Good health is something that you might take for granted—until you or someone close to you gets sick. Then, the value of good health becomes all too obvious. Why do you get sick? How do you get better? What is the best way for you to avoid getting sick in the first place? These are questions that people have been asking for centuries. Today, in most cases, these questions can be answered.

A disease is any change, other than an injury, that disrupts the normal functions of the body. Some diseases are produced by agents, such as bacteria, viruses, and fungi. Others are caused by materials in the environment, such as cigarette smoke. Still others, such as hemophilia, are inherited. Disease-causing agents are called pathogens, which means “sickness-makers.” Diseases caused by pathogens are generally called infectious diseases.

The Germ Theory of Disease

For thousands of years, people believed that diseases were caused by curses, evil spirits, or night vapors. In the mid-nineteenth century, a new explanation was put forth based on the work of the French chemist Louis Pasteur and the German bacteriologist Robert Koch. The observations of Pasteur and Koch led them to conclude that infectious diseases were caused by microorganisms of different types, commonly called germs. This idea is now known as the germ theory of disease.

The world is filled with microorganisms of every shape and description. How can scientists be sure that a particular organism causes a certain disease? In 1883, Allen Steere of Yale University had a chance to ask that question. In a small area of Connecticut, Steere found 39 children and several adults suffering from pain and joint inflammation. Their symptoms looked like a rare form of childhood arthritis. However, Steere thought that there were far too many cases of arthritis for such a small population. He looked for another explanation. The rural location of the outbreak and the fact that most of the cases had started in summer or early fall made Steere suspect, at first, that this could be an infectious disease carried by an insect.

Diseases can be inherited, caused by materials in the environment, or produced by pathogens. Certain species of ticks often carry bacteria or viruses, so their bites can transmit disease.

**Figure 40–1** Diseases can be inherited, caused by materials in the environment, or produced by pathogens. Certain species of ticks often carry bacteria or viruses, so their bites can transmit disease.

(magnification: about 30×)

**Guide for Reading**

**Key Concepts**
- What causes disease?
- How are infectious diseases transmitted?

**Vocabulary**
- disease
- pathogen
- germ theory of disease
- Koch’s postulates
- vector
- antibiotic

**Reading Strategy: Using Prior Knowledge**
Before you read, make a list of some of the diseases that you have had. As you read, determine which pathogen might have caused each disease.

**Objectives**

40.1.1 Identify the causes of disease.
40.1.2 Explain how infectious diseases are transmitted.
40.1.3 Describe how antibiotics fight infection.

**Vocabulary Preview**
Tell students that the term pathogen refers to an agent that causes disease. Ask: How do you think the term pathogen is related to the germ theory of disease? (Germ is another term for pathogen. According to the theory, germs, or pathogens, cause disease.)

**Reading Strategy**
Students are likely to list respiratory infections such as colds and flu and gastrointestinal infections that cause stomachaches and diarrhea. They should determine which pathogen might have caused each disease.

**Address Misconceptions**
Explain that some diseases have multiple causes. For example, some types of cancer, such as lung cancer, are caused by environmental factors, for example, cigarette smoke. Other types of cancer, such as cervical cancer, are caused by pathogens (for cervical cancer, human papilloma virus).

**Technology**
- iText, Section 40–1
- BioDetectives Videotapes, “Influenza: Tracking a Virus”; “Hantavirus: A Tale of Mice and People”
- Transparencies Plus, Section 40–1

**Demonstration**
Help students appreciate the importance of the germ theory of disease by showing them death rates by cause of death in the United States population for the late 1800s and also for a recent year. Then, ask: How did the number of deaths caused by infectious diseases change? (It fell dramatically.) Add that identifying germs as the cause of infectious diseases was the first step in bringing these diseases under control.
**Koch’s Postulates**

### Demonstration

Demonstrate the importance of using sterile techniques when applying Koch’s second postulate. Hold a wire loop in the flame of a Bunsen burner for a few seconds. Allow the loop to cool, dip it in a bacterial culture, and run it over sterile agar in a petri dish. **(CAUTION: Use a safe strain of bacteria, such as *E. coli*, from a scientific supply company, and apply sterile techniques to the handling of the bacterial culture.)** Sterilize the loop again, let it cool, and run it over sterile agar in a second petri dish. Incubate both dishes at 37°C for 24 hours, and then have students observe the differences in the agar. **(Bacteria should be visible growing in the first petri dish but not the second.)**

Ask: **Which step of the demonstration caused the different outcomes in the two petri dishes?** **(The re sterilization of the wire loop)** **How does this demonstration relate to Koch’s second postulate?** **(If you had been trying to isolate and grow a pathogen in the petri dishes, only the second dish would produce a pure culture. The first petri dish would have produced bacteria in addition to the pathogen.)**

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**Sure enough, many of the children reported that their problems began with what they thought was an insect bite. The bite was followed by an expanding skin rash. Steere called the infection Lyme disease after the town of Lyme, Connecticut, where it was first discovered. Steere and his colleagues were able to link the skin rash to the bite of the tiny deer tick (*Ixodes scapularis*). One of Steere’s colleagues, Dr. Willy Burgdorfer, found an unusual spiral-shaped bacterium (*Borrelia burgdorferi*) in the ticks. Steere found the same bacterium in patients with Lyme disease. Could this bacterium be the cause of Lyme disease?**

For ethical reasons, Steere did not try to infect healthy children with the bacterium. However, when the bacterium was injected into laboratory mice, they developed arthritis and other symptoms, just as the children had. From the sick mice, Steere recovered the bacteria, which were then injected into healthy mice. The healthy mice then developed the disease. Steere and his colleagues had found the organism that caused Lyme disease. The process Steere used is shown in **Figure 40–2.**

### Koch’s Postulates

The groundwork for Allen Steere’s work with Lyme disease was actually laid more than a hundred years earlier by Robert Koch. From his studies with various bacteria, Koch developed a series of rules still used today to identify the microorganism that causes a specific disease. These rules are known as **Koch’s postulates.** Koch’s postulates can be stated as follows:

1. The pathogen should always be found in the body of a sick organism and should not be found in a healthy one.
2. The pathogen must be isolated and grown in the laboratory in pure culture.
3. When the cultured pathogens are placed in a new host, they should cause the same disease that infected the original host.
4. The injected pathogen should be isolated from the second host. It should be identical to the original pathogen.

Why are these rules important? Because identifying pathogens that cause disease is the first step toward preventing or curing the ailments they produce.
Agents of Disease

For many pathogens, the human body provides just the right conditions for growth—a suitable body temperature, a watery environment, and an abundance of nutrients. The large intestine, for example, harbors dense colonies of bacteria that help in the process of digestion. Bacteria and yeast are also found in the mouth and throat. Fortunately, most of these organisms are harmless, and many are actually beneficial.

If this is true, then exactly how do pathogens cause disease? Some pathogens, including viruses and some bacteria, destroy cells as they grow. Other bacteria release toxins that harm an organism. Still others, especially parasitic worms, produce sickness when they block the flow of blood, remove nutrients from the digestive system, and disrupt other bodily functions. The *Ascaris* worm in Figure 40–3 is a parasitic worm.

**Viruses** Viruses are tiny particles that invade and replicate within living cells. Viruses attach to the surface of a cell, insert their genetic material in the form of RNA or DNA, and take over many of the functions of the host cell. Viruses can infect nearly every type of organism—including plants, animals, and bacteria. Diseases caused by viruses include the common cold, influenza, smallpox, and warts.

**Bacteria** Most bacteria are harmless to humans. Unfortunately, the few that do cause serious diseases. Bacteria cause disease in one of two ways—either by breaking down the tissues of the infected organism for food or by releasing toxins that harm the body. Bacterial diseases include streptococcus infections, diphtheria, botulism, and anthrax.

**Protists** You may not associate protists with disease, but a protist causes what may be the single most damaging infectious disease afflicting humans—malaria. Malaria is caused by *Plasmodium*, a protist that is spread from person to person by mosquitoes. Insects also spread another protist known as *Trypanosoma*. *Trypanosoma* protists live in the bloodstream of vertebrate animals. The protist feeds off the nutrients in the host organism’s blood. *Trypanosoma* causes African sleeping sickness. Contaminated water supplies are responsible for amebic dysentery, a serious infection caused by the protist *Entamoeba*.

