Chapter 39

Immunity from Disease

What You'll Learn

- You will describe how infections are transmitted and what causes the symptoms of diseases.
- You will explain the various types of innate and acquired immune responses.
- You will compare antibody and cellular immunity.

Why It's Important

Your body constantly faces attack from disease-causing organisms. A knowledge of your immune system will help you understand how your body defends itself and works to maintain homeostasis.

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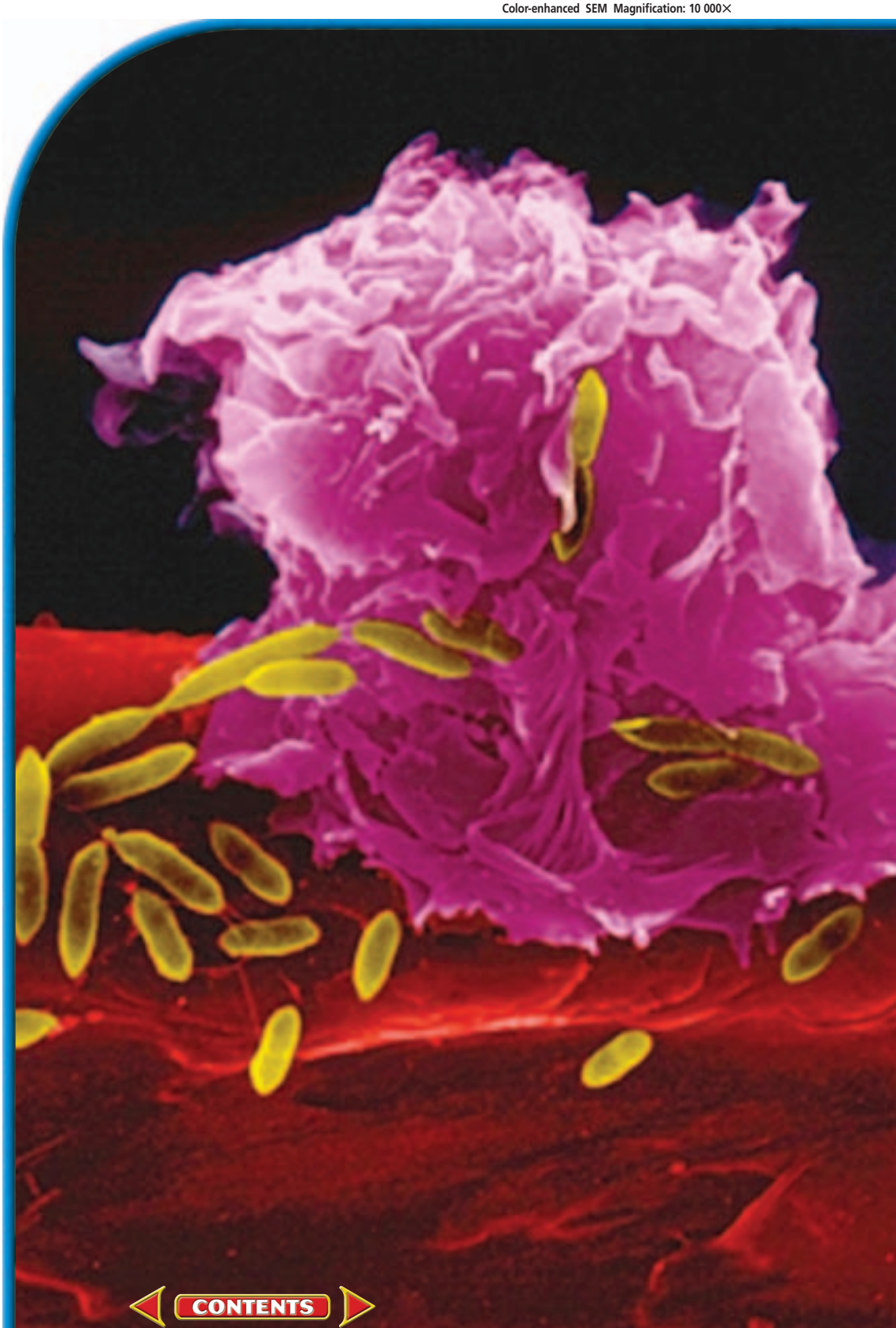

Understanding the Photo

This color-enhanced lymphocyte, a type of white blood cell produced by the immune system, is attacking the rod-shaped bacteria that have invaded the body.

Biology Online

Visit bdol.glencoe.com to
- study the entire chapter online
- access Web Links for more information and activities on immunity
- review content with the Interactive Tutor and self-check quizzes

Dr. Dennis Kunkel/Phototake, NYC

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Section 39.1

The Nature of Disease

SECTION PREVIEW

Objectives

Outline the steps of Koch's postulates.

Describe how pathogens are transmitted.

Explain what causes the symptoms of a disease.

