cells.

▶ MAIN IDEAS

- Many body systems work to produce nonspecific responses.
- Cells of the immune system produce specific responses.
- The immune system rejects foreign tissues.

VOCABULARY

inflammation, p. 950

antigen, p. 951

memory cell, p. 951

cellular immunity, p. 952

humoral immunity, p. 953

tissue rejection, p. 954

Review

T cell, B cell



CALIFORNIA STANDARDS

10.a Students know the role of the skin in providing nonspecific defenses against infection.

10.b Students know the role of antibodies in the body's response to infection.

10.f* Students know the roles of phagocytes, B-lymphocytes, and T-lymphocytes in the immune system.

Connect Your body responds to pathogens in several different ways. For example, when you get a mosquito bite, your skin might swell and itch. After you are bitten, the skin around the bite becomes swollen, and the cells of your immune system attack the pathogens that entered the skin through the bite.

▶ MAIN IDEA

Many body systems work to produce nonspecific responses.

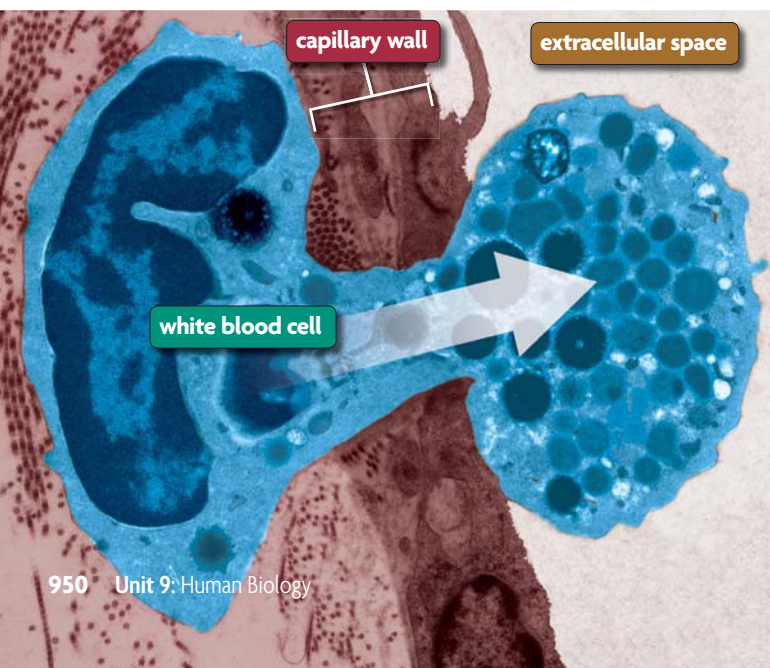
The body responds to pathogens and foreign particles with specific and nonspecific responses. Responses that occur on the cellular level are called specific defenses. Specific responses are slightly different for each pathogen. Nonspecific immune responses are those that happen in the same way to every pathogen. Some examples of nonspecific defenses are inflammation and fever.

Inflammation

Inflammation is a nonspecific response that is characterized by swelling, redness, pain, itching, and increased warmth at the affected site. Inflammation occurs when a pathogen enters the body or when the body's other tissues become damaged. For example, if you scrape your knee, it swells up. This occurs because the body is trying to head off pathogens that enter the body through the newly broken skin.

An inflammation response begins when mast cells or basophils release chemicals called histamines in response to a pathogen invasion. Histamines cause the cells in blood vessel walls to spread out. When this happens, fluids can move out of the blood vessel and into the surrounding tissues. White blood cells squeeze out of the capillary and move toward the site of infection, as shown in **FIGURE 31.8**. Once outside of the circulatory system, the white blood cells fight off the infection. When the pathogens are defeated, swelling stops, and tissue repair begins. Inflammation is a normal body response, but sometimes it occurs in response to things other than pathogens, as you will read in Section 31.5.

FIGURE 31.8 When pathogens invade your body, white blood cells squeeze through the capillary wall and move toward the infection. (LM; magnification 6500×)



Fever

Fevers develop when mast cells or macrophages release chemicals that cause the hypothalamus to increase the body's temperature. When the infection is controlled and the mast cell's chemicals are no longer being made, the body temperature returns to normal.

Fever is a response that affects the entire body. Low fevers, around 37.7°C (100°F), stimulate the production of interferons. Recall that interferons are proteins that prevent viruses from reproducing. Low fevers also increase the activity of white blood cells by increasing the rate at which they mature, as shown in **FIGURE 31.9**. Having many mature white blood cells is important because only mature cells can destroy pathogens. The more mature white blood cells in the body, the more quickly the body can fight off an infection.

While low fevers speed up pathogen destruction, high fevers—more than 39°C, or 103°F—are dangerous. Under high fever conditions, the hypothalamus can no longer regulate body temperature. Enzymes that control chemical reactions in the body stop functioning. High fever can cause seizure, brain damage, and even death.

Connect What body systems, other than the immune system, help to produce inflammation and fever?

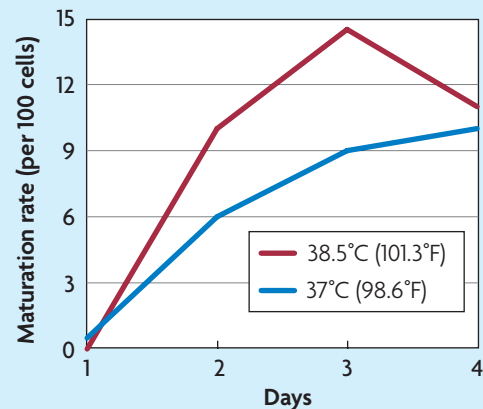
▶ MAIN IDEA

Cells of the immune system produce specific responses.

Specific immune defenses lead to acquired immunity, and they occur on the cellular level. For these specific immune defenses to work, the body must be able to tell the difference between its own healthy cells and foreign or infected cells. **Antigens** (AN-tih-juh-nz) are protein markers on the surfaces of cells and viruses that help the immune system identify a foreign cell or virus. If pathogens are the invading army that is waging war on the immune system, then you can think of antigens as the pathogens' uniforms.

When the immune system detects a pathogen, it triggers an immune response. There are two types of specific immune system responses: cellular and humoral immune responses. Although the two responses are different, as you will read on the next page, they both produce acquired immunity. Immunity is acquired when your body produces memory cells after fighting off an infection. **Memory cells** are specialized T and B cells that provide acquired immunity because they “remember” an antigen that has previously invaded your body. So when memory cells come across this antigen a second time, they quickly destroy the pathogen before the body has a chance to get sick. You will learn more about how memory cells work in Section 31.4, when you read about vaccines. Now, we will discuss how the immune system fights a pathogen that it is encountering for the first time.

FIGURE 31.9 WHITE BLOOD CELL MATURATION



Scientists put immature white blood cells in a nutrient solution and found that they matured faster when the cells were heated as in a low fever (red line).

Source: Roberts, N. J. Jr. and R. T. Stergbigel.
American Society of Microbiology

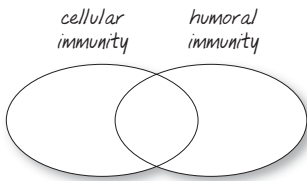
Connecting CONCEPTS

T cells and B cells Recall from the previous section that T and B cells are lymphocytes that are specialized to fight off pathogens.

- T cells destroy infected body cells.
- B cells produce proteins that inactivate pathogens.

TAKING NOTES

Use a Venn diagram to compare and contrast the cellular and humoral immune responses as you read this section.