**Worms** Flatworms and roundworms are also responsible for a number of serious human diseases. People in many tropical regions of the world can become infected by a parasitic flatworm known as *Schistosoma*. These flatworms live part of their lives in snails and then leave the snails to enter the fresh water of streams and rice paddies. *Schistosoma* worms frequently infect people working in rice fields. Other parasitic worms that infect humans include tapeworms and hookworms.

What are three diseases caused by protists?

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**FACTS AND FIGURES**

All about tetanus

Although tetanus was described by Hippocrates 2400 years ago, its prevalence has been masked because it strikes individuals and does not cause epidemics. The organism that causes tetanus, the bacillus *Clostridium tetani*, is found mainly in soil. It can enter the body through any break in the skin, from a superficial scratch to a puncture wound. Because *C. tetani* is anaerobic, it grows best in deeper tissues, so puncture wounds are especially prone to developing tetanus infections. The bacterium produces one of the most powerful toxins known. It affects the nervous system and causes painful muscle contractions, especially in the muscles of the neck, jaw, and thorax. It frequently leads to death. Fortunately, tetanus can be prevented with a vaccine.

Answers to . . .

*Checkpoint* Malaria, African sleeping sickness, and amebic dysentery

**Figure 40–2** To make sure that only the suspected pathogen has been transferred to the new host
How Diseases Are Spread

Build Science Skills

Designing Experiments Challenge students to design an experiment to measure the effects of frequent hand-washing on the transmission of infectious diseases such as the common cold. Each experimental design should include a clearly stated research question, a description of the variables to be tested and how they will be measured, and an explanation of how other variables will be controlled.  

Make Connections

Environmental Science List some vector-borne diseases found in the United States and the vectors that spread them, such as Rocky Mountain spotted fever, which is spread by ticks, and encephalitis, which is spread by mosquitoes. Ask: What are some ways you could reduce the spread of these diseases? (Students are likely to say by eliminating the vectors, for example, by spraying with pesticides, or by avoiding contact with the vectors, for example, by wearing protective clothing.) Are there any drawbacks to these approaches? (Unless pesticides are pathogen-specific, they can harm other organisms.)

How Diseases Are Spread

Infectious diseases can be transmitted in a number of ways. Some infectious diseases are spread from one person to another through coughing, sneezing, or physical contact. Other infectious diseases are spread through contaminated water or food. Still others are spread by infected animals.

Physical Contact Some infectious diseases can be spread by direct physical contact. For example, a disease may be transmitted when a healthy person touches a person with a disease. Some of the most dangerous pathogens are spread from one person to another by sexual contact.

Most diseases are spread by indirect contact. For example, some pathogens can be carried through the air. If a person with a cold or virus coughs or sneezes, thousands of droplets are released, as shown in Figure 40–4. The pathogens can also settle on objects. If you touch those objects, the pathogens can be transferred to your hands, and you can infect yourself by touching your mouth or nose.

Some behaviors can help to control transmission of diseases spread by physical contact. Simple measures, such as covering your mouth with a tissue when you cough, can limit the spread of infection. Washing your hands thoroughly and often also helps to prevent the spread of many pathogens.

Contaminated Food and Water Have you ever had food poisoning? Food poisoning is caused by eating food that contains pathogens. Bacteria are always present in uncooked meat. Bacteria also grow quickly in warm, partially cooked food. If food is cooked thoroughly, the risk of food poisoning due to contamination may be reduced. Contaminated water also causes disease, especially in parts of the world with poor sanitation and untreated sewage.

Infected Animals Animals, such as the mosquito shown in Figure 40–5, also spread infectious disease. Animals that carry pathogens from person to person are called vectors. Malaria, Lyme disease, West Nile virus, and rabies are diseases carried by vectors. Avoiding tall grass and wooded areas where deer and field mice dwell will limit your exposure to ticks that carry Lyme disease. Staying away from wild animals can reduce your risk of being bitten by a rabid animal.

Fungi Most fungi are harmless, but a few are capable of causing serious problems. One genus of fungi, Tinea, is particularly adept at penetrating the outer layers of skin. When it attacks the skin between the toes it produces the infection known as athlete’s foot. The same fungus can infect the scalp, where it results in rough, scaly patches known as ringworm. Other types of fungi infect the mouth, the throat, and even the fingernails and toenails.

The black death

Bubonic plague—or the black death, as it was referred to in the Middle Ages—is caused by a bacillus, Yersinia pestis, that is transmitted by fleas. Y. pestis is usually spread among wild rodent populations, but it can also spread to other mammals, including humans. Huge epidemics of bubonic plague have afflicted human populations throughout history. For example, in the mid-1300s, bubonic plague swept across Europe and killed roughly a quarter of the human population. Between 1890 and 1930, more than 13 million people worldwide died of plague. Most people are surprised to learn that plague is still present today in wild rodent populations in many areas of the world, including some parts of the United States, and that local outbreaks of plague occasionally occur in human populations. Fortunately, the disease now can be treated successfully with antibiotics.
Fighting Infectious Diseases

Because prevention isn’t always possible, drugs have been developed for use against some types of pathogens. Antibiotics are perhaps the most useful single class of infection-fighting drugs. Antibiotics are compounds that kill bacteria without harming the cells of the human or animal hosts. Antibiotics work by interfering with the cellular processes of microorganisms.

Discovery of Antibiotics   Many antibiotics are produced naturally by living organisms. Other antibiotics are synthetic. One antibiotic, penicillin, was discovered accidentally in 1928 by the Scottish bacteriologist Alexander Fleming. Fleming had been growing _Staphylococcus_ bacteria in a culture dish. One day, he noticed that the culture of bacteria had been contaminated by a species of green mold called _Penicillium notatum_. On closer observation, Fleming saw something surprising. The bacteria were not growing near the mold. Something produced by the mold was apparently inhibiting their growth. Later, researchers discovered that penicillin—the name Fleming gave the antibiotic—interferes with the growth of bacteria.

Antibiotics have no effect on viruses. However, antiviral drugs have been developed to fight certain viral diseases. These drugs generally inhibit the ability of viruses to invade cells and to multiply once inside cells.

Over-the-Counter Drugs You probably know that you can buy many medicines without a prescription. These medicines, called over-the-counter drugs, treat only the symptoms of the disease—including cough, congestion, and fever. These medicines help you feel better, but they do not actually treat the cause of the infection. The best treatment for most infections includes rest, a well-balanced diet, and plenty of fluids.

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Section 40–2

1 FOCUS

Objectives
40.2.1 Identify the body’s nonspecific defenses against invading pathogens.
40.2.2 Describe the function of the immune system.

Vocabulary Preview

Explain that immunity means resistance to infection. Then, challenge students to fill in the blanks in the following statements with the correct Vocabulary terms containing the word immunity. Immune response outside cells, involving antibodies, is called _____ immunity. (humoral) Immunity involving killer T cells is called _____ immunity. (cell-mediated) When the body is injected with antibodies, it is called _____ immunity. (passive) When the body makes antibodies in response to an antigen, it is called _____ immunity. (active) After students read the section, they should check to see if their answers were correct.

Reading Strategy

Have students preview the section by studying the figures and reading the captions.

2 INSTRUCT

Nonspecific Defenses

Build Science Skills

Applying Concepts Ask: If you eat food that contains bacteria, which nonspecific defenses will help protect your body from illness? (Lysozyme in saliva and stomach acid and digestive enzymes in the stomach)

40–2 The Immune System

W ith pathogens all around us, it might seem like a miracle that you aren’t sick all of the time. There’s a reason, of course, why most of us enjoy good health. Our bodies have a protective system—a series of defenses that guard against disease.

The immune system is the body’s main defense against pathogens. The immune system recognizes, attacks, destroys, and “remembers” each type of pathogen that enters the body. It does this by producing specialized cells that inactivate pathogens. For each kind of pathogen, the immune system produces cells that are specific to that pathogen. The function of the immune system is to fight infection through the production of cells that inactivate foreign substances or cells. This process is called immunity.

The immune system includes two general categories of defense mechanisms against infection: nonspecific defenses and specific defenses. Nonspecific defenses are like the fortress walls of the system. They guard against infections by keeping most things out of the body. Specific defenses work like security guards. They track down harmful pathogens that have managed to break through the body’s nonspecific defenses.