Review Vocabulary

virus: a disease-causing, nonliving particle composed of an inner core of nucleic acids surrounded by a capsid; replicates inside a living cell (p. 475)

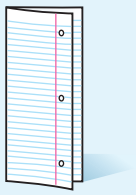
New Vocabulary

pathogen
infectious disease
Koch's postulates
endemic disease
epidemic
antibiotic

FOLDABLES Study Organizer

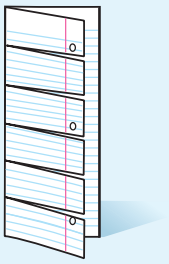
Disease Make the following Foldable to help you answer questions about disease.

STEP 1 **Fold** a vertical sheet of notebook paper from side to side.



STEP 2 **Cut** along every fifth line of only the top layer to form tabs.

STEP 3 **Label** the tabs with one question that relates to each of the red heads in the section. For example, "What causes disease?"



Answer Questions As you read Section 39.1, fill in your answers to the questions about disease beneath the appropriate tabs.

What is an infectious disease?

The cold virus causes a disease—a change that disrupts the homeostasis in the body. Disease-producing agents such as bacteria, protozoans, fungi, viruses, and other parasites are called **pathogens.** The main sources of pathogens are soil, contaminated water, and infected animals, including other people.

Not all microorganisms are pathogenic. In fact, the presence of some microorganisms in your body is beneficial. At birth, microorganisms establish themselves on your skin and in your upper respiratory system, lower urinary and reproductive tracts, and lower intestinal tract. ***Figure 39.1*** shows some common bacteria that live on your skin.

Figure 39.1
These bacteria establish a more-or-less permanent residence in or on your skin, but do not cause disease under normal conditions.

Color-enhanced SEM Magnification: 17 000×

David M. Phillips/Visuals Unlimited

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Table 39.1 Human Infectious Disease

Disease	Cause	Affected Organ System	Transmission
Smallpox	Virus	Skin	Droplet
Chicken pox	Virus	Skin	Droplet
Rabies	Virus	Nervous system	Animal bite
Poliomyelitis	Virus	Nervous system	Contaminated water
Colds	Viruses	Respiratory system	Direct contact
Influenza	Viruses	Respiratory system	Direct contact
HIV/AIDS	Virus	Immune system	Exchange of body fluids
Hepatitis B	Virus	Liver	Exchange of body fluids
Tetanus	Bacteria	Nervous system	Puncture wound
Food poisoning	Bacteria	Digestive system	Contaminated food/water
Strep throat	Bacteria	Respiratory system	Droplet
Diphtheria	Bacteria	Respiratory system	Droplet
Tuberculosis	Bacteria	Respiratory system	Droplet
Spinal meningitis	Bacteria	Nervous system	Droplet

These microorganisms have a symbiotic relationship with your body. Microorganisms that colonize the body help maintain equilibrium within the body by keeping harmful bacteria and other microorganisms from growing. If conditions change and the beneficial organisms are eliminated, pathogens can establish themselves and cause infection and disease. If the beneficial organisms enter areas of the body where they are not normally found or if a person becomes weakened or injured, these formerly harmless organisms can become potential pathogens.

Word Origin

pathogen from the Greek words *pathos,* meaning "to suffer," and *geneia,* meaning "producing"; Pathogens cause diseases.

Any disease caused by the presence of pathogens in the body is called an **infectious** (ihn FEK shus) **disease.** ***Table 39.1*** lists some of the infectious diseases that occur in humans.

Determining What Causes a Disease

One of the first problems scientists face when studying a disease is finding out what causes the disease. Not all diseases are caused by pathogens. Some disorders are inherited, such as hemophilia (hee muh FIH lee uh), which is caused by a recessive allele on the X chromosome, and sickle-cell anemia. Others, such as osteoarthritis (ahs tee oh ar THRI tus), may be caused by wear and tear on the body as it ages. Some diseases, such as cirrhosis (suh ROH sihs), are caused by exposure to chemicals or toxins such as alcohol that destroy liver cells. Other diseases can be caused by malnutrition. Scurvy, which results in poor wound healing, swollen gums, and loosening of teeth, is caused by a deficiency of vitamin C. Pathogens cause infectious diseases and some cancers. In order to determine which pathogen causes a specific disease, scientists follow a standard set of procedures.

Reading Check **List** the different causes of disease.

First pathogen identified

The first proof that pathogens actually cause disease came from the work of Robert Koch (KAHK) in 1876. Koch, a German physician, was looking for the cause of anthrax, a deadly disease that affects mainly

cattle and sheep but can also occur in humans. Koch discovered a rod-shaped bacterium in the blood of cattle that had died of anthrax. He cultured the bacteria on nutrients and then injected samples of the culture into healthy animals. When these animals became sick and died, Koch isolated the bacteria in their blood and compared them with the bacteria he had originally isolated from anthrax victims. He found that the two sets of blood cultures contained the same bacteria.