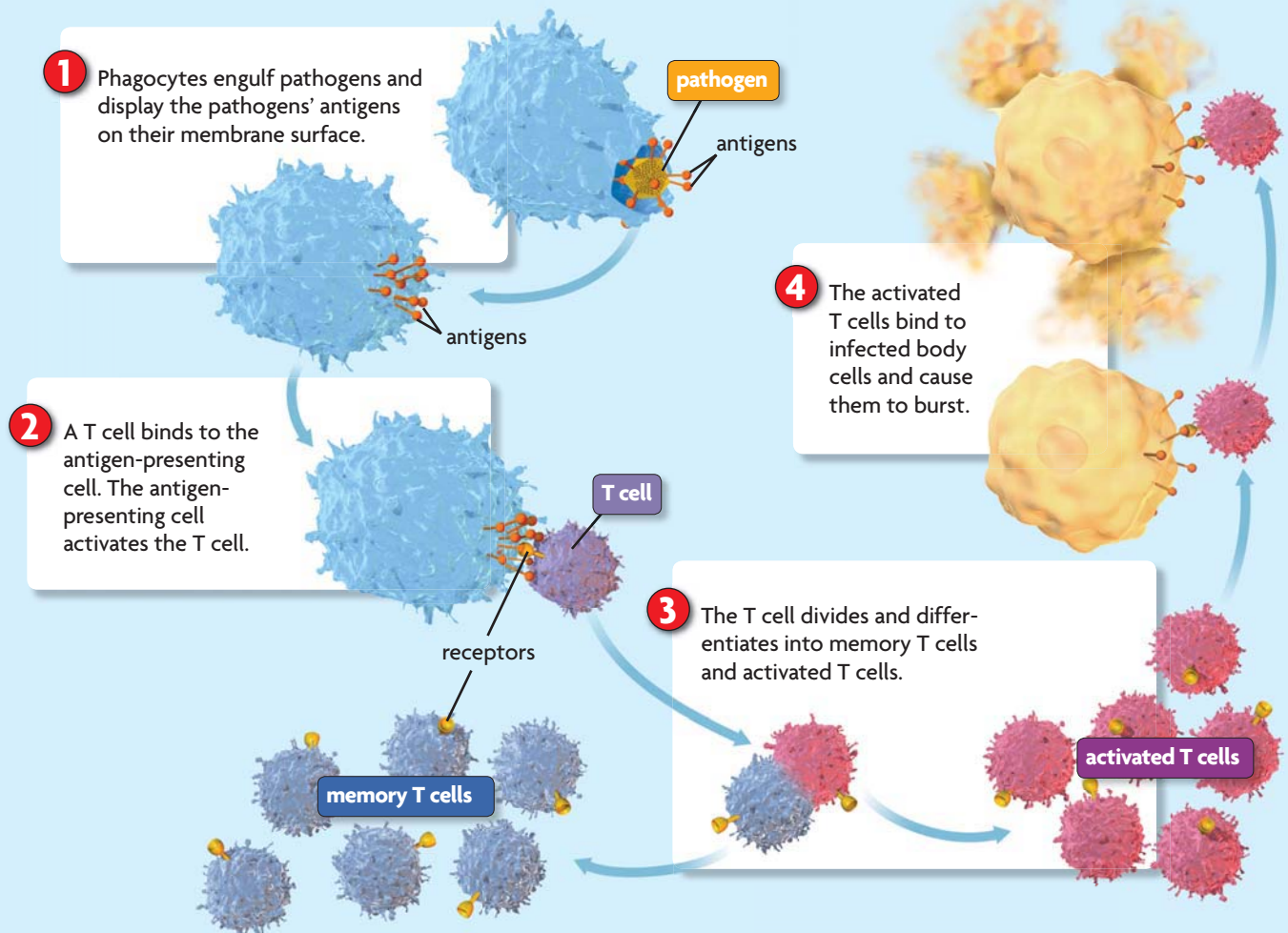
Cellular Immunity

Cellular immunity is an immune response that depends on T cells. As shown in **FIGURE 31.10**, T cells attach to infected body cells and cause them to burst. Before they can do this, however, T cells must become activated.

- 1 A phagocyte recognizes a foreign invader and engulfs it. Once inside the phagocyte, the invader's antigens are removed, and the phagocyte displays them on its cell membrane. A phagocyte that displays foreign antigens on its membrane is called an antigen-presenting cell.
- 2 A T cell encounters the antigen-presenting cell and binds to it. The antigen-presenting cell releases proteins that activate the T cell.
- 3 When a T cell is activated, it begins to divide and differentiate into two different types of T cells: activated and memory. The activated T cells will fight the current infection, but the memory T cells act as reserves that will wait for future invasions.
- 4 The activated T cells bind to and destroy infected body cells.

FIGURE 31.10 Cellular Immunity

In **cellular immunity**, T cells destroy infected body cells.



Analyze What allows T cells to identify infected body cells?

Humoral Immunity

Humoral immunity is a type of immune response that depends on antibodies. Different types of antibodies fight pathogens by either causing them to burst, inactivating them, or causing them to clump, as shown in **FIGURE 31.11**.

- 1 A pathogen binds to a B cell. The B cell engulfs the pathogen and puts part of the antigen onto its surface.
- 2 When a T cell encounters the antigen-presenting B cell, it binds to the antigens. Then the T cell releases proteins that activate the B cell.
- 3 Once activated, the B cell divides and differentiates into activated B cells and memory B cells.
- 4 Activated B cells produce as many as 2000 pathogen-specific antibodies per second. In some cases, antibodies cause pathogens to clump.
- 5 Phagocytes engulf and destroy the pathogen clumps.

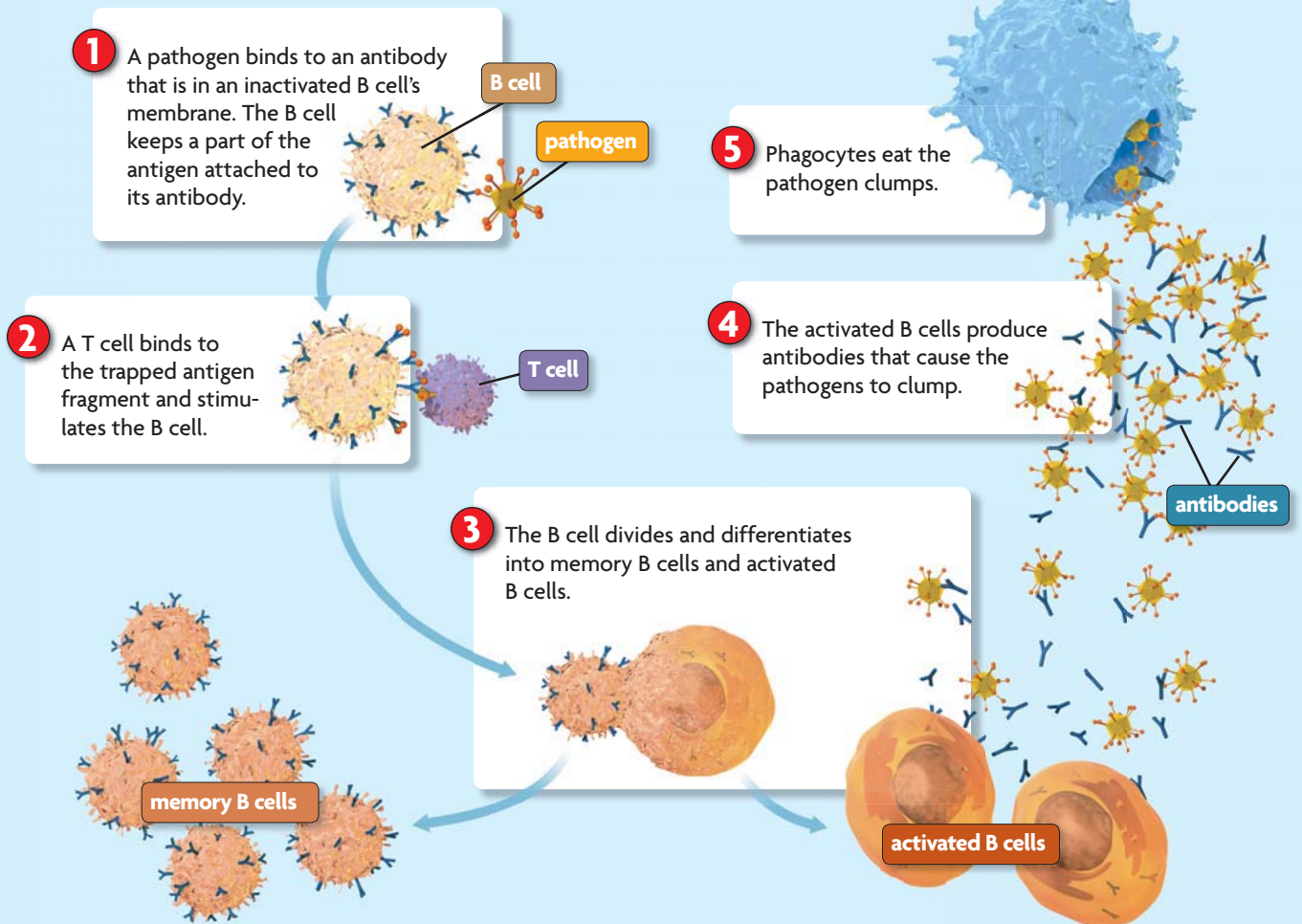
VOCABULARY

Humoral immunity comes from the Latin word *humor*, which means “fluid.” *Humoral immunity* refers to the immunity given by antibodies that travel in the blood and other body fluids.

Compare What are some similarities between the cellular and humoral responses?

FIGURE 31.11 Humoral Immunity

In **humoral immunity**, B cells produce antibodies that help destroy pathogens.



Analyze How do T cells contribute to the humoral immune response?

▶ MAIN IDEA

The immune system rejects foreign tissues.

Connecting CONCEPTS

Blood Typing Blood cells have different proteins, called Rh factors, on their cell walls. Review **Chapter 30** for more information on how blood types affect a person's ability to receive blood transfusions.

All cells have protein markers on their surfaces. Your body must constantly decide whether your healthy cells are, in fact, your own or foreign cells. Sometimes you do not want your body to be able to identify foreign tissues and cells. For example, when you receive a blood transfusion or an organ transplant, you want to fool your body into ignoring the foreign tissues' protein markers. If protein markers on donated tissue differ from your cells' proteins, an immune response can occur and the transplanted tissue will be attacked and rejected. **Tissue rejection** occurs when the recipient's immune system makes antibodies against the protein markers on the donor's tissue.

Antigen receptors on the surface of your white blood cells determine whether your immune system will attack or ignore a transplanted tissue. Cells with protein markers that fit into the white blood cells' receptor molecules are foreign. Cells with protein markers that do not interact with white blood cells' receptor molecules are not detected by the immune system.