Nonspecific Defenses

Nonspecific defenses do not discriminate between one threat and another. These defenses include physical and chemical barriers.

First Line of Defense The function of the first line of defense is to keep pathogens out of the body. This role is carried out by skin, mucus, sweat, and tears. Your body’s most important nonspecific defense is the skin. Very few pathogens can penetrate the layers of dead cells at the skin’s surface. The importance of the skin as a barrier against infection becomes obvious as soon as the skin is broken. When that happens, pathogens can enter your body and multiply. As they grow, they cause the symptoms of an infection, such as swelling, redness, and pain.

Many secretions of the body, including mucus, saliva, and tears, contain lysozyme, an enzyme that breaks down the cell walls of many bacteria. In addition, oil and sweat glands in the skin produce an acidic environment that kills many bacteria.

Figure 40–6 The immune system fights infection. The production of mucus is one of your body’s defenses. Pathogens can get trapped in mucus the way the long brown strand of dirt shown in the micrograph is trapped.

Print:
• Laboratory Manual B, Chapter 40 Lab
• Teaching Resources, Section Review 40–2, Chapter 40 Real-World Lab
• Reading and Study Workbook A, Section 40–2
• Adapted Reading and Study Workbook B, Section 40–2
• Lesson Plans, Section 40–2

Technology:
• iText, Section 40–2
• Animated Biological Concepts Videotape Library, 44 Inflammatory Response, 45 Humoral Immunity, 46 Cell-Mediated Immunity
• Transparencies Plus, Section 40–2
Demonstration
Use a microprojector and a drop of pond water on a slide to show students how amoebas feed. Point out the amoebas on the slide. As students watch their activity, ask: What do amoebas do to consume their prey? (They engulf, or surround, their prey.) Explain that phagocytes engulf bacteria and other pathogens in the same way. L1 L2

Make Connections
Health Science Explain that since interferons were discovered in 1957, doctors have been excited about the possibility of using them to prevent disease. In 1980, an interferon became the first biopharmaceutical to be successfully mass-produced using genetic engineering. Mass production made interferons available for research and clinical purposes. Challenge interested students to find out the results of interferon research since 1980 and report to the class on what they learn. (Students will find that interferons show promise against many viral diseases and some cancers.) L2 L3

Pathogens can also enter your body through other body openings, including your mouth and nose. Your body has other nonspecific defenses that protect these openings. Mucus in your nose and throat helps to trap pathogens. The cilia that line your nose and throat help to push pathogens away from your lungs. Stomach acid and digestive enzymes destroy many pathogens that make their way to your stomach.

Second Line of Defense If pathogens do manage to enter your body, they may multiply quickly, releasing toxins into your tissues. When this happens, the inflammatory response—a second line of defense—is activated. The inflammatory response is a nonspecific defense reaction to tissue damage caused by injury or infection. When pathogens are detected, the immune system produces millions of white blood cells, which fight the infection. Blood vessels near the wound expand, and white blood cells move from the vessels to enter the infected tissues. Many of these white blood cells are phagocytes, which engulf and destroy bacteria. The infected tissue may become swollen and painful. The inflammatory response is summarized in Figure 40–7.

The immune system also releases chemicals that increase the core body temperature. You may have experienced this elevated body temperature, called a fever. The increased body temperature is advantageous because many pathogens can survive only within a narrow temperature range. An elevated temperature slows down or stops the growth of such pathogens. The higher body temperature also increases the heart rate so that the white blood cells get to the site of infection faster. Physicians know that a fever and an increased number of white blood cells are two indications that the body is hard at work fighting infection. What is the role of phagocytes in the inflammatory response?

Second Line of Defense
If pathogens do manage to enter your body, they may multiply quickly, releasing toxins into your tissues. When this happens, the inflammatory response—a second line of defense—is activated.

Word Origins
Phagocyte comes from the Greek phag, meaning “eat,” and kutos, meaning “cell.” Thus, a phagocyte is a cell that eats or engulfs. If the Greek prefix macro- means “large,” what might the word macrophage mean?

Differentiated Instruction - Solutions for All Learners
Inclusion/Special Needs
The material in this section may be difficult for some students to understand. Encourage them to focus mainly on the figures and captions. Name the processes that are illustrated in Figures 40–7 through 40–10. For each figure, describe the process, and have students follow through the diagram and read the labels as you do. Urge students to ask questions about each process as you describe it. L1

Advanced Learners
Have students who are gifted writers create a story about nonspecific defenses. Their stories should take the point of view of a pathogen and correctly portray the action and order of the nonspecific defenses the pathogen must overcome when it enters the body. Urge students to read their work to the class. Have other students identify the nonspecific defenses as they are described in the stories. L3

Answer to . . .
Phagocytes engulf and destroy bacteria.
Specific Defenses

Use Visuals

Figure 40–8 Point out that the drawings are greatly simplified abstractions of what are in reality complex molecules. Make sure students realize that the drawing on the right is just an enlargement of the drawing on the left with the antigens removed, making the antigen-binding sites easier to see.

Demonstration

Demonstrate to students how the immune system responds to specific pathogens. Select ten student volunteers. Have the students use poster board, string, scissors, and markers to make five signs (attached to string so they can be worn around the neck) labeled: Whooping Cough, Strep Throat, Bacterial Pneumonia, Diphtheria, and Tetanus. Also have the students cut five squares of poster board in half, each one in a different way so that it forms two unique pieces that fit together like pieces of a jigsaw puzzle but that do not fit with any of the other pieces. Then, assign five of the students to wear the signs and play the roles of bacteria. Give each of them one half of a puzzle, and have them line up at the back of the room. Assign the remaining five students to be B cells, give them the other halves of the puzzles, and have them line up at the front of the room. Finally, tell the bacteria to “invade” the room and the B cells to “attack” the bacterium that has the matching puzzle piece. When a B cell finds the bacterium that is its match, both should sit down. After the last pair sits down, ask: What do the puzzle pieces carried by the “bacteria” represent? (Antigens) What do the puzzle pieces carried by the “B cells” represent? (Antibodies)

Interferon When viruses enter the body, the body sometimes reacts in a different way. Sometimes, virus-infected cells produce a group of proteins that help other cells resist viral infection. Scientists named these proteins interferons because they “interfere” with the growth of the virus. Interferons inhibit the synthesis of viral proteins in infected cells and help block viral replication. This process slows down the progress of infection and often gives the specific defenses of the immune system time to respond.

Specific Defenses

If a pathogen is able to get past the body’s nonspecific defenses, the immune system reacts with a series of specific defenses that attack the particular disease-causing agent. These defenses are called the immune response. A substance that triggers this response is known as an antigen. Viruses, bacteria, and other pathogens may serve as antigens.

The cells of the immune system that recognize specific antigens are two types of lymphocytes: B lymphocytes (B cells) and T lymphocytes (T cells). B cells provide immunity against antigens and pathogens in the body fluids. This process is called humoral immunity. T cells provide a defense against abnormal cells and pathogens inside living cells. This process is called cell-mediated immunity.

Humoral Immunity When a pathogen invades the body, its antigens are recognized by a small fraction of the body’s B cells. These B cells grow and divide rapidly, producing large numbers of plasma cells and memory B cells.

Plasma cells release antibodies. Antibodies are proteins that recognize and bind to antigens. The antibodies are carried in the bloodstream to attack the pathogen that is causing the infection. As the antibodies overcome the infection, the plasma cells die out and stop producing antibodies.

Once the body has been exposed to a pathogen, millions of memory B cells remain capable of producing antibodies specific to that pathogen. These memory B cells greatly reduce the chance that the disease could develop a second time. If the same antigen enters the body a second time, a secondary response occurs. The memory B cells divide rapidly, forming new plasma cells. The plasma cells produce the specific antibodies needed to destroy the pathogen.

Antibody Structure As shown in Figure 40–8, an antibody molecule has two identical antigen-binding sites. It is at these sites that one or two specific antigens bind to the antibody. Applying Concepts: How do antibodies help in the immune response?

- They can see how the design compares with the “real thing.” This activity helps students anticipate the complexity of specific defense cells before they actually read about them.
Make Connections

Chemistry Explain that the stem of each Y-shaped antibody is essentially the same but the end of each arm has a region that is unique. In this area, two polypeptide chains are folded to form a groovelike cavity that is complementary to the contour and electric charge of a particular antigen. Ask: How do these differences in the antigen-binding sites of antibodies occur? (The genes that code for the two polypeptide chains rearrange themselves in slightly different ways in each B cell.)