A procedure to establish the cause of a disease

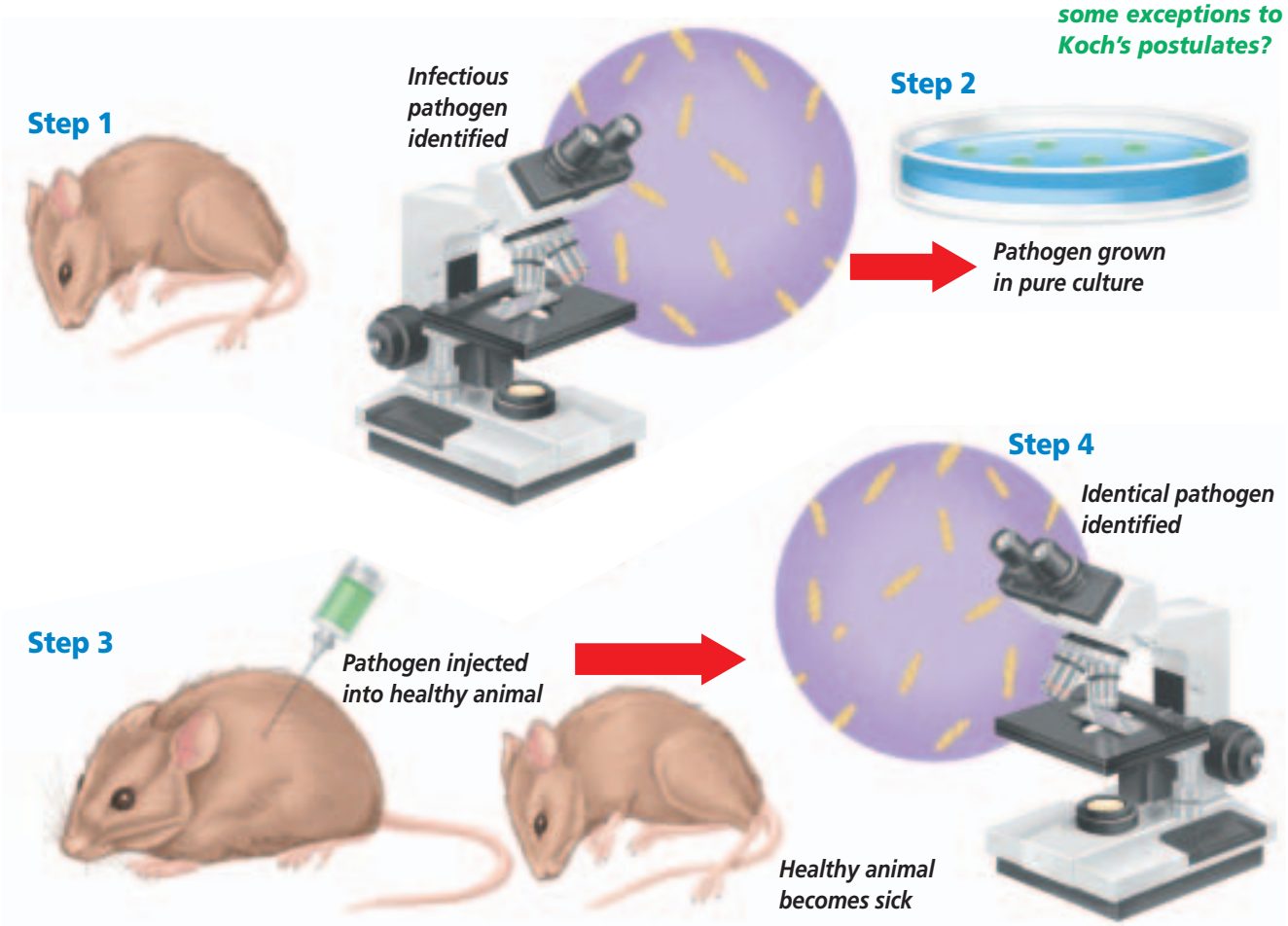
Koch established experimental steps, shown in ***Figure 39.2***, for directly relating a specific pathogen to a specific disease. These steps, first published in 1884, are known today as **Koch's postulates:**

1. The pathogen must be found in the host in every case of the disease.
2. The pathogen must be isolated from the host and grown in a pure culture—that is, a culture containing no other organisms.
3. When the pathogen from the pure culture is placed in a healthy host, it must cause the disease.
4. The pathogen must be isolated from the new host and be shown to be the original pathogen.

Exceptions to Koch's postulates

Although Koch's postulates are useful in determining the cause of most diseases, some exceptions exist. Some organisms, such as the pathogenic bacterium that causes the sexually transmitted disease syphilis (SIH fuh lus), have never been grown on an artificial medium. Viral pathogens also cannot be cultured this way because they multiply only within cells. As a result, living tissue must be used as a culture medium for viruses.