People have thousands of different combinations of protein markers on their cells. The fewer of these protein markers that differ between a donor's tissue and a recipient's, the better the chance that the recipient's immune system will not attack the donor tissue. For this reason, it is important that tissues are analyzed to determine whether a donor and recipient are compatible. To prevent tissue rejection, recipients must take drugs that decrease the activity of their immune system. These drugs weaken the person's immune response against all pathogens. This leaves the recipient less able to fight off infections from viruses, bacteria, and fungi.

Other times, the immune system loses the ability to recognize the body's healthy cells. When this happens, the immune system attacks the healthy body cells. These diseases are called autoimmune diseases, and you will read more about them in Section 31.5.

Infer Why might it be beneficial for a person to get blood or tissues donated from a relative instead of a non-related donor?

31.3 ASSESSMENT



REVIEWING ▶ MAIN IDEAS

1. How does **inflammation** help the immune system to fight pathogens? **10.a**
2. What is the main difference between **cellular immunity** and **humoral immunity**? **10.b, 10.f***
3. What is **tissue rejection**, and why does it occur? **10.f***

CRITICAL THINKING

4. **Contrast** What are the differences between a specific and a nonspecific immune response? **10.a, 10.f***
5. **Synthesize** Explain how the proteins on the surface of white blood cells, pathogens, and transplanted tissues interact to produce an immune response. **10.f***

Connecting CONCEPTS

6. **Genetics** Doctors can test a person's blood to determine what types of proteins are on the surface of the person's blood cells. This is called blood typing. Why does blood typing reduce the likelihood of tissue rejection in blood transfusions? **10.f***

31.4

Immunity and Technology

KEY CONCEPT Living in a clean environment and building immunity help keep a person healthy.

▶ MAIN IDEAS

- Many methods are used to control pathogens.
- Vaccines artificially produce acquired immunity.

VOCABULARY

antiseptic, p. 955

vaccine, p. 956

antibiotic resistance, p. 955



CALIFORNIA STANDARDS

10.c Students know how vaccination protects an individual from infectious diseases.

10.d Students know there are important differences between bacteria and viruses with respect to their requirements for growth and replication, the body's primary defenses against bacterial and viral infections, and effective treatments of these infections.

FIGURE 31.12 Antibiotics have killed the bottom cell by weakening its cell wall and causing it to burst. (colored TEM; magnification 55,000×)

Connect Because infectious diseases are spread from person to person, the risk of getting sick increases when there are many people in one area. Luckily, scientists have developed many different ways to control the spread of disease. Cleaning supplies, medicines, and vaccines are technologies that help to prevent against sickness or treat people who are already sick.

▶ MAIN IDEA

Many methods are used to control pathogens.

Because pathogens can have such a negative effect on health, scientists have developed many ways to kill pathogens that our immune system might otherwise have a hard time fighting off. One way to prevent infection is to keep your environment clean. Cleaning can kill pathogens before they ever have a chance to enter your body and make you sick.

Heat and chemicals kill pathogens that are outside of the body. **Antiseptics** (an-tih-SEHP-tihks) are chemicals, such as soap, vinegar, and rubbing alcohol, that kill pathogens. Rubbing alcohol, for example, weakens cell membranes. Without a strong cell membrane, the microbe's nutrients leak out, and the microbe bursts, as shown in **FIGURE 31.12**. Antiseptics are not specific, meaning that they can kill many different types of pathogens.

Once pathogens enter the body, sometimes they can be killed with medicines. Antibiotics are medicines that target bacteria or fungi and keep them from growing or reproducing. Antibiotics work in a variety of ways. For example, penicillin makes bacteria unable to form cell walls. The bacteria cannot divide successfully, and they burst. Other antibiotics stop pathogens from reproducing.

Unlike antiseptics, antibiotics target one type of bacterium or fungus. As antibiotic use has become more common, antibiotic-resistant bacteria have evolved. As you read in Chapter 18, **antibiotic resistance** occurs when bacteria mutate so that they are no longer affected by antibiotics. Mutations make the bacteria resistant to the effects of antibiotics. When bacteria become resistant, scientists must find new medicines that can kill these mutant bacteria.

Compare and Contrast What are the similarities and differences between antiseptics and antibiotics?



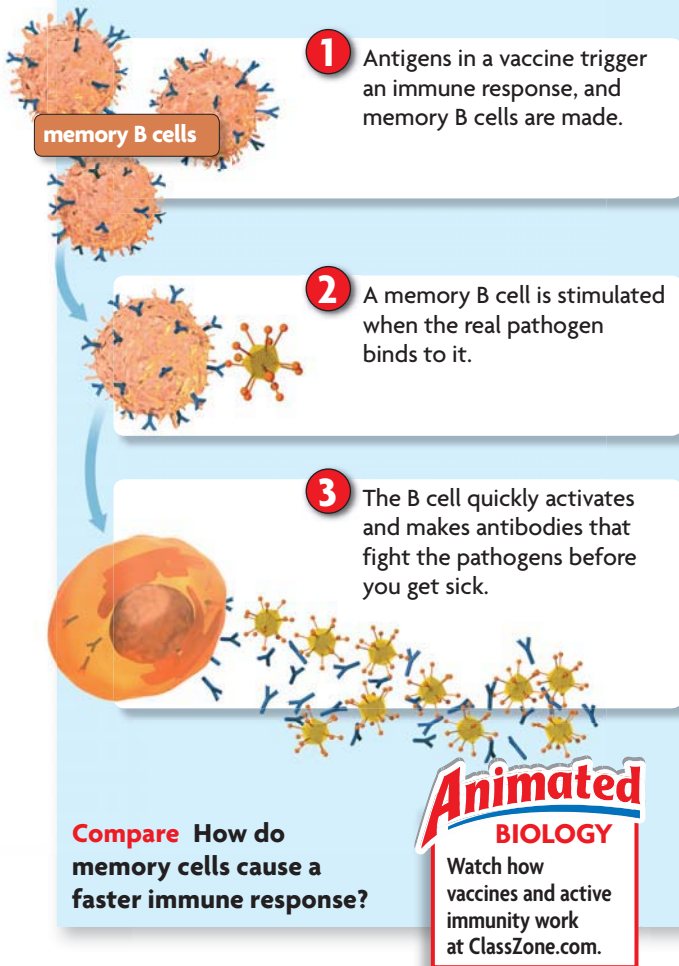
▶ MAIN IDEA

Vaccines artificially produce acquired immunity.

Vaccination cannot cure a person who is sick because vaccines only work to prevent infection. Vaccination allows a person to develop memory cells and acquired immunity against an illness without actually contracting the disease.

FIGURE 31.13 Vaccine Response

Vaccines stimulate an immune response so that you will not get sick if the real pathogen infects you.



A **vaccine** is substance that contains the antigen of a pathogen. The antigen causes your immune system to produce memory cells, but you will not get sick. You do not get sick because the pathogen is weakened, and it cannot reproduce or attack your cells. When you are exposed to a pathogen and have not been vaccinated, you get sick because the pathogen reproduces faster than your immune system can respond. You stop being sick when your B or T cells win the fight over the infection.

If the pathogen enters your body after you are vaccinated, your memory B cells make antibodies right away, as shown in **FIGURE 31.13**. If you have not been vaccinated, your body must go through the entire humoral immune response, and the pathogen has enough time to make you feel sick.

There are four main types of vaccines.

- Some vaccines contain whole dead bacteria or viruses.
- Live attenuated vaccines contain weak living pathogens.
- Component vaccines use only the parts of the pathogen that contain the antigen, such as the protein coat of a virus that has had its genetic material removed.
- Toxoid vaccines are made from inactivated bacterial toxins, which are chemicals a bacterium produces that causes a person to become ill.

Apply Why do you think that some vaccines, such as the flu vaccine, need to be given every year?

31.4 ASSESSMENT



REVIEWING **▶** MAIN IDEAS

1. Under what circumstances might antibiotics not be useful in treating a disease caused by a pathogen? **10.d**
2. How does the immune system respond to a pathogen that the person has been vaccinated against? **10.c**

CRITICAL THINKING

3. **Summarize** Write out and describe the steps that your immune system takes when you are vaccinated. **10.c**
4. **Apply** Why is the immune response faster after vaccination than the response that occurs the first time a pathogen invades? **10.c**

Connecting **CONCEPTS**

5. **Evolution** Explain why **antibiotic resistance** is considered to be evidence of evolution. (Hint: Review Chapter 18 and the information about natural selection.) **10.d**

31.5

Overreactions of the Immune System

KEY CONCEPT An overactive immune system can make the body very unhealthy.

▶ MAIN IDEAS

- Allergies occur when the immune system responds to harmless antigens.
- In autoimmune diseases, white blood cells attack the body's healthy cells.

VOCABULARY

allergy, p. 957

allergen, p. 957

anaphylaxis, p. 958

CALIFORNIA STANDARDS

10.f* Students know the roles of phagocytes, B-lymphocytes, and T-lymphocytes in the immune system.

Connect Eating a peanut can be deadly for a person who has an allergy. People who are allergic to peanuts can have their immune response activated by eating just one peanut or some peanut butter. An allergy is an overreaction in which the immune system produces an extreme response to a harmless protein marker. Other times, the immune system overreacts because it loses its ability to recognize the body's own healthy tissues.

▶ MAIN IDEA

Allergies occur when the immune system responds to harmless antigens.