Use Visuals

Figure 40–9 Have students follow the flowchart as you read the captions, starting with the first step and ending with the last. Make sure students can identify the cells involved in each step.

FACTS AND FIGURES

**Phagocyte power**
Phagocytes develop from stem cells in bone marrow. Types of phagocytes include neutrophils, eosinophils, and monocytes, which mature into macrophages. Phagocytes are drawn by altered chemical gradients into an area of damaged or invaded tissues. There, they engulf and destroy pathogens and other foreign substances by endocytosis. In endocytosis, the plasma membrane of the phagocyte encloses the pathogen at or near the cell surface of the phagocyte. Then, the membrane pinches off to form a closed endocytic vesicle around the pathogen. The endocytic vesicle provides a “traveling compartment” that enables the pathogen to be transported into the cytoplasm of the phagocyte. Once inside the cytoplasm, the endocytic vesicle fuses with lysosomes, and the pathogen is destroyed.

Answer to . . .

Figure 40–8 By binding to antigens on the surfaces of pathogens and linking pathogens together in a large mass, which attracts phagocytes and makes engulfment easier.
Use Visuals

Figure 40–10 Check students’ comprehension of the flowchart by asking: What causes a T cell to become a helper T cell? (Activation by a macrophage) What causes a killer T cell to attack the infected cell? (Activation by a helper T cell)

Build Science Skills

Applying Concepts Point out that cell-mediated immunity is particularly important for diseases caused by eukaryotic pathogens. Ask: Which pathogens are eukaryotic, and what are some of the diseases they cause? (Protists, fungi, and worms are eukaryotic pathogens. Some of the diseases they cause include malaria, beef tapeworm, and athlete’s foot.)

Cell-Mediated Immunity The body’s primary defense against its own cells when they have become cancerous or infected by viruses is known as cell-mediated immunity. Cell-mediated immunity is also important in fighting infection caused by fungi and protists. When viruses or other pathogens get inside living cells, antibodies alone cannot destroy them.

During cell-mediated immunity, T cells divide and differentiate into killer T cells (cytotoxic T cells), helper T cells, suppressor T cells, and memory T cells. Killer T cells track down and destroy the bacteria, fungi, protozoan, or foreign tissue that contains the antigen. Helper T cells produce memory T cells. The memory T cells, like the memory B cells, will cause a secondary response if the same antigen enters the body again. As the pathogenic cells are brought under control, suppressor T cells release substances that shut down the killer T cells. The process of cell-mediated immunity is summarized in Figure 40–10.

Transplants Although killer T cells are helpful in the immune system, they make the acceptance of organ transplants difficult. Body cells have marker proteins on their surfaces that allow the immune system to recognize the cells. If an organ was going to be transplanted into your body, your immune system would recognize the transported organ as foreign and attack it. Your immune system damages and destroys the transplanted organ. This process is known as rejection. To prevent organ rejection, doctors search for a donor whose cell markers are nearly identical to the cell markers of the recipient. Recipients must take drugs—usually for the rest of their lives—to suppress the cell-mediated immune response.

Figure 40–10 During the cell-mediated immune response, T cells provide defense against abnormal cells and pathogens inside living cells. The yellow objects in the scanning electron micrograph are killer T cells attacking a cancer cell. Comparing and Contrasting How are humoral immunity and cell-mediated immunity similar? How are they different?

Cells that eat cells

A significant step in understanding the immune system came in 1883 with the work of Elie Metchnikoff. The Russian biologist was researching the cause of inflammation in animals, using sea star larvae as research subjects because they have transparent bodies that allow for clear observation of internal processes. Wondering how the organism’s cells would react to a foreign body, Metchnikoff plucked a thorn from one of the roses in his rose garden and plunged it into a larva. A day later, he noticed the thorn was surrounded by a swarm of cells. Through further study, he identified similar cells in humans, specifically the white blood cells in pus. He recognized that these cells are able to digest foreign particles, and he named the cells phagocytes, from the Greek words meaning “to eat” and “cells.”
How does cell-mediated immunity work?

**Materials** 3 red balloons; 3 yellow balloons; 3 light-blue balloons; red, purple, and light-blue adhesive notes; toothpick

**Procedure**
1. Partially inflate and tie the balloons. The balloons represent pathogens. The different colors represent different surface antigens. Put the inflated balloons on the table.
2. The adhesive notes represent antibodies that can bind to antigens on the surface of a pathogen of the same color. Use the adhesive notes to model the binding of antibodies to antigens on pathogens.
3. The toothpick represents a killer T cell. Use the toothpick to burst any balloons marked by adhesive notes.

**Analyze and Conclude**
1. Using Models How did you model the binding of antibodies to matching antigens in step 2?
2. Using Models What signals a killer T cell to attack a pathogen?
3. Using Models What do the yellow balloons and purple adhesive notes represent in the model?

**Acquired Immunity**

More than 200 years ago, the English physician Edward Jenner wondered if it might be possible to produce immunity against one of the deadliest diseases of the day—smallpox. Jenner knew that a mild disease called cowpox was often contracted by milkmaids. Jenner observed that the milkmaids who contracted cowpox developed an immunity to smallpox. Was there a way, he wondered, to deliberately infect people with cowpox and thus protect them from getting the more serious disease of smallpox?

To answer this question, Jenner took fluid from one of the sores of a cowpox patient and put the fluid into a small cut that he made on the arm of a young farm boy named Jamie Phipps. As expected, Jamie developed a mild cowpox infection. Two months later, Jenner performed a daring experiment. He injected Jamie with fluid from a smallpox infection. Fortunately for Jamie, the experiment was a success—the boy did not develop smallpox. His cowpox infection had made him immune to smallpox.

**Active Immunity** The injection of a weakened form of a pathogen to produce immunity is known as a vaccination. *Vaccin* is the Latin word for “cow,” reflecting the history of Jenner's first vaccination experiment. Today, more than 20 serious human diseases can be prevented by vaccination. Like early vaccines, modern vaccines stimulate the immune system to create millions of plasma cells ready to produce specific types of antibodies.

**Facts and Figures**

**So many flu strains, so little time**
Influenza, or flu, is caused by an airborne virus. It occurs in periodic epidemics, which sometimes have a high death toll. For example, a 1968 flu epidemic killed almost 700,000 people worldwide in just six weeks. Scientists have developed fairly effective flu vaccines, but it takes at least six months to prepare a vaccine once the particular strain of flu virus is isolated. Mutations occur frequently in the flu virus, and new strains appear every couple of years, so scientists cannot predict for certain which strain of flu virus will strike in a given year. Therefore, a vaccine that is effective against one year’s strain of flu virus may prove useless against the next year’s strain.

**Answers to . . .**

Immunity in which killer T cells destroy infected cells

**Figure 40–10** Both are specific defenses. In humoral immunity, B cells produce antibodies against the pathogen. In cell-mediated immunity, killer T cells attack infected cells.


**40–2 (continued)**

**Build Science Skills**

**Inferring** Ask: Why does passive immunity last for only a few weeks or months? (Passive immunity occurs when antibodies are injected into the blood or ingested in milk. Because antigens are not included with the antibodies, the immune system does not “learn” how to make the antibody. Once the antibodies are destroyed, the person is no longer immune.)

**3 ASSESS**

**Evaluate Understanding**

Have students make a concept map entitled “Defenses Against Pathogens,” using the following terms: non-specific defenses, specific defenses, humoral immunity, cell-mediated immunity, first-line defenses, and second-line defenses.

**Reteach**

Play a quiz game in which you read definitions of the Vocabulary terms and student contestants try to identify the terms from the definitions.

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**40–2 Section Assessment**

1. **Key Concept** Describe the body’s nonspecific defenses against pathogens.
2. **Key Concept** Describe the function of the immune system.
3. How do interferons protect the body against viruses?
4. How are antigens related to antibodies?
5. **Critical Thinking Comparing and Contrasting** How are active and passive immunity similar? How are they different?

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**Conducting a Debate**

Getting vaccinated is much safer than getting the disease that the vaccine prevents. However, like any drug, vaccines are capable of causing serious problems. Interview five people about their thoughts on vaccinations. As a class, arrange a debate that addresses both the benefits and risks of vaccinations.