Figure 39.2
Koch's postulates are steps used to identify an infectious pathogen.
Describe ***What are some exceptions to Koch's postulates?***



The Spread of Infectious Diseases

For a disease to continue and spread, there must be a continual source of the disease organisms. This source can be either a living organism or an inanimate object on which the pathogen can survive.

Reservoirs of pathogens

The main source of human disease pathogens is the human body itself. In fact, the body can be a reservoir of disease-causing organisms. People may transmit pathogens directly or indirectly to other people. Sometimes, people can harbor pathogens without exhibiting any signs of the illness and unknowingly transmit the pathogens to others. These people are called carriers and are a significant reservoir of infectious diseases.

Other people may unknowingly pass on a disease during its first stage, before they begin to experience symptoms. This symptom-free period, while the pathogens are multiplying within the body, is called an incubation period. Humans can unknowingly pass on the pathogens that cause colds, streptococcal (strep tuh KAH kul) throat infections, and sexually transmitted diseases (STDs) such as gonorrhea (gah nuh REE uh) and AIDS during the incubation periods of these diseases.

Animals are other living reservoirs of microorganisms that cause disease in humans. For example, some types of influenza, commonly known as the flu, rabies, and Lyme disease are transmitted to humans from animals.

The major nonliving reservoirs of infectious diseases are soil and water. Soil harbors pathogens such as fungi and the bacterium that causes botulism, a type of food poisoning. Water contaminated by feces of humans and other animals is a reservoir for several pathogens, especially those responsible for intestinal diseases.

Figure 39.3
Diseases can be transmitted to humans from reservoirs in various ways.

B Airborne transmission by droplets of water or dust spreads pathogens.

A Common inanimate objects such as this glass of juice may harbor and transmit pathogens.

C Insects and other arthropods are the most common pathogen vectors.

(l)Ken Frick, (c)Matt Meadows, (r)Elaine Shay

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Transmission of disease

Pathogens can be transmitted to a host from reservoirs in four main ways: by direct contact, by an object, through the air, or by an intermediate organism called a vector. ***Figure 39.3*** illustrates several routes of transmission.

The common cold, influenza, and STDs are spread by direct contact. STDs, such as genital herpes and the virus that causes AIDS, are usually transmitted by the exchange of body fluids, especially during sexual intercourse.

Bacteria and other microorganisms can be present on nonliving objects such as money, toys, or towels. Transmission occurs when people unknowingly handle contaminated objects. This type of transmission can be prevented by thoroughly cleaning objects such as eating utensils and countertops that can harbor pathogens, and by washing your hands often throughout each day.

Airborne transmission of a disease can occur when a person coughs or sneezes, spreading pathogens contained in droplets of mucus into the air. *Streptococcus*, the bacterium that causes strep throat infections, and the virus that causes measles are two examples of disease-causing organisms that can be spread through the air.

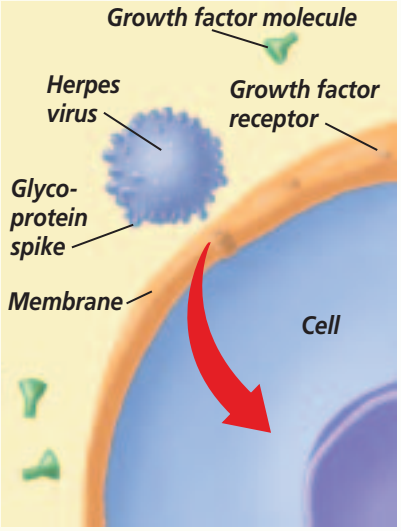
Diseases transmitted by vectors are most commonly spread by insects and arthropods. Diseases such as malaria and the West Nile virus are transmitted by mosquitoes. Lyme disease and Rocky Mountain spotted fever are diseases that are transmitted by ticks. The bubonic plague—a disease that swept through Europe in the 1400s, killing up to one-quarter of the population—was caused by a bacterium that was transmitted from infected rats to humans by fleas. Flies also are significant vectors of disease. They transmit pathogens when they land on infected materials, such as animal wastes, and then land on fresh food that is eaten by humans. A current international concern is the intentional spreading of disease organisms such as anthrax spores, as occurred in the fall of 2001 in the United States through contaminated mail. To learn more about how diseases are spread, refer to the *Problem-Solving Lab* here and the *MiniLab* on the next page.