More than half of all Americans have an allergy. You probably know someone who is allergic to something—dogs, bee stings, or drugs, such as penicillin. An **allergy** is an oversensitivity to a normally harmless antigen. When someone has an allergy, the immune system produces antibodies in response to an allergen. **Allergens** are antigens that cause an allergic reaction.

When an allergen enters the body, mast cells or basophils release histamine, as shown in **FIGURE 31.14**. Histamine is a chemical that causes nonspecific immune responses, such as inflammation. Another type of white blood cell, eosinophils, also seems to have a role in allergic reactions. Eosinophils normally release poisonous chemicals that kill parasites that they encounter. These chemicals can also cause an inflammation response. Recall from Section 31.3 that in a normal inflammation response, cells release histamine. When

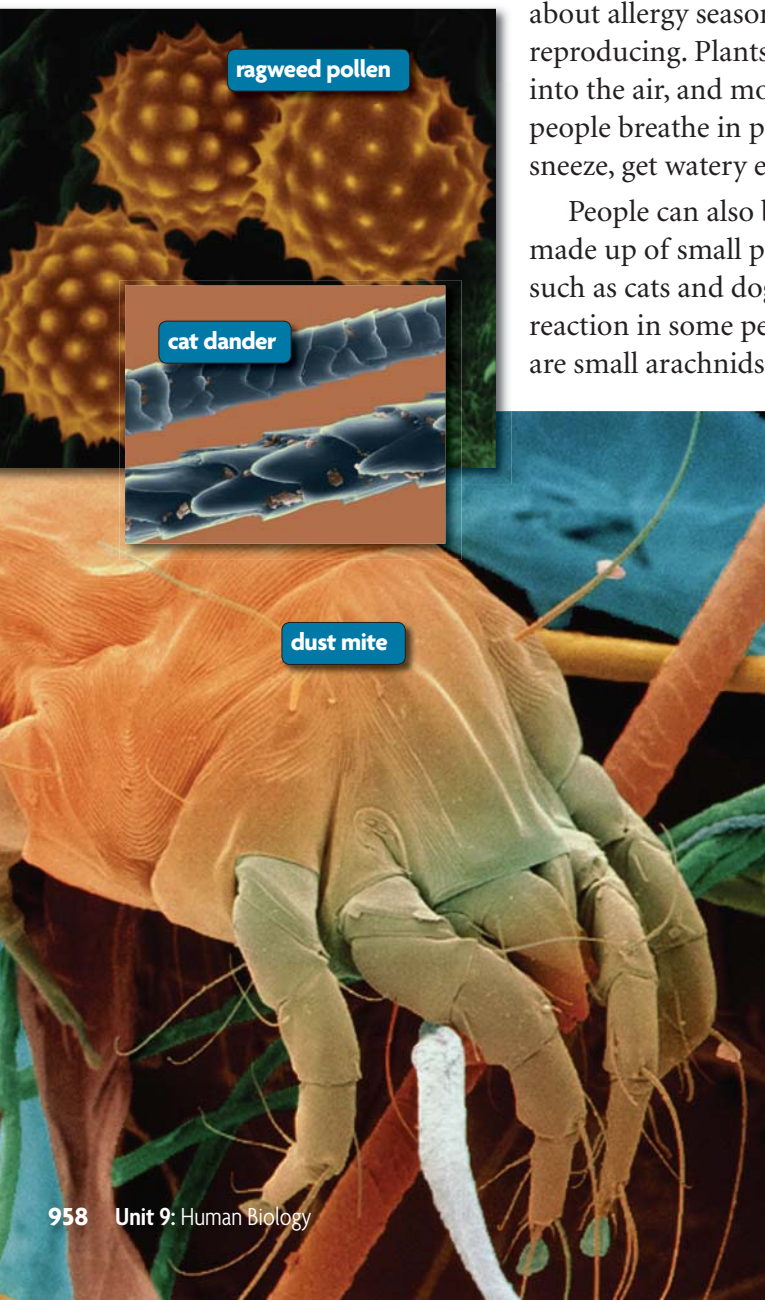
histamine is released in response to a pathogen, the inflammation helps fight infection. When inflammation occurs in response to an allergen, the inflammation is unnecessary because it provides no benefit to the individual.

Scientists and doctors do not know why some individuals have allergies but others do not. Research suggests that some allergies are triggered by the overabundance of a certain type of antibody, and that a person's genetic makeup determines if a person has allergies. Other studies suggest that allergies are triggered when an allergen, such as one found in food, is given to a child at a certain stage in life.

FIGURE 31.14 A basophil cell produces histamine, a chemical that triggers inflammation. (colored TEM; magnification 11,500×)



FIGURE 31.15 Common airborne allergens include pollen, animal dander, and dust mite wastes. (colored SEMs; magnifications: ragweed 1000×; cat dander about 300×; dust mite 300×)



Food Allergens

An allergic reaction can occur when a person eats a specific type of food. In the United States, one to two adults in every 100 have a severe allergy to at least one type of food, and five to eight children out of 100 have a food allergy. Although any type of food can cause an allergy, the most common food allergens are milk, eggs, peanuts and tree nuts, soy, wheat, fish, and shellfish.

If a person's allergic response is severe, he or she may experience anaphylaxis. **Anaphylaxis** (AN-uh-fuh-LAK-sihs) is a condition that occurs when the immune system releases a large amount of histamine, which causes airways to tighten and blood vessels to become porous. When the airways tighten, air cannot enter the lungs or other tissues. When blood vessels become porous, blood leaks out of the circulatory system, causing the body to shut down. If not treated immediately, anaphylaxis can cause death.

Airborne Allergens

Airborne allergens, such as the ones shown in **FIGURE 31.15**, are those that cause allergic responses when they are breathed in. You may have heard people talk about allergy season. Allergy season occurs when certain plants and molds are reproducing. Plants—such as ragweed, dandelions, and grass—release pollen into the air, and molds release spores as part of their reproductive cycle. When people breathe in pollen or spores, the histamine response may make them sneeze, get watery eyes, or become congested.

People can also be allergic to things that are indoors. Dander, which is made up of small particles in animal hair, makes some people allergic to pets, such as cats and dogs. Chemicals in animal saliva can also trigger an allergic reaction in some people. Others are allergic to the feces of dust mites, which are small arachnids that live in dust balls and cloth. In some cases, allergic reactions to airborne allergens can cause asthma. During an asthma attack the airways tighten, and breathing becomes difficult. Some people with asthma carry inhalers containing medicine that opens up the airways, reversing the effects of an asthma attack.

Chemical Allergens

Chemical allergens include metals that come in contact with the skin or those that enter the blood through injection or digestion. In metal allergies, people develop rashes when certain types of metal rest on their skin for too long. Ten percent of people in the United States are allergic to nickel, a metal that is common in jewelry.

Other chemicals, such as the venom from bee stings or drugs such as penicillin, can cause allergic reactions. These chemicals can cause anaphylaxis in a person with a severe allergy.

Compare and Contrast How is an allergic response the same as and different from a normal inflammation response?

MAIN IDEA

In autoimmune diseases, white blood cells attack the body's healthy cells.

Autoimmune diseases are those that occur when the immune system cannot tell the difference between the body's healthy and unhealthy cells. Normally, immune system cells attack only foreign substances, such as pathogens and infected or abnormal cells. With autoimmune diseases, the body treats its own cells as though they are foreign invaders.

In Type 1 diabetes, the immune system destroys cells in the pancreas. As a result, the pancreas makes less insulin. Without insulin, the body cannot remove glucose from the blood. Type 1 diabetes can cause death if a person does not get extra insulin into the body. There are more than 60 other autoimmune diseases. Some of the most common ones are described in

FIGURE 31.16.

Scientists do not know why some people develop autoimmune diseases. Research suggests that a person's genes may make them more likely to get an autoimmune disease, but that the actual immune system attack is triggered by another factor—a virus, a drug, or an environmental toxin. Currently, doctors cannot cure autoimmune diseases, but they can provide treatments that lessen the diseases' effects.

FIGURE 31.16 Common Autoimmune Diseases

AUTOIMMUNE DISEASES	BODY SYSTEMS AFFECTED	THE IMMUNE SYSTEM . . .	HOW MANY AFFECTED
Rheumatoid arthritis	integumentary	breaks down tissues that line joints, making movement difficult	70 in 10,000
Type 1 diabetes mellitus	endocrine, digestive	attacks the pancreas, stopping the digestion of sugars	60 in 10,000
Hashimoto's thyroiditis	endocrine	attacks the thyroid gland, causing it to make fewer hormones	15 in 10,000
Multiple sclerosis (MS)	nervous	breaks down myelin sheaths, disrupting nerve communication	10 in 10,000
Graves' disease	endocrine	stimulates the thyroid gland, causing it to make more hormones	5 in 10,000

Apply How do autoimmune diseases disrupt other body systems?

31.5 ASSESSMENT



REVIEWING MAIN IDEAS

- Under what conditions is an antigen called an **allergen**?
- Why might an autoimmune disease be considered a failure of the immune system? **10.f***

CRITICAL THINKING

- Infer** Some **allergies** are treated with drugs called antihistamines. How do you think antihistamines might work? **10.f***
- Analyze** Why does someone experiencing **anaphylaxis** need to receive medicine through injection instead of swallowing a pill?