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**40–2 Section Assessment**

1. Unbroken skin is a barrier to pathogens. If pathogens penetrate the skin, they cause an inflammatory response. Pathogens that enter through the mouth or nose are trapped in mucus, or attacked by lysozyme, digestive enzymes, and stomach acid. Viruses trigger the production of interferons.
2. To protect the body against pathogens
3. Interferons inhibit the progress of viral infections, which may give specific defenses time to respond.
4. An antigen is a substance on the surface of a pathogen that triggers an immune response. Antibodies are molecules that are custom-made to bind to specific antigens.
5. They both provide antibodies against a specific pathogen. Active immunity is often permanent; passive immunity is temporary.

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**Figure 40–11** Vaccines stimulate the immune system to produce plasma cells. **Applying Concepts** What type of immunity do vaccines produce?

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**Figure 40–11** Active immunity

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**You & Your Community**

Students should find that medical professionals and public health officials strongly support vaccinations because they prevent epidemic outbreaks of disease and prevent deaths. However, vaccinations cause side effects in a number of people. For this reason, some people do not think vaccinations should be mandatory. Assign several students to represent each viewpoint. Assign a moderator and a timekeeper to ensure that each side has the same amount of time to present its views.

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If your class subscribes to the iText, use it to review the Key Concepts in Section 40–2.
40–3 Immune System Disorders

Although the immune system defends the body from a wide range of pathogens, sometimes disorders occur in the immune system itself. There are three different types of disorders. These disorders include allergies, autoimmune diseases, and immunodeficiency diseases.

Allergies

The most common overreactions of the immune system to antigens are known as allergies. Common allergies include those to pollen, dust, mold, and bee stings. Antigens that cause allergic reactions are called allergens. Some common allergens are shown in Figure 40–12.

When allergy-causing antigens enter the body, they attach themselves to mast cells. Mast cells are specialized immune system cells that initiate the inflammatory response. The activated mast cells release chemicals known as histamines. Histamines increase the flow of blood and fluids to the surrounding area. They also increase mucus production in the respiratory system. The increased mucus production brings on the sneezing, watery eyes, runny nose, and other irritations that make a person with allergies so uncomfortable. If you have allergies, you may have taken antihistamines. Antihistamines are drugs that are used to counteract the effects of histamines.

Figure 40–12 Common allergens include ragweed pollen, dust, and dust mites. In the SEM of the dust ball, notice the insect parts, gray spider webbing, and other dirt. Dust mites live in furniture, mattresses, and even pillows. Inferring Why do you think it is recommended that people wash their bed coverings in hot water?
Chapter 40

Autoimmune Diseases

Make Connections

Health Science  Point out that there are many autoimmune diseases in addition to those listed in the text. Another relatively common example is systemic lupus erythematosus (SLE). In this disease, the immune system attacks normal connective tissue, and this leads to inflammation and pain in the joints, among other symptoms.

Asthma

Use Community Resources

Arrange to have a nurse, physician’s assistant, or other medical professional visit the class. Ask the visitor to explain the various causes of asthma as well as the different types of medications used to treat asthma. Encourage students to ask any questions they might have.

Vocabulary: Word Analysis

Beginning  Write disease and antibiotic on the board. Then, rewrite each word as a separate prefix and base, i.e., dis- and ease, and anti- and biotic. Explain that the two prefixes, dis- and anti-, can have similar meanings; they can mean “against,” or “opposing.” Explain that ease can mean “comfort” or “wellness,” and that disease is the opposite of comfort or wellness. Similarly, biotic comes from a word meaning “life,” and an antibiotic acts against harmful living things, specifically bacteria. Discuss other words with these prefixes, such as disagree, discomfort, and antifreeze.

Intermediate  After the beginning-level activity, have the students form a collaborative writing group to write sentences using each term. Have a volunteer from the group read the sentences.

Asthma

Some allergic reactions can create a dangerous condition called asthma. Asthma is a chronic respiratory disease in which the air passages become narrower than normal. This narrowing of the air passages causes wheezing, coughing, and difficulty in breathing. Many factors, including both heredity and environment, play a role in the onset of the symptoms of asthma.

Asthma is a leading cause of serious illness among children, and can be a life-threatening disease. If treatment is not started early enough or if medications are not taken properly, asthma can lead to permanent damage or destruction of lung tissue.

Asthma attacks can be triggered by respiratory infections, exercise, emotional stress, and certain medications. Other triggers include cold air, pollen, dust, tobacco smoke, pollution, molds, and pet dander.

There is no cure for asthma; however, people who have asthma can sometimes control the condition. If the attacks are caused by an allergy, a series of tests can identify what substances cause the problem. Medications are sometimes used to relieve the symptoms of asthma. Often, these medications relax the smooth muscles around the airways, making breathing easier.

ESL SUPPORT FOR ENGLISH LANGUAGE LEARNERS

CHECKPOINT  What happens in the lungs during an asthma attack?

Asthma

Figure 40–13  When the immune system makes a mistake and attacks the body’s own cells, it produces an autoimmune disease. Multiple sclerosis is one example of an autoimmune disease in which axons in the optic nerve, brain, or spinal cord are affected. Symptoms of multiple sclerosis include problems with balance and motor coordination.

Autoimmune Diseases

The immune system could not defend your body against a host of invading pathogens unless it was able to distinguish those pathogens from the cells and tissues that are part of your body. In other words, the immune system usually has the ability to distinguish “self” from “nonself.” When the immune system makes a mistake and attacks the body’s own cells, it produces an autoimmune disease. In an autoimmune disease, the immune system produces “antiself” antibodies.

Some examples of autoimmune diseases include Type I diabetes, rheumatoid arthritis, myasthenia gravis, and multiple sclerosis (MS). In Type I diabetes, antibodies attack the insulin-producing cells of the pancreas. In rheumatoid arthritis, antibodies attack connective tissues around the joints. In myasthenia gravis, antibodies attack neuromuscular junctions. Multiple sclerosis is an autoimmune disease in which antibodies destroy the functions of the neurons in the brain and spinal cord.

Some autoimmune diseases are treated with medications that alleviate specific symptoms. For example, people who have Type I diabetes can be given insulin injections. Other autoimmune diseases are treated with medications that suppress the immune response. However, these medications also affect the normal immune response against pathogens, so this type of therapy is not used often or is carefully monitored. As researchers find out more about autoimmune diseases, they hope to develop more effective treatments.
AIDS, an Immunodeficiency Disease

Another type of immune system disorder is immunodeficiency disease. In one type of immunodeficiency disease, the immune system fails to develop normally. A second type of immunodeficiency disease is AIDS. AIDS results from a viral infection that destroys helper T cells. As the number of helper T cells declines, the normal immune response breaks down.

During the late 1970s, some physicians in Europe and the United States were bewildered. Some of their patients were dying from infections produced by microorganisms that didn’t normally cause disease. Previously healthy people began to suffer from unusual illnesses such as *Pneumocystis carinii* (a kind of pneumonia), Kaposi’s sarcoma (a rare form of skin cancer), and severe fungal infections of the mouth and throat. Normally, such infections are prevented by the immune system. Individual doctors realized that the symptoms were a signal that the immune systems of their patients had been weakened.

Some doctors recognized that these illnesses were actually symptoms of a new disease. Doctors in Los Angeles suggested the name AIDS—for acquired immune deficiency syndrome. As more cases appeared, researchers realized that this “syndrome” was actually an infectious disease caused by a pathogen that was unknown to the scientific community.

**The Virus That Causes AIDS** In 1983, researchers identified the cause of AIDS—a virus that they named HIV for human immunodeficiency virus. HIV is a retrovirus—a virus that carries its genetic information in RNA, rather than DNA. HIV turned out to be a deadly and efficient virus for two reasons. First, HIV evades the defenses of the immune system. Second, HIV attacks key cells in the immune system, destroying the body’s defenses and leaving the body with no protection against other pathogens.

