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.

Guide for Reading

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. Immunity involving killer T cells is called ______ immunity. When the body is injected with antibodies, it is called ______ immunity. When the body makes antibodies in response to an antigen, it is called ______ immunity. 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

With 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.

SECTION RESOURCES

Print:

• Laboratory Manual B, Chapter 40 Lab
• Teaching Resources, Lesson Plan 40–2, Adapted Section Summary 40–2, Adapted Worksheets 40–2, Section Summary 40–2, Worksheets 40–2, Section Review 40–2
• Reading and Study Workbook A, Section 40–2
• Adapted Reading and Study Workbook B, Section 40–2

Technology:

• iText, Section 40–2
• Animated Biological Concepts DVD, 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.

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.)

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.

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?

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.

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.

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.

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?

Macrophage means a large cell that eats or engulfs.
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 is shaped like the letter Y and has two identical antigen-binding sites. Small differences in the amino acids affect the shapes of the binding sites. The shape of the binding site makes it possible for the antibody to recognize a specific antigen with a complementary shape. The different shapes give antibodies the ability to recognize a large variety of antigens. It is estimated that a healthy adult can produce about 100 million different types of antibodies.
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 protozoa. 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.

Comparing and Contrasting How are humoral immunity and cell-mediated immunity similar? How are they different?

Cells that eat cells

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.”
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. Vacca 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.

Quick Lab

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

Use Community Resources

Have students contact their local health department to obtain a schedule of recommended vaccinations from birth to adulthood. Then, have students create a poster to convey the information in an eye-catching way. If possible, arrange to have their posters displayed at a location in the community where families with young children are likely to see them, for example, at a public library or preschool.

Answers to . . .

Sucroceur 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.

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An antigen is a substance on the surface of a pathogen that triggers an immune response. Active immunity, the type of immunity produced by the body in response to an antigen, as a result of the immune response. Active immunity may develop as a result of natural exposure to an antigen (fighting an infection) or from deliberate exposure to the antigen (through a vaccine).

Passive immunity lasts only a short time because eventually the body destroys the foreign antibodies.

Like active immunity, passive immunity can develop naturally or by deliberate exposure. One kind of natural immunity occurs when antibodies produced by the mother are passed to the fetus during development (across the placenta) or in early infancy through breast milk. This immunity protects a child against most infectious diseases for the first few months of its life, or longer if the infant is breast-fed.

Sometimes, antibodies are administered to fight infection or prevent disease. For example, travelers to certain regions of the world are given vaccines before leaving home. These vaccines may contain antibodies against tropical diseases, such as malaria. People who have been bitten by rabid animals are injected with antibodies that attack the rabies virus. This is another example of passive immunization.

The type of immunity produced by the body’s reaction to a vaccine is known as active immunity. Active immunity appears after exposure to an antigen, as a result of the immune response. Active immunity may develop as a result of natural exposure to an antigen (fighting an infection) or from deliberate exposure to the antigen (through a vaccine).

Passive immunity is temporary; passive immunity is temporary. Like active immunity, passive immunity can develop naturally or by deliberate exposure. One kind of natural immunity occurs when antibodies produced by the mother are passed to the fetus during development (across the placenta) or in early infancy through breast milk. This immunity protects a child against most infectious diseases for the first few months of its life, or longer if the infant is breast-fed.

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