Connecting CONCEPTS

- Ecology** Bee stings can be deadly for people who are allergic to them, but in most people, a bee sting simply hurts and warns the person to leave the insect alone. How are stingers beneficial to the survival of bee species?

31.6

Diseases That Weaken the Immune System

KEY CONCEPT When the immune system is weakened, the body cannot fight off diseases.

▶ MAIN IDEAS

- Leukemia is characterized by abnormal white blood cells.
- HIV targets the immune system.

VOCABULARY

leukemia, p. 960
opportunistic infection, p. 961
human immunodeficiency virus (HIV), p. 961
acquired immune deficiency syndrome (AIDS), p. 963

Review
T cells



CALIFORNIA STANDARDS

10.e Students know why an individual with a compromised immune system (for example, a person with AIDS) may be unable to fight off and survive infections by microorganisms that are usually benign.

Connect There is no cure for AIDS. But people who are infected with HIV do not die directly from it—some people don't know that they're infected for more than ten years. Instead, as HIV weakens the immune system, they become sick with other diseases. Illnesses that weaken the immune system, such as an AIDS infection, make it easy for other pathogens to infect the body and take over.

▶ MAIN IDEA

Leukemia is characterized by abnormal white blood cells.

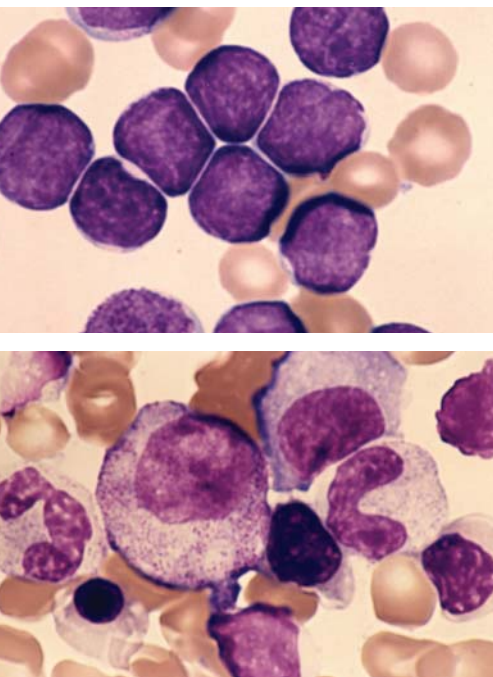


FIGURE 31.17 The cells affected by leukemia (top) do not have a ring of cytoplasm around the organelles, as the healthy blood cells (bottom) do. (magnification unknown)

Bone marrow is a tissue found within bones. Red bone marrow makes red and white blood cells and platelets. In healthy marrow, new blood cells replace mature ones that die. Sometimes, blood cells do not mature properly.

Leukemia is cancer of the bone marrow. Unlike other cancers, leukemia does not form tumors. Instead, it prevents the bone marrow from functioning properly. In one type of leukemia, the bone marrow produces white blood cells that do not develop properly. Because the cells are immature, they cannot fight infections. Here is how leukemia weakens the immune system.

- Bone marrow produces white blood cells that don't mature. These cells are smaller and have less cytoplasm than mature ones, as shown in **FIGURE 31.17**.
- In effort to replace the defective white blood cells, the bone marrow produces more and more white blood cells. However, none of these new cells mature into effective white blood cells.
- Eventually, the bone marrow spends all of its time making white blood cells. As a result, it makes fewer red blood cells and platelets than are needed to replace those that die or become damaged.

To cure leukemia, the cancerous bone marrow must be replaced with healthy marrow from a donor. Before a bone marrow transplant takes place, the recipient is given large doses of radiation and chemotherapy to kill all the abnormal bone marrow cells. Then the donor marrow is put into the body. If the transplant is successful, the donor marrow will make healthy blood cells.

However, problems can arise from bone marrow transplants. In graft-versus-host disease (GVHD), the donor marrow makes antibodies against the host's healthy tissues. Chemotherapy and radiation treatments also kill both cancerous cells and healthy cells, leaving the immune system weak and open to opportunistic infections. An **opportunistic infection** is an infection caused by a pathogen that a healthy immune system would normally be able to fight off. When the immune system is weakened, an opportunistic infection can make a person very sick.

Analyze Shortness of breath and inability to form blood clots are common symptoms of leukemia. How does the disease lead to these symptoms?

▶ MAIN IDEA

HIV targets the immune system.

The World Health Organization estimates that more than 40 million people in the world have HIV/AIDS. During the 1980s, fewer than 2 million people had the virus. The **human immunodeficiency virus (HIV)**, illustrated in **FIGURE 31.18**, is a retrovirus that attacks and weakens the immune system. A retrovirus is a type of virus that contains RNA instead of DNA. HIV is a retrovirus that has nine genes. HIV weakens the immune system, and the body is likely to get opportunistic infections.

HIV Transmission

Although HIV is a very dangerous pathogen, it can only live in human blood cells and thus will not survive for long outside of the human body. For this reason, HIV is not transmitted through shaking hands with an infected individual, or swimming in a pool with an infected person. HIV cannot be transmitted through insect bites either. Insects that suck blood, such as ticks or mosquitoes, quickly digest the blood cells in their guts. Once the blood is digested, HIV dies.

A person becomes infected with HIV when the virus enters his or her bloodstream. HIV is passed from person to person through the mixing of blood and other body fluids. HIV is transmitted through sexual intercourse with an infected individual. It can also be passed from mothers to their unborn babies through the umbilical cord. A person might also get HIV if his or her skin is pierced by a needle that an infected individual recently used. Hypodermic needles used for injecting some illegal drugs and needles used for body piercing and tattooing have transmitted HIV between individuals. However, needles that your doctor uses to give shots or take blood do not transmit HIV because doctors use a new needle for every patient.

HIV Reproduces in T Cells

HIV infects T cells, the white blood cells that trigger the body's immune responses. When HIV enters a T cell, the T cell becomes ineffective and can no longer stimulate an immune response. While the T cell cannot function in the immune system, it remains alive as a host and produces new HIV. A single T cell can give rise to thousands of HIV viruses before it eventually dies.