Problem-Solving Lab 39.1

Design an Experiment

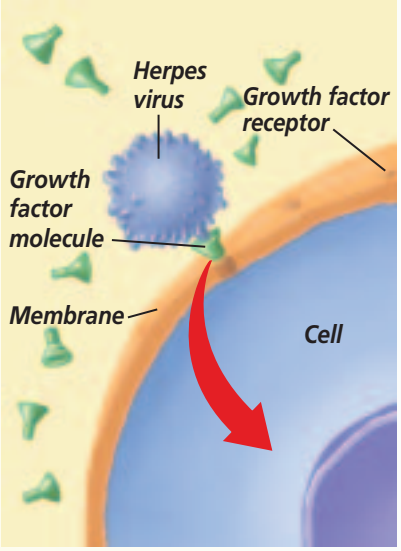
How does the herpes simplex virus spread?

Herpes (HER peez) simplex virus, which causes cold sores, infects a person for life, occasionally reproducing and then spreading to other cells in the body of its host. Scientists have been interested for a long time in how the herpes virus actually enters a cell.



Solve the Problem

Scientists have found that the herpes virus infects a cell in one of two possible ways. It may latch onto a cell receptor with its own glycoprotein spike, or it may use this spike to grab a growth factor molecule that latches onto the receptor, as shown in the diagram.



Thinking Critically

Experiment Design an experiment to determine the method by which the herpes virus enters a cell.

MiniLab 39.1

Experiment

Testing How Diseases Are Spread Microorganisms cannot travel over long distances by themselves. Unless they are somehow transferred from one animal or plant to another, infections will not spread. One method of transmission is by direct contact with an infected animal or plant.

Rotten apples

Procedure

1. Label four plastic bags 1 to 4.
2. Put a fresh apple in bag 1 and seal the bag.
3. Rub a rotting apple over the entire surface of the remaining three apples. The rotting apple is your source of pathogens. **CAUTION:** ***Make sure to wash your hands with soap and water after handling the rotting apple.***
4. Put one of the apples in bag 2.
5. Put one of the apples in bag 3 and drop the bag to the floor from a height of about 2 m.
6. Use a cotton ball to spread alcohol over the last apple. Let the apple air-dry and then place it in bag 4.
7. Store all of the bags in a dark place for one week.
8. Without opening the sealed bags, compare the apples and record your observations. **CAUTION:** ***Give all apples to your teacher for proper disposal.***

Analysis

1. **Explain** What was the purpose of the apple in bag 1?
2. **Describe** What happened to the rest of the apples?
3. **Infer** Why is it important to clean a wound with disinfectant?

What causes the symptoms of a disease?

When a pathogen invades your body, it encounters your immune system, which consists of individual cells, tissues, and organs that work together to protect the body against organisms that may cause infection or disease. If the pathogen overcomes the defenses of your immune system, it can metabolize and multiply, causing damage to the tissues it has invaded, and even killing host cells.

Damage to the host by viruses and bacteria

You already know that viruses cause damage by taking over a host cell's genetic and metabolic machinery. Many viruses also cause the eventual death of the cells they invade.

Most of the damage done to host cells by bacteria is inflicted by toxins. Toxins are poisonous substances that are sometimes produced by microorganisms. These poisons are transported by the blood and can cause serious and sometimes fatal effects. Toxins can inhibit protein synthesis in the host cell, destroy blood cells and blood vessels, produce fever, or cause spasms by disrupting the nervous system.

Figure 39.4
Before the days of modern medicine, wounded soldiers faced the additional, deadly danger of becoming infected with tetanus bacteria. **Infer** ***What conditions of a battlefield are ideal for tetanus bacteria?***

For example, the toxin produced by tetanus bacteria affects nerve cells and produces uncontrollable muscle contractions. If the condition is left untreated, paralysis and death occur. Tetanus bacteria are normally present in soil, and as ***Figure 39.4*** illustrates, a soldier could become infected with tetanus as a result of wounds received on the battlefield. If dirt transfers the bacteria into a deep wound on the body, the bacteria begin to produce the toxin in the wounded area. A small amount of this toxin, about the same amount as the ink used to make a period on this page, could kill 30 people.

Patterns of Diseases

In today's highly mobile world, diseases such as influenza can spread rapidly as people fly from one part of the country or world to another. Therefore, identifying a pathogen, its method of transmission, and the geographic distribution of the disease it causes are major concerns of government health departments. The Centers for Disease Control and Prevention, the central source of disease information in the United States, publishes a weekly report about the incidence of specific diseases.

Some diseases, such as typhoid fever, occur only occasionally in the United States. These periodic outbreaks often occur because someone traveling in a foreign country has brought the disease back home. On the other hand, many diseases are constantly present in the population. Such a disease is called an endemic disease. The common cold is an **endemic disease.**

Sometimes, an **epidemic** breaks out. An epidemic occurs when many people in a given area are afflicted with the same disease at about the same time. Influenza is a disease that often achieves epidemic status, sometimes spreading to many parts of the world. During the early 1950s, a polio epidemic spread across the United States. Victims of this disease were paralyzed or died when the polio virus attacked the nerve cells of the brain and spinal cord. Many survived only after being placed in an iron lung—a machine that allowed the patient to continue to breathe, as shown in ***Figure 39.5.*** You can learn more about emerging and re-emerging diseases in the *BioLab* at the end of the chapter.