Among HIV’s main targets are the helper T cells. When the HIV virus attacks a helper T cell, it attaches to receptor molecules on the cell membrane. This allows the virus to enter the cell, as shown in Figure 40–14. Once the viral core is inside the cell, it forces the host cell to make DNA copies of the virus’s RNA. Some of those copies insert themselves into host cell DNA and stay there permanently. Other copies remain in the cytoplasm. The viral DNA may remain inactive in the host cell for varying periods of time. When activated, it directs the production of new viral RNA and proteins that are assembled into new virus particles. These viruses eventually leave the infected cell and infect new cells. The immune system produces antibodies for HIV. Unfortunately, these antibodies are not effective in stopping the progression of the disease.

Despite the production of antibodies, HIV destroys ever-increasing numbers of T cells, crippling the immune system. By counting the number of the helper T cells, the progression of HIV infection can be monitored. The fewer helper T cells, the more advanced the disease.

**Address Misconceptions**

Point out that the terms HIV infection and AIDS are often used interchangeably. Explain that a person with an HIV infection may or may not have symptoms of the disease AIDS. In fact, an infected person may have no idea that he or she is even infected. Add that a person is diagnosed with AIDS only after the HIV infection has caused immune system damage leading to specific unusual infections, such as fungal infections in the mouth and rare forms of skin cancer. The clinical definition of AIDS includes a helper T cell count of 200/mm³ of blood or lower.

**Build Science Skills**

**Applying Concepts** Check students’ comprehension of the way HIV causes disease. Ask: How does HIV “trick” helper T cells into making new copies of HIV? (HIV forces host T cells to make DNA copies of viral RNA. The DNA, in turn, directs the production of new viral RNA and proteins that are assembled into new virus particles.) Ask: How does HIV enter the central nervous system? (By hiding inside certain blood cells)

**Make Connections**

**Health Science** Emphasize the point that the symptoms of AIDS are not caused directly by HIV but rather by the damage HIV does to the immune system. Explain that similar symptoms are produced by other causes of immune system damage or dysfunction, including immunosuppressant drugs, which are given to people who have organ transplants.

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**Answer to . . .**

Smooth muscle contractions reduce the size of air passageways in the lungs and make breathing very difficult.

**Figure 40–14** White blood cell
**Make Connections**

**Health Science** Explain that HIV infections can be detected with a blood test for the presence of antibodies to HIV. A positive test indicates that the antibodies are present, and a negative test indicates that the antibodies are not present.

Ask: *What do you think a false negative result indicates? (That antibodies are present but not detected by the test)* Point out that someone who was very recently infected with HIV might have a false negative result because the immune system has not yet produced enough antibodies to be detected in the blood.

**Use Community Resources** Invite a professional who works with people with AIDS to speak to the class about the medical, emotional, and financial consequences of living with AIDS. Possible speakers might include a public-health nurse, home healthcare provider, or social worker. Urge students to ask questions at the end of the presentation.

**HIV and helper T cells**

Two types of HIV virus are known: HIV–1 and HIV–2. In both types, each viral particle consists of a protein core that surrounds its RNA and several copies of the enzyme reverse transcriptase. When the virus attaches to a helper T cell, the protein core becomes wrapped in a lipid envelope derived from the T cell’s plasma membrane. The virus progresses from the surface of the T cell to the cell interior. Once the virus is inside the T cell, the reverse transcriptase uses the viral RNA as a template for making DNA. This DNA is then inserted into a chromosome of the helper T cell. When the helper T cell is activated, it transcribes the HIV DNA along with portions of its own DNA, thus inadvertently producing copies of viral RNA. The viral RNA is translated into viral proteins, which assemble to form new viruses that go on to infect and destroy more helper T cells.

As the number of helper T cells decreases, the body becomes more and more susceptible to other diseases. The diseases that attack a person with a weakened immune system are called opportunistic diseases.

**Transmission of HIV** Although HIV is a deadly disease, it is not easily transmitted. It is not transmitted through casual contact. HIV can only be transmitted through the exchange of blood, semen, vaginal secretions, or breast milk.

There are four main ways that HIV can be transmitted:
- through any form of sexual intercourse with an infected person;
- through shared needles or syringes that are contaminated with the blood of an infected person;
- through contact with blood or blood products of an infected person; and
- from an infected mother to child, either during pregnancy, during birth, or during breast-feeding.
Preventing HIV Infection  Fortunately you can choose behaviors that will help you reduce your risk of becoming infected with HIV. The only no-risk behavior with respect to HIV and AIDS is abstinence. Within a committed sexual relationship such as marriage, sexual fidelity between two uninfected partners presents the least risk of becoming infected with HIV.

Avoiding drug use is also important for reducing the risk of HIV infection. People who share contaminated needles to inject themselves with drugs are at a high risk for contracting HIV. People who have sex with drug abusers are also at high risk.

Before 1985, HIV was transmitted to some hemophiliacs and surgical patients through transfusions of infected blood or blood products. Such cases have been nearly eliminated by screening the blood supply for HIV antibodies and by discouraging potentially infected individuals from donating blood.

Can AIDS Be Cured?  At present, there is no cure for AIDS. However, progress has been made in developing drugs that make it possible to survive HIV infection for years. Unfortunately, HIV mutates and evolves very rapidly. For this reason, the virus has been able to evolve into many different strains that are resistant to virtually all drugs used against them. Because HIV evolves so rapidly, no one has developed a vaccine that offers protection for any length of time.

At present, the only way to control the virus is to use expensive multidrug and multivitamin “cocktails” that fight the virus in several ways. Thanks to these drugs, more HIV-infected people are now living with HIV rather than dying from it.

Unfortunately, the knowledge that HIV can be treated (though not cured) has given people the idea that HIV infection is not as serious as it was a decade ago. In one year, more than 5 million people around the world became infected with HIV, including roughly 800,000 people under the age of 15. That same year, more than 3 million people around the world died of AIDS, bringing the total number of deaths worldwide to more than 20 million people.

1. Key Concept  What happens in an autoimmune disease?
2. Key Concept  Describe the various ways HIV is transmitted from person to person.
3. What are the two main types of immune system disorders?
4. Why is it difficult for a person with HIV to fight off infections?
5. Critical Thinking Applying Concepts  In treating asthma, the first thing many physicians do is ask patients to list times and places they have experienced asthmatic reactions. Why do you think doctors do this?
AIDS is a threat on every continent in the world, but nowhere has its effect been more devastating than in Africa. Thirty million of the world's 42 million people infected with HIV live in Africa. In some African countries, the HIV-infection rate is as high as one in three people. Leaders from around the world disagree on how the AIDS epidemic should be handled. Some argue that generic drugs should be made available. Others argue that the focus should be on AIDS prevention and education. Still others think that some money needs to be spent on the millions of AIDS orphans.

The Viewpoints

Make Drugs More Affordable
AIDS workers in Africa believe that more affordable drugs should be the top priority. HIV-infected people in Africa do not have access to the advanced medicines that people have in the United States. In Africa, the use of antiviral drugs is not common. Although the antiviral drugs do not cure AIDS, they help prolong life as long as they are taken on a regular basis. To increase access to these drugs, activists are looking for generic drugs, which would be lower in cost. Large pharmaceutical companies, however, don’t like this idea because they say that generic drugs violate the companies’ patents on such antiviral drugs.

Spend Money for Prevention
Many people in HIV-infected populations do not have basic knowledge about AIDS, including how HIV is spread. Thus, what is needed is an intensive program of public health education to stop the spread of the virus. If prevention programs including education and counseling were available, the incidence of new HIV infections could be reduced.

Spend Money on AIDS Orphans
More than 11 million children have lost parents to AIDS. Orphanages are overflowing with children who have no one to look after them. It is expected in Ethiopia—the country with the fastest-growing HIV-infection rate—that the number of orphans could increase about 150 percent over the next ten years. Because of this growing problem, a number of people feel that some of the money used to fight AIDS should be given to care for these orphans.

Research and Decide

1. Analyzing the Viewpoints To make an informed decision, learn more about this issue by consulting library or Internet resources. Then, list the key arguments for each of the viewpoints.

2. Forming Your Opinion Given limited resources to fight HIV, how would you decide the allocation of those resources? Would you spend all of the money on one area, or would you split it up among the different areas? What are the reasons for your decision?