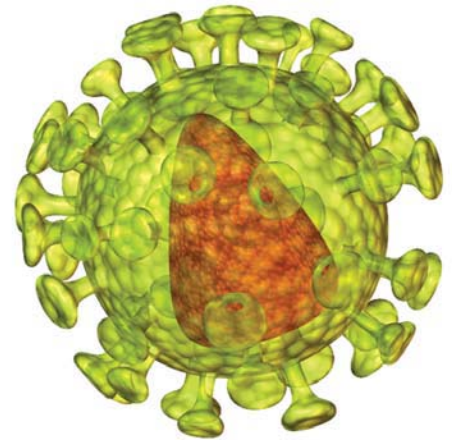
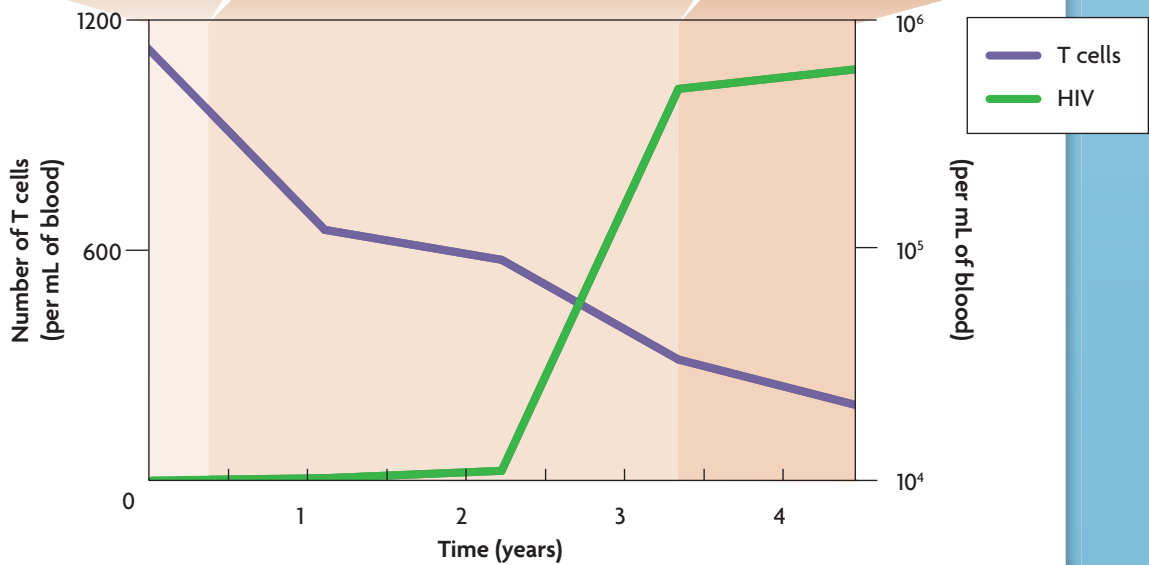
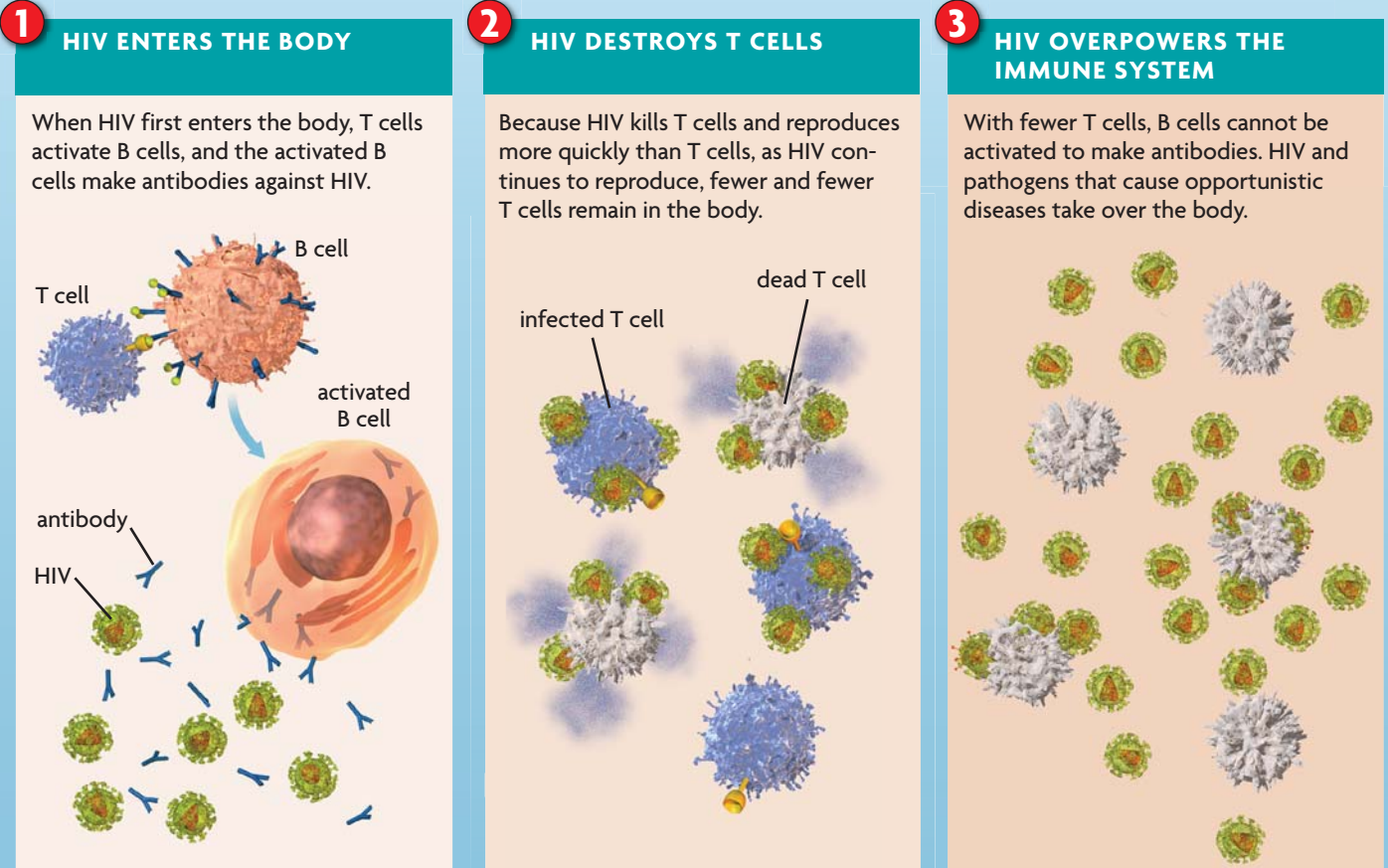


FIGURE 31.18 HIV is a small retrovirus that is covered with bumps, which are its antigens. This illustration shows an HIV about 500,000 times its actual size.

FIGURE 31.19 HIV Destroys T cells

HIV reproduces within T cells, killing T cells and weakening the immune system.



Source: Mellors, J.W. et al.
Annals of Internal Medicine.

CRITICAL VIEWING

Why might a graph comparing HIV and antibodies have a similar shape to the one above, which compares HIV and T cells?

As HIV reproduces, the body cannot make replacement T cells fast enough. As the immune system weakens, opportunistic infections begin to take over.

During the first few weeks of infection, a person usually does not feel sick. Although HIV is infecting some T cells, there are still enough healthy T cells that B cells can be activated to produce antibodies against HIV, as shown in **FIGURE 31.19**. At this stage, HIV is diagnosed by determining whether a person's blood contains antibodies against HIV.

After the initial infection, an infected person can have HIV for ten years or more without experiencing any symptoms. During this stage, more and more T cells become infected, and each cell produces thousands of HIV cells, as shown in **FIGURE 31.20**. Soon, the bone marrow cannot replace dead T cells quickly enough, and the body develops opportunistic infections and AIDS.

HIV Leads to AIDS

Acquired immune deficiency syndrome (AIDS) is the final stage of the immune system's decline due to HIV. Whereas HIV is a virus, AIDS is the condition of having a worn-out immune system. A person with AIDS can have several opportunistic infections—such as fungal infections, tuberculosis, pneumonia, viral infections, and cancers—and very few T cells. AIDS always results in death because a person's body cannot fight off its many infections.

Treatment of an HIV infection is expensive, complicated, and only slows—but does not cure—the disease. Treatment involves a combination of three to four antiviral drugs that are taken as often as five times each day. These drugs can cause many unpleasant side effects and can be very expensive. What's more, as HIV mutates, a patient might need to use many different drug combinations to keep the infection under control. Also, HIV mutates rapidly, and so far no vaccine has provided complete protection against the new strains of HIV that are constantly evolving.

Apply How does the destruction of T cells lead to the failure of the overall immune system?

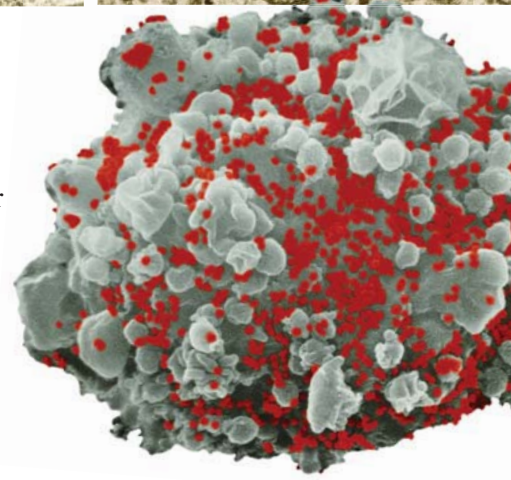
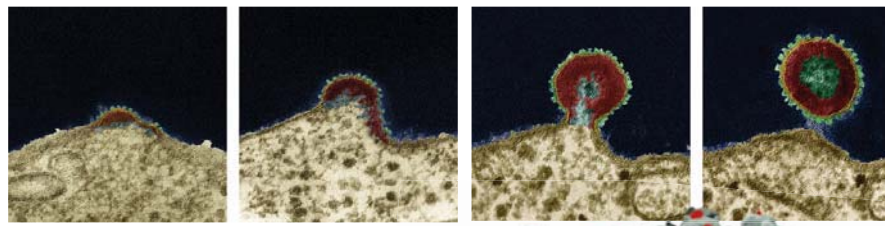


FIGURE 31.20 Thousands of HIV, shown in red, will bud off a T cell before the T cell dies. (top: colored TEM, magnification 105,000 \times ; bottom: colored SEM, magnification 5000 \times)

31.6 ASSESSMENT



REVIEWING MAIN IDEAS

1. How does **leukemia** affect a person's entire body?
2. How do **HIV** and **AIDS** differ?

CRITICAL THINKING

3. **Analyze** Why won't people who take multiple medications to treat HIV infections ever be cured? **10.e**
4. **Compare and Contrast** Which cells of the immune system are affected by HIV and leukemia, and what parts of the immune response do these cells influence? **10.e**

Connecting CONCEPTS

5. **Antibiotics** You learned in Chapter 18 that viruses cannot be treated with antibiotics. Why, then, might doctors prescribe antibiotics to patients with HIV anyway? **10.e**

Use these inquiry-based labs and online activities to deepen your understanding of immune system response.



IE.1.g Recognize the usefulness and limitations of models and theories as scientific representations of reality.

INVESTIGATION

Modeling T Cell Activation

In this lab, you will make a model that shows how a T cell becomes activated. Recall that T cells have receptors on the cell membrane surface that recognize and react with antigens. In a process similar to the lock-and-key method used by enzymes and the substrates they act on, each T cell reacts specifically with only one antigen.

SKILL Modeling

PROBLEM How does a T cell become activated?