Figure 39.5
During the early 1950s polio epidemic, many patients were placed in iron-lung machines like those shown here.

Treating Diseases

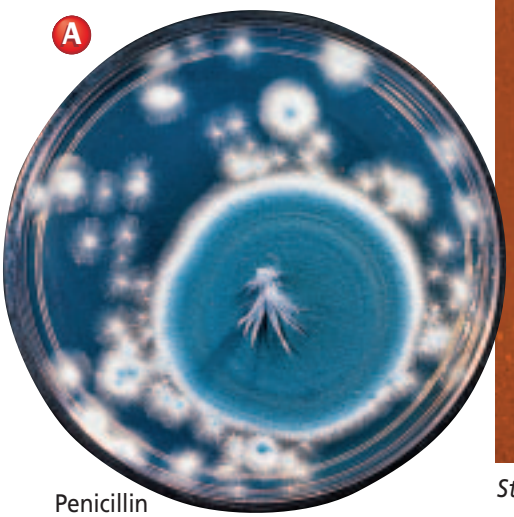
A person who becomes sick often can be treated with medicinal drugs, such as antibiotics. An **antibiotic** is a substance produced by a microorganism that, in small amounts, will kill or inhibit the growth and reproduction of other microorganisms, especially bacteria. Antibiotics are produced naturally by various species of bacteria and fungi. Although antibiotics can be used to cure some bacterial infections, antibiotics do not have an affect on viruses.

Word Origin

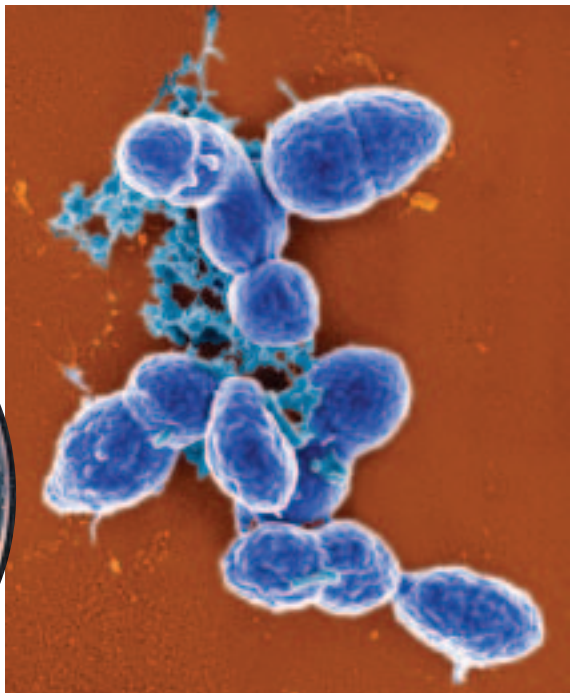
epidemic from the Greek words *epi,* meaning "upon," and *demos,* meaning "people"; An epidemic is a disease found among many people in an area.

Bettmann-UPI/CORBIS

Figure 39.6
Penicillin is an antibiotic produced by a fungus **(A).** Some types of bacteria, including *Streptococcus pneumoniae* are penicillin-resistant **(B).**



Penicillin



Streptococcus pneumoniae

Color-enhanced SEM
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With the continued use of antibiotics, bacteria can become resistant to the drugs. That means the drugs become ineffective. Penicillin, an antibiotic produced by a fungus, was used for the first time in the 1940s and is still one of the most effective antibiotics known. However, penicillin has now been in use for more than 50 years, and more and more types of bacteria have evolved that are resistant to it. Bacteria that are resistant to penicillin produce an enzyme that breaks down this antibiotic. Examples of penicillin-resistant bacteria include *Streptococcus pneumoniae*, shown in ***Figure 39.6***, and the organism that causes the STD gonorrhea. The resistance of *Streptococcus pneumoniae* to penicillin is a problem because penicillin is the primary drug used to treat pneumonia, ear infections, and meningitis, all of which can be caused by this organism.

The use of antibiotics is only one way to fight infections. Your body also has its own built-in defense system—the immune system—that works to keep you healthy.

Word Origin

antibiotic from the Greek words *anti,* meaning "against," and *bios,* meaning "life"; An antibiotic is given to control a bacterial infection.

Section Assessment

Understanding Main Ideas

1. Outline and explain the steps of Koch's postulates.
2. What are the major reservoirs of pathogens?
3. List the different ways in which pathogens are transmitted.
4. How do pathogens, such as some bacteria and viruses, cause disease symptoms?

Thinking Critically

5. Sometimes patients contract a secondary infection while in the hospital. What possible ways could a disease be transmitted to a hospital patient?