BACKGROUND

Putting HIV and AIDS in context
No one knows why HIV appeared suddenly in the late 1970s, although most scientists believe it originated in Africa. It could have been a virus in monkeys that mutated and infected humans, but it has never been isolated from any animal source. In the United States and Europe, HIV has been transmitted most often among male homosexuals and intravenous drug users. In Africa, it has been transmitted almost solely among heterosexuals. Heterosexual transmission is also on the rise in Latin America. Besides education and treatment, a third way to possibly slow the AIDS epidemic is through vaccination. Scientists have been working for years on a vaccine to prevent HIV infection, but developing a vaccine has been difficult because HIV mutates rapidly. Nonetheless, a vaccine may be available in the near future.
Staying healthy involves more than the battles against pathogens. You interact constantly with both living and nonliving parts of your environment. Aspects of your environment that are important to health include the buildings in which you live, the people with whom you share those spaces, the air you breathe, the water you drink, and the food you eat.

Factors that have the potential to affect health in a negative way are called risk factors. A risk factor is anything that increases the chance of disease or injury. Both heredity (the genes you carry) and environmental factors can affect your health. Environmental factors that can affect your health include air and water quality, poisonous wastes in landfills, and exposure to solar radiation.

Air Quality
The air you breathe comes into very close contact with your delicate lung tissue and blood. It shouldn’t be surprising, therefore, that the quality of the air is very important to your health. But what is meant by “air quality”? Air quality refers to the number and concentrations of various gases present, as well as the nature and amount of tiny particles suspended in the air. Gases that are important to air quality include carbon monoxide and ozone. Particles in the air include dust, pollen, or particles produced by cars and trucks or the burning of coal. If the concentration of these impurities gets too high, they can become risk factors for various health problems.

Carbon Monoxide Carbon monoxide (CO) is an odorless gas produced when certain compounds are burned. Carbon monoxide is found in automobile exhaust and cigarette smoke. Carbon monoxide also can be produced by the furnace of a heating system or by space heaters that burn fuel.

Recall that hemoglobin in red blood cells usually helps carry oxygen to the cells of your body. If you inhale carbon monoxide, that gas binds to hemoglobin, preventing it from carrying oxygen. As a result, the body does not receive the oxygen it needs. Overexposure to carbon monoxide can be fatal.

Ozone Ozone (O₃), a highly reactive form of oxygen, is another gas found in the air that is a potential risk factor when it occurs at ground level. Ozone is produced by vehicle exhaust and factory emissions. When the air is stagnant, ozone accumulates. When ozone levels are high, you should limit your time outdoors as much as possible, especially if you have a respiratory condition such as asthma, bronchitis, or emphysema.
**Airborne Particulates** Airborne particulates of many different kinds can also be risk factors. Tiny dust mites, pollen, mold spores, and animal dander can trigger allergic reactions that can lead to respiratory problems or make existing health problems worse. Some potential sources of airborne particulates that can be found indoors are shown in Figure 40–17.

Another type of particulate that can cause serious harm is the metal lead. Lead can poison the liver, kidneys, and nervous system. Lead poisoning in babies and young children can also result in slow mental development.

Lead became a serious problem because for many years it was added to gasoline to improve the performance of engines. When that gas was burned, tiny particulates of lead were released into the air. People inhaled lead particulates as they breathed. Many more lead particulates were washed into rivers and streams. When research revealed the health problems that resulted, leaded gasoline was phased out and replaced with unleaded gasoline. Within a few years, levels of lead in surface waters dropped dramatically.

Another particulate that can be carried in air is asbestos, which was commonly used for insulation. Asbestos can fragment into tiny fibers that are small enough to remain suspended in air for some time. When inhaled repeatedly, asbestos fibers can cause lung cancer.

**Water Quality**

Water, like air, can carry biological and chemical pollution. Biological pollutants in water, such as human and animal wastes, can contain bacteria or viruses that can cause cramps, vomiting, diarrhea, or diseases such as hepatitis or cholera.

Some chemical pollutants can cause organ damage. Others interfere with the development of organs and tissues, causing birth defects. Still others can damage DNA, causing normal cells to become cancerous.

**Figure 40–17** Air pollution can occur indoors as well as outdoors. Indoor air pollutants include fumes and vapors given off by carpets, paints, and household cleaning products.

**Differentiated Instruction**

**Solutions for All Learners**

**Inclusion/Special Needs**

On the board or an overhead transparency, work with at-risk students to create a concept map that incorporates the headings and subheadings in the section. After the concept map is completed, have students add examples to it. For example, under radiation, they could add UV radiation, X-rays, or radon. Tell students to copy the completed concept map into their class notebook and use it as a study guide.

**Less Proficient Readers**

Guide students who need extra help in organizing the material in the section. Have them draw a line down the middle of a sheet of paper. Then, as they read, have them fill in the left side of the paper with a list of environmental factors that adversely affect health. They should fill in the right side of the paper with a list of steps they can take to maintain their health. Advise them to save the paper as a study guide.
Bioterrorism

In recent years, bioterrorism has become a new health threat. Bioterrorism is the intentional use of biological agents to disable or kill individuals. Bioterrorism can involve the intentional release of infectious agents—viruses (such as smallpox) or bacteria (such as anthrax)—or the spread of toxic compounds (such as botulinus toxin) extracted from living organisms.

Some forms of bioterrorism pose risks in part because research and public health measures have been so successful in the past. For example, worldwide vaccination programs eliminated smallpox around the world years ago. As a result, almost no one has been vaccinated against the virus for decades. Thus, the release of smallpox virus could cause serious problems.

Other forms of bioterrorism involve treating pathogens to maximize their ability to infect and cause disease. Anthrax is a disease that is common in cattle-ranching areas, but it is usually present in a form that either is not easily transmitted or is not life-threatening. The spores of anthrax bacteria, however, can be treated to make them light and fine enough to be spread through the air and inhaled—which produces a possibly fatal infection. Medical, research, and military establishments are still in the process of performing research and evaluating the best ways to minimize the risks of bioterrorism.

FACTS AND FIGURES

Not just anthrax and smallpox

Media attention has made the public aware of the potential threat of bioterrorism with the smallpox virus and anthrax bacteria. However, other pathogens are also potential agents of bioterrorism, including the bacterium that causes tularemia and the virus that causes hemorrhagic fever. Both have been studied in germ warfare laboratories for decades. In addition, the hemorrhagic fever virus has been weaponized by the United States and Russia, and the tularemia bacterium may already have been used as a weapon by the former Soviet Union in World War II. Both pathogens are normally found in nonhuman animal populations. When introduced to human populations, they cause potentially fatal, flulike illnesses. Aerosol dispersal could result in hundreds of thousands of people being infected and thousands of lives being lost.
Cancer

Make Connections

Environmental Science  Explain how destruction of the ozone layer in Earth’s atmosphere has increased the amount of ultraviolet radiation to which people are potentially exposed. Ask: How is this likely to affect rates of skin cancer? (The rates are likely to increase.) Add that skin cancer rates have in fact increased since the late 1900s.

Demonstration

Point out that tumors can often be detected by physical exam or X-ray but determining whether a tumor is cancerous usually requires a biopsy. Explain that a biopsy is the surgical removal of a small mass of tissue of a tumor so it can be examined under a microscope for evidence of cancer. Use a microprojector and show students slides of normal and cancerous cells. Alternatively, you can show students pictures of normal and cancerous cells from histology textbooks or Internet sites. Ask: How do the normal and cancerous cells appear to differ? (Cancer cells are often small, mitotically active cells with little sign of cell differentiation.)

Cancer

Cancer is a life-threatening disease in which cells multiply uncontrollably and destroy healthy tissue. Cancer is a unique disease because the cells that cause it are not foreign cells but rather the body’s own cells. This fact has made cancer difficult to treat and to understand.

All forms of cancer are ultimately caused by harmful mutations in genes that control cell growth and development. Sometimes, cancer arises almost entirely because some factor in the environment damages DNA. An increased likelihood of developing some cancers can be inherited.

Cancers begin when something goes wrong with the controls that normally regulate cell growth and reproduction. A single cell or a group of cells begin to grow and divide uncontrollably, often resulting in the formation of a mass of growing tissue known as a tumor. However, not all tumors are cancerous. Some tumors are benign, or noncancerous. A benign tumor does not spread to surrounding healthy tissue or to other parts of the body. Cancerous tumors, on the other hand, are malignant, which means that they can invade and destroy surrounding healthy tissue.

As the cancer cells spread, they absorb the nutrients needed by other cells, block nerve connections, and prevent the organs they invade from functioning properly. Soon, the delicate balances that exist in the body are disrupted, and life-threatening illness results.