PROCEDURE

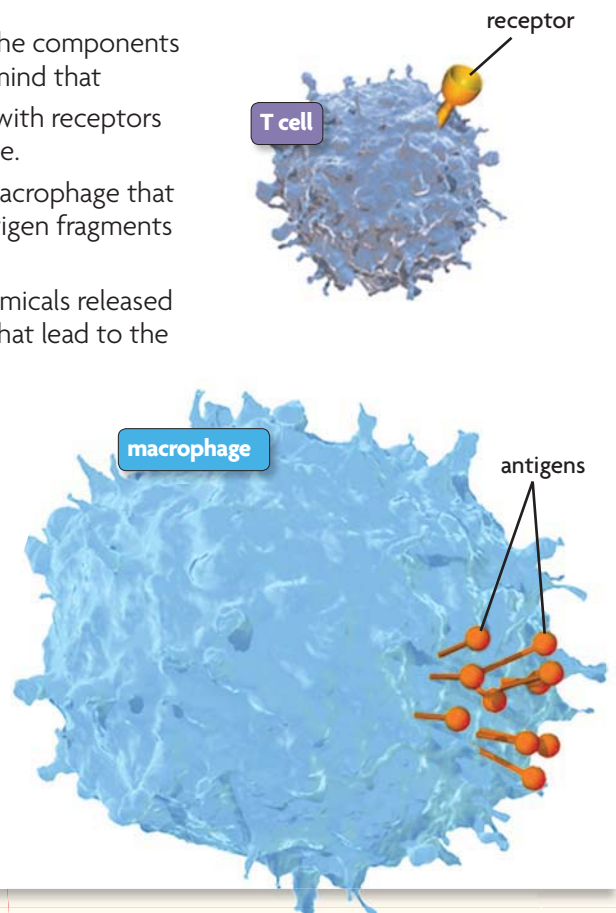
- Decide how you will model each of the components involved in T cell activation. Keep in mind that
 - You will need to represent a T cell with receptors on the surface of the cell membrane.
 - You will also need to represent a macrophage that has ingested an antigen and has antigen fragments on its cell surface.
 - You will also need to represent chemicals released by the macrophage and the T cell that lead to the production of more T cells.
- Refer to Section 31.3 for more information and diagrams about T cell activation as you determine which materials you will use for constructing your models.
- Make your model.

ANALYZE AND CONCLUDE

- Evaluate** What are the limitations of your model?
- Evaluate** How would your model change if you wanted to show how a T cell is involved in the activation of a B cell?

MATERIALS

- sheet of white paper
- 5 colors of construction paper
- colored markers
- glue
- scissors



INVESTIGATION

What Is an Autoimmune Disease?

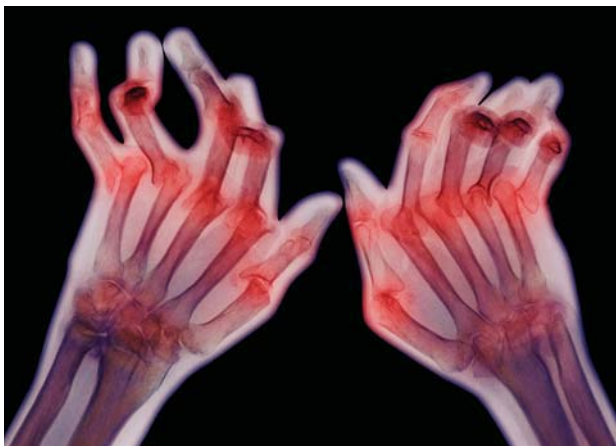
Sometimes the immune system attacks and damages the body's own healthy tissues. An autoimmune disorder is a disease that occurs when the immune system can no longer tell the difference between the body's own cells and foreign cells. Graves' disease, a disorder in which antibodies attach to receptors on cells in the thyroid gland, results in an overactive thyroid gland that must be treated with medication, surgery, or radiation.

SKILL **Researching**

PROBLEM What is the nature of the autoimmune disease?

PROCEDURE

1. Choose one of the following autoimmune diseases:
 - a. Myasthenia gravis
 - b. Lupus
 - c. Rheumatoid arthritis
 - d. Rheumatic fever
2. Perform research to find the cause of the disease.
3. How does the disease progress?
4. What are the possible treatments?

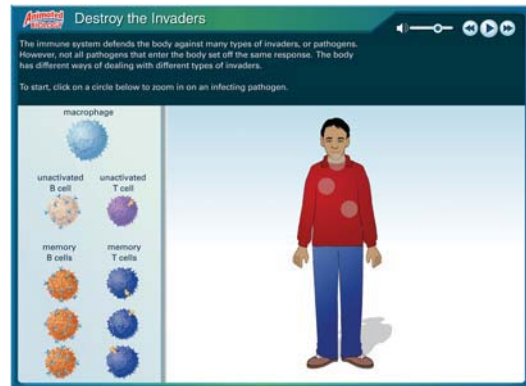


This x-ray image shows the hands of a person who is affected with rheumatoid arthritis.

ANIMATED BIOLOGY

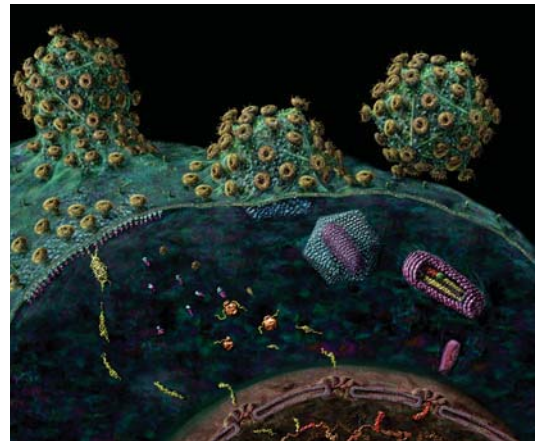
Destroy the Invaders

Can you keep someone from contracting an illness? Use a set of immune cells to mount attacks against a variety of pathogens to keep the person healthy.



WEBQUEST

HIV infects people all over the world. You will learn more about how this deadly virus works and causes AIDS. Explore how HIV is treated and look into ongoing research devoted to overcoming HIV.



DATA ANALYSIS ONLINE

The West Nile virus first appeared in North America in 1999. The first reported infections were in the New York City area. Since then, it has spread across the United States. Graph the number of West Nile virus cases and discover just how quickly the virus spread.

KEY CONCEPTS

Vocabulary Games

Concept Maps

Animated Biology

Online Quiz

31.1 Pathogens and Human Illness

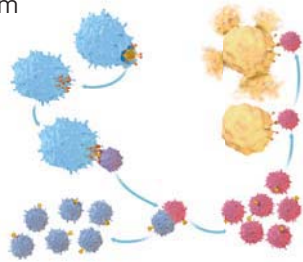
Germ theory hypothesized that microbes—not spir- its—caused disease. Viruses, bacteria, fungi, pro- tozoa, and parasitic worms are examples of pathogens. These pathogens can be spread through physical contact, the air, or vectors.

31.2 Immune System

The immune system consists of organs, cells, and molecules that fight infections. Skin and mucous membranes work to keep pathogens out of the body. Once a pathogen is inside the body, the circulatory and lymphatic systems transport white blood cells to the infection site. Some microbes and viruses do not cause illness because a person has some type of immunity.

31.3 Immune Responses

The immune system has many responses to pathogens and foreign cells. Nonspecific responses, such as inflammation and fever, are those that react the same to every pathogen. Specific responses, such as the cellular and humoral responses, are different for every patho- gen. The immune system might initiate a spe- cific response against transplanted tissues.



31.4 Immunity and Technology

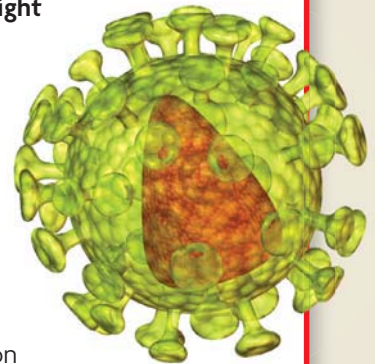
Living in a clean environment and building immunity help keep a person healthy. Antiseptics destroy pathogens outside of the body, and antibiotics destroy pathogens inside of the body. Vaccines activate an immune response without getting a person sick. When the pathogen does invade, a vaccinated person’s immune response is so quick that the person will not get sick.

31.5 Overreactions of the Immune System

An overactive immune system can make the body very unhealthy. Allergies occur when the immune system responds to a harmless antigen. In autoimmune diseases, white blood cells attack the body’s healthy cells.

31.6 Diseases That Weaken the Immune System

When the immune system is weak- ened, the body cannot fight off diseases. Leukemia is characterized by imma- ture white blood cells. HIV attacks T cells so that other pathogens can take over the body. When a person has very few T cells and several opportunistic diseases, the person has a condition called AIDS.



Synthesize Your Notes

Concept Map Use a concept map to organize your notes about lymphocytes.

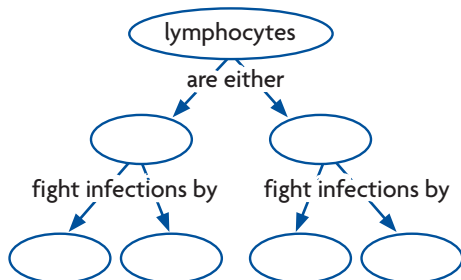


Chart Use a three-column chart to compare similar concepts.

Word	Definition	How It Is Differ- ent from Others
antigen		
allergen		
protein marker		

Chapter Assessment

Chapter Vocabulary

31.1 germ theory, p. 941
pathogen, p. 941
vector, p. 944

31.2 immune system, p. 945
phagocyte, p. 946
T cell, p. 946
B cell, p. 946
antibody, p. 947
interferon, p. 947
passive immunity, p. 948
active immunity, p. 948

31.3 inflammation, p. 950
antigen, p. 951
memory cell, p. 951
cellular immunity, p. 952
humoral immunity, p. 953
tissue rejection, p. 954

31.4 antiseptic, p. 955
antibiotic resistance, p. 955
vaccine, p. 956

31.5 allergy, p. 957
allergen, p. 957
anaphylaxis, p. 958

31.6 leukemia, p. 960
opportunistic infection, p. 961
human immunodeficiency virus (HIV), p. 961
acquired immune deficiency syndrome (AIDS), p. 963

Reviewing Vocabulary

Vocabulary Connections

For each group of words below, write a sentence or two to clearly explain how the terms are connected. For example, for the terms *HIV* and *AIDS*, you could write, “HIV weakens the immune system and leads to AIDS.”