Skill Review

6. **Experiment** Design an experiment that could determine whether a recently identified bacterium causes a type of pneumonia. For more help, refer to *Experiment* in the **Skill Handbook.**

(l)Patricia Barber/Custom Medical Stock Photo, (r)Gary D. Gaugler/Photo Researchers

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Section 39.2

Defense Against Infectious Diseases

SECTION PREVIEW

Objectives

Identify the cells, tissues, and organs that make up the immune system.

Compare innate and acquired immune responses.

Distinguish between antibody and cellular immunity.

Review Vocabulary

antibody: a protein in the blood plasma produced in reaction to antigens that react with and disable antigens (p. 977)

New Vocabulary

innate immunity
phagocyte
macrophage
pus
interferon
acquired immunity
tissue fluid
lymph
lymph node
lymphocyte
T cell
B cell
vaccine

Microscopic Enemies

Using an Analogy You can't see it, but a war is going on around these teenagers. In fact, the same sort of war is occurring around you. Millions of unseen enemies are present everywhere—in the air, on the ground, and even on your clothes. Defenders ready to protect you from the onset of attack are inside your body.

Infer *How does your body save you from the microscopic foes that cause infectious diseases? How do the body's defenses protect you from these unseen enemies?*

Lymphocytes (inset), types of white blood cells, help protect you from diseases.

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Innate Immunity

Your body produces a variety of white blood cells that defend it against invasion by pathogens that are constantly bombarding you. No matter what pathogens are present, your immune system is always ready. The body's earliest lines of defense against any and all pathogens make up your nonspecific, **innate immunity.**

Skin and body secretions

When a potential pathogen contacts your body, often the first barrier it must penetrate is your skin. Like the walls of a castle, intact skin is a formidable physical barrier to the entrance of microorganisms.

In addition to the skin, pathogens also encounter your body's secretions of mucus, oil, sweat, tears, and saliva. The main function of mucus is to prevent various areas of the body from drying out. Because mucus is slightly viscous (thick), it also traps many microorganisms and other foreign substances that enter the respiratory and digestive tracts. Mucus is continually swallowed and passed to the stomach, where acidic gastric juice destroys most bacteria and their toxins. Sweat, tears, and saliva all contain the enzyme lysozyme, which is capable of breaking down the cell walls of some bacteria.

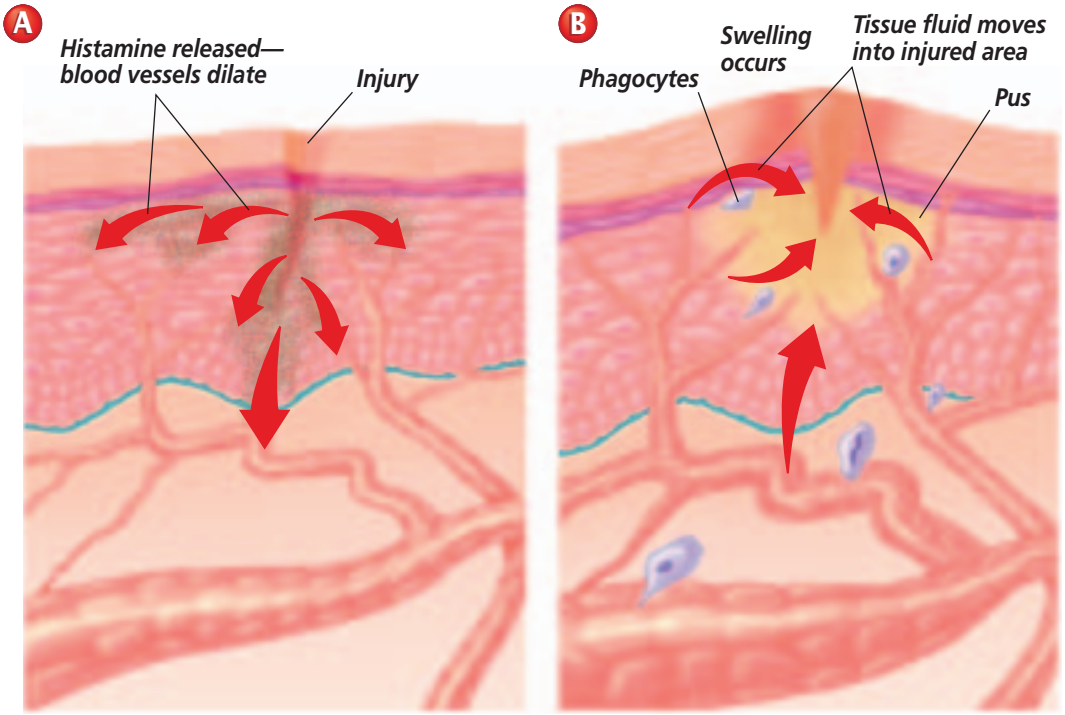

Figure 39.7
When tissues become inflamed, histamine release causes blood vessels to dilate **(A).** Tissue fluid leaks out of the vessels into the injured area, causing swelling **(B).**