Causes of Cancer  Cancers are caused by defects in the genes that regulate cell growth and division. There are several sources of such defects. They may be inherited, be caused by viruses, or may result from mutations in DNA that occur spontaneously or are produced by chemicals or radiation.

Chemical compounds cause cancer by triggering mutations in the DNA of normal cells. Chemical compounds that are known to cause cancer are called carcinogens. Some carcinogens are produced in nature. One of these, aflatoxin, is produced by molds that grow on peanuts. Others, such as chloroform and benzene, are synthetic compounds. Some of the most powerful chemical carcinogens are found in tobacco smoke. In the United States, cigarette smoking is responsible for nearly half the cancers that occur.

Most forms of radiation—including sunlight, X-rays, and nuclear radiation—cause cancer by producing mutations in DNA. If mutations occur in genes that control cell growth, a normal cell may be transformed into a cancer cell. Most cases of skin cancer, for example, are caused by the ultraviolet radiation in sunlight. For this reason, it is important to avoid prolonged exposure to the sun.
Radon is another source of radiation. Radon is a radioactive gas that is found naturally in some rocks and that sometimes leaks into the foundations of buildings. If your home is located in an area where radon is present, it can be tested for the presence of radon.

**Treating Cancer**  
As with other diseases, prevention is the best defense. The best way to fight cancer is by protecting your DNA from agents that cause cancer. For example, you can dramatically reduce your risk of developing lung cancer by not smoking. In addition, regular exercise and a balanced diet with plenty of fruits and vegetables can help to lower your cancer risk.

Physicians also stress that if a cancer is detected early the chances of treating it successfully may be as high as 90 percent. Regular checkups and tests are an important preventive measure. Recommended tests depend on a person’s age, gender, and family history. Self-examinations for skin, breast, or testicular cancer are also helpful when combined with regular checkups. Your doctor can give you instructions for performing these self-examinations.

### FACTS AND FIGURES

**Radon and cancer**

The invisible, odorless, radioactive gas radon is released through the decay of uranium in soil and rocks. When uranium decays, it emits tiny radioactive particles that can damage the cells lining the lungs, and long-term exposure can lead to lung cancer. Radon’s link with lung cancer was first discovered when scientists discovered that underground uranium miners died of lung cancer at far-higher-than-expected rates. Although everyone breathes in some radon every day, it is usually at very low levels that have little if any health risks. However, radon can reach dangerously high levels in well-insulated homes and other buildings. As a result, it is estimated to be responsible for about 10 percent of annual lung cancer cases in the United States, making radon second only to cigarette smoking as a cause of lung cancer.

### Cancer Mortality

Cancer is a disease that is easier to treat if it is detected early. There are also things you can do to decrease your risk of cancer, such as eating a diet high in fruits, vegetables, and fiber; staying out of the sun; and not smoking. The data in the table show the 5-year mortality rates of five different types of cancer since 1950. Use the data to answer the questions.

1. Using Tables and Graphs  
   Construct a line graph of the data in the table.

2. Using Tables and Graphs  
   Which type of cancer has shown the greatest increase in mortality rate?

3. Inferring  
   What can you infer about the use of tobacco in men over the last 50 years? In women?

4. Predicting  
   Given the trend in melanoma cancer deaths over the past 50 years, predict the incidence in 1995–1998 in both men and women.

5. Inferring  
   Why do you think the incidence of death from breast cancer has stayed relatively stable over the last 50 years?

### Cancer Mortality Rates (per 100,000 people)

<table>
<thead>
<tr>
<th>Year</th>
<th>Lung</th>
<th>Colon</th>
<th>Melanoma</th>
<th>Breast</th>
<th>Prostate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>1950–54</td>
<td>25.51</td>
<td>4.98</td>
<td>16.94</td>
<td>18.49</td>
<td>1.20</td>
</tr>
<tr>
<td>1960–64</td>
<td>42.15</td>
<td>6.39</td>
<td>17.86</td>
<td>17.48</td>
<td>1.67</td>
</tr>
<tr>
<td>1970–74</td>
<td>60.79</td>
<td>12.80</td>
<td>19.49</td>
<td>16.43</td>
<td>2.18</td>
</tr>
<tr>
<td>1980–84</td>
<td>71.30</td>
<td>23.33</td>
<td>21.22</td>
<td>15.52</td>
<td>2.95</td>
</tr>
<tr>
<td>1995–98</td>
<td>68.00</td>
<td>34.30</td>
<td>20.50</td>
<td>14.10</td>
<td>?</td>
</tr>
</tbody>
</table>

**Answers**

1. Check students’ line graphs to make sure that they have plotted the data correctly.
2. Lung cancer for both men and women.
3. Tobacco use in both sexes has increased dramatically.
4. Accept all logical responses. Male rate may be around 4.0; female rate may be around 1.8–1.9.
5. Self-exams have helped in early detection of cancers, increasing the rate of survival. Also, there are a variety of treatments available to breast cancer patients.
Maintaining Health

Build Science Skills

Applying Concepts  Ask students to think of at least one specific way that they can maintain their health for each of the four general ways that are presented in the section: healthful diet, exercise and rest, abstaining from harmful activities, and regular checkups. (Possible ways include avoiding high-fat foods; working out three or more times a week; saying no to drugs, alcohol, and sex; and getting regular checkups.)

Make Connections

Health Science  Review some of the regular screening tests recommended for most adults, including testicular and breast self-exams, mammograms, Pap smears, and colonoscopies. Discuss the role of screening in early detection and successful treatment of the diseases.

3 ASSESS

Evaluate Understanding

Ask students to make a concept map of environmental factors that affect health.

Reteach

Using the chalkboard or an overhead transparency, work with students to make an outline of the section by writing the section headings and subheadings as outline topics and subtopics and calling on students to fill in important details.

Maintaining Health

To keep your immune system working efficiently, you can practice behaviors that reduce your exposure to pathogens and maintain overall good health. Healthful behaviors include eating a healthful diet, getting plenty of exercise and rest, abstaining from harmful activities, and having regular checkups.

Healthful Diet  Food provides the nutrients and energy your cells need to function properly. To help all your body systems work at their best, it is important to eat a balanced diet that provides essential nutrients. Eating foods that are low in saturated fat and cholesterol may help prevent obesity. Eating plenty of fruits, vegetables, and whole grains will also help protect you from certain cancers, especially colon and rectal cancers.

Exercise and Rest  Regular exercise helps move blood throughout the body and maintains cardiovascular fitness. Exercise also helps maintain an appropriate body weight, which helps prevent certain kinds of heart disease. Adequate rest is important for keeping your body functioning well. For most people, adequate rest means getting about eight hours of sleep each night.

Abstaining From Harmful Activities  Drugs, including alcohol and tobacco products, can have harmful effects on the body. Many types of drugs, including alcohol, can slow or depress the immune system. Smoking and tobacco products also cause a variety of respiratory conditions as well as certain cancers, including cancers of the lung, mouth, and throat.

Some diseases can be spread through sexual contact with an infected person. These sexually transmitted diseases (STDs) include HIV, chlamydia, and gonorrhea. The only way to absolutely prevent exposure to sexually transmitted diseases is to abstain from all sexual activity.

Regular Checkups  It usually is easier to treat a disease if it is discovered early. You can perform regular self-examinations for skin cancer, breast cancer, and testicular cancer. By getting regular checkups, you can help maintain your health.

40–4 Section Assessment

1. **Key Concept** Describe the environmental factors that affect your health.
2. **Key Concept** Name three things you can do to maintain your health.
3. List some of the causes of cancer.
4. Why are regular medical check-ups and self-examinations important?
5. **Critical Thinking Classifying** Should cancer be considered an infectious disease? Explain your answer.

The Cell Cycle

Recall the cell cycle from Section 10–2. In which phase do you think cells would be most vulnerable to damage from radiation? Explain your choice. What characteristic of cancer cells might make them especially vulnerable?

Connecting Concepts

Cells would be most vulnerable to damage from radiation during the S phase of the cell cycle, when DNA is being replicated. Cancer cells would be especially vulnerable to radiation because cancer is characterized by rapid cell division.

Interactive Textbook

If your class subscribes to the iText, use it to review the Key Concepts in Section 40–4.