1. pathogen, vector
2. T cells, B cells
3. antibody, antigen

Keep It Short

For each vocabulary term below, write a short, precise phrase that describes its meaning. For example, a short phrase to describe *leukemia* could be “cancer of the bone marrow.”

4. interferon
5. inflammation
6. cellular immunity
7. antiseptic

Greek and Latin Word Origins

8. The term *phagocyte* comes from the Greek word *phagos*, meaning “to eat.” Explain how this meaning relates to the word *phagocyte*.
9. The word *antibiotic* contains the prefix *anti-*, from a Greek word meaning “opposite,” and the Greek word *bios*, meaning “life.” Explain how, together, these meanings relate to the term *antibiotic resistance*.

Reviewing MAIN IDEAS

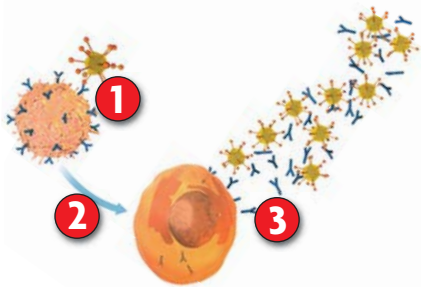
10. Why do Koch’s postulates and germ theory apply to infectious diseases but not noninfectious diseases?
11. What are some types of pathogens, and how do they attack the body? **10.d**
12. What are some ways that pathogens spread? **10.d**
13. How do other body systems help the immune system respond to infections? **10.a**
14. How do phagocytes, antibodies, and interferons help to fight pathogens? **10.b, 10.f***
15. How are passive immunity and active immunity similar and different? **10.f***
16. How does fever help to fight infections? **10.f***
17. How do specific immune responses lead to active immunity? **10.b, 10.f***
18. How might organ transplants, which are meant to save a person’s life, endanger the person? **10.b, 10.f***
19. People say, “Too much of a good thing can be bad.” How does this statement relate to the use of antibiotics? **10.d**
20. How does a vaccine produce active immunity without making a person sick? **10.c, 10.f***
21. How do autoimmune diseases disrupt homeostasis? **9.a**
22. How does leukemia weaken the immune system? **10.e**
23. What is the difference between HIV and AIDS? **10.e**

Critical Thinking

- 24. Apply** In 1918, scientists found a bacterium in the lungs of some people who died of flu. The bacteria were given to healthy volunteers, but only some volunteers developed flulike symptoms. Using germ theory, decide whether this bacterium caused flu. **10.d**
- 25. Connect** How does the evolution of pathogens, specifically bacteria and viruses, negatively affect humans' ability to stay healthy? **10.c, 10.d**
- 26. Synthesize** If you get stung by a bee, the skin around the bite will swell. Explain the process that produced the swelling. Use and define the terms *vector*, *allergen*, *inflammation*, and *white blood cell* in your answer.
- 27. Compare and Contrast** How can the humoral immune response both help and hurt the body? **10.b, 10.f***
- 28. Analyze** People infected with HIV are said to be HIV-positive because they have the antibodies for the virus. Why don't antibodies, which normally protect the body against pathogens, protect people who are HIV-positive from developing AIDS? **10.b, 10.e**
- 29. Explain** Summarize the process by which a vaccine helps the body fight off pathogens. Begin with what happens when a person gets vaccinated, and conclude with the destruction of the invading pathogen. **10.b, 10.e**
- 30. Infer** Compare the normal humoral immune response to the response after someone is vaccinated. Which steps of the humoral response probably take the longest, allowing the pathogen to make the body sick? **10.c**

Interpreting Visuals

Use the diagram below to answer the next three questions.



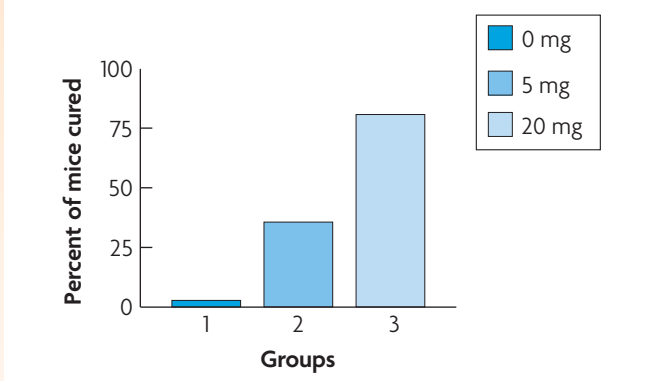
- 31. Summarize** What is happening in each numbered part of the process shown above? **10.b, 10.c**
- 32. Apply** Before this process could take place, one of two events must have occurred. What are the two events?
- 33. Analyze** What kind of immunity is shown here? **10.b**

Analyzing Data

Use the graph below to identify data flaws and answer the next two questions.

A researcher designs an experiment to determine what dose of a new antibiotic must be given to patients to kill the bacteria that cause pneumonia. The researcher infects three groups of mice with three different strands of pneumonia bacteria. Group 1 is not given any antibiotic. The researcher gives Groups 2 and 3 different doses of the antibiotic. The results are shown below.

MICE CURED WITH ANTIBIOTICS



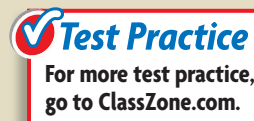
- 34. Analyze** Can the researcher conclude that the largest dose of antibiotic is necessary to cure pneumonia? Why or why not?
- 35. Evaluate** How could this investigation be redesigned to better answer the researcher's question?

Connecting CONCEPTS

- 36. Design a Video Game** Imagine that you are creating a video game in which the player can choose to be a T cell or a B cell. Describe the player's goals for each version of the game. How will the player direct the cells in their mission to seek out and destroy the invading pathogens?
- 37. Design an Experiment** One fall, children who live in a wooded area become ill. They develop an itchy rash, a hacking cough, and a sick feeling in their stomachs. One local doctor tells concerned parents that their children had an allergic reaction to something in the woods and advises that the children rest in bed. Another doctor thinks that a bacterium causes the sickness and prescribes medicine for the children. Design an experiment to determine who is correct. (**Hint:** What evidence do you need to prove a pathogen caused a disease?)



CALIFORNIA STANDARDS-BASED ASSESSMENT



1. In the 1850s, Louis Pasteur conducted many experiments and based on his results, proposed that specific microorganisms cause disease. This proposal is an example of a scientific **IE.1.f**

- A hypothesis.
- B guess.
- C theory.
- D experiment.

2.

Set Up for Chicken Pox Experiment		
Volunteer	Injected with Dead Chicken Pox Virus	Injected with Distilled Water
A	X	
B		X
C	X	X

A scientist studies three volunteers who never had chicken pox by injecting each with a dead virus, distilled water, or a combination of the two. The experimental design is described in the table above. After the injection, whose blood stream would *most* likely contain antibodies for the chicken pox virus? **10.c**

- A volunteer A only
- B volunteer B only
- C volunteers A and B
- D volunteers A and C

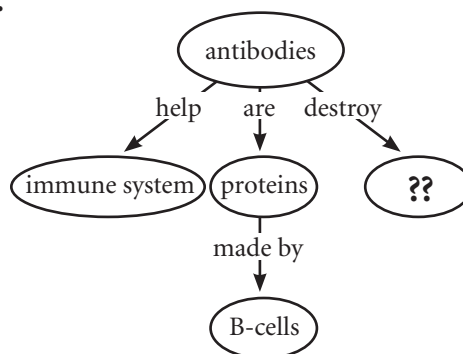
3. A person infected with HIV is more likely to become sick with other diseases because **10.e**

- A people infected with HIV must take drugs to suppress the immune system.
- B pathogens can enter the bodies of people infected with HIV during surgery.
- C HIV mutates quickly into other diseases that affect the immune system.
- D HIV attacks the cells that produce immune responses.

4. Mucous membranes and the skin are nonspecific defenses against infection. The functions of the skin in immunity are to block the entry of pathogens and to **10.a**

- A release white blood cells.
- B produce antibodies.
- C secrete sweat and oil.
- D activate active immunity.

5.



Which word *best* completes this concept map? **10.b**

- A white blood cells
- B red blood cells
- C pathogens
- D vectors

6. Some interferons stimulate noninfected cells to produce thick coats that prevent viruses from infecting the cells. Which statement *best* explains why interferons are effective against viruses but not bacteria? **10.d**

- A Bacteria are living microorganisms, but viruses are not.
- B Interferons affect viral DNA, but do not affect bacterial DNA.
- C Bacteria have a cell wall, but viruses only have a protein coat.
- D Viruses need to enter a cell to reproduce, but bacteria do not.

THINK THROUGH THE QUESTION

To answer this question, think about how bacteria and viruses are different. Which of these differences is related to the way interferons act?