Inflammation of body tissues

If a pathogen manages to get past the skin and body secretions, your body has several other nonspecific defense mechanisms that can destroy the invader and restore homeostasis. Think about what happens when you get a splinter. If bacteria or other pathogens enter and damage body tissues, inflammation (ihn fluh MAY shun) results. Inflammation is characterized by four symptoms—redness, swelling, pain, and heat. As ***Figure 39.7*** shows, inflammation begins when damaged tissue cells called mast cells, and white blood cells called basophils release histamine (HIHS tuh meen). Histamine causes blood vessels in the injured area to dilate, which makes them more permeable to tissue fluid. These dilated blood vessels cause the redness of an inflamed area. Fluid that leaks from the vessels into the injured tissue helps the body destroy toxic agents and restore homeostasis. This increase in tissue fluid causes swelling and pain, and may also cause a local temperature increase. Inflammation can occur as a reaction to other types of injury as well as infections. Physical force, chemical substances, extreme temperatures, and radiation may also inflame body tissues.

Phagocytosis of pathogens

Pathogens that enter your body may encounter cells that carry on phagocytosis. Recall that phagocytosis occurs when a cell engulfs a particle. **Phagocytes** (FA guh sites) are white blood cells that destroy pathogens by surrounding and engulfing them. Phagocytes include monocytes, which develop into macrophages, neutrophils, and eosinophils. Macrophages are present in body tissues. The other types of phagocytes circulate in the blood.

Macrophages are white blood cells that provide the first defense against pathogens that have managed to enter the tissues. Macrophages, shown in ***Figure 39.8,*** are found in the tissues of the body. They are sometimes called giant scavengers, or big eaters, because of the manner in which they engulf pathogens or

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damaged cells. Lysosomal enzymes inside the macrophage digest the particles it has engulfed.

If the infection is not stopped by the tissue macrophages, another type of phagocyte, called a neutrophil, is attracted to the site. They also destroy pathogens by engulfing and digesting them.

If the infection is not stopped by tissue macrophages and neutrophils, there is a third method of defense. A different type of phagocyte begins to arrive on the scene. Monocytes are small, immature macrophages that circulate in the bloodstream. These cells squeeze through blood vessel walls to move into the infected area. Once they reach the site of the infection they mature and are now called macrophages. They then begin consuming pathogens and dead neutrophils by phagocytosis. Once the infection is over, some monocytes mature into tissue macrophages that remain in the area, prepared to fend off a new infection.

After a macrophage has destroyed large numbers of pathogens, dead neutrophils, and damaged tissue cells, it eventually dies. After a few days, infected tissue harbors a collection of live and dead white blood cells, multiplying and dead pathogens, and body fluids called **pus.** Pus formation usually continues until the infection subsides. Eventually, the pus is cleared away by macrophages.

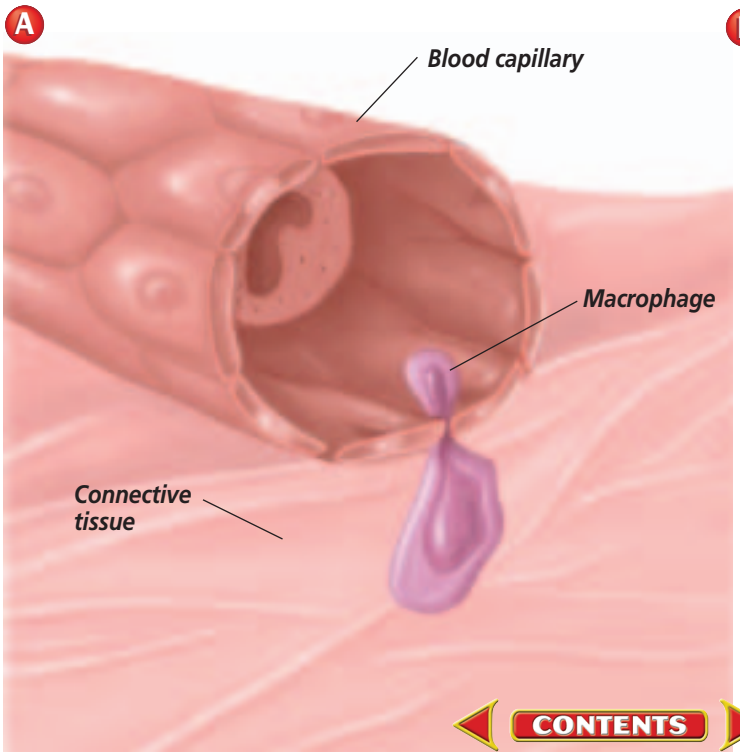
Which white blood cells are involved in the body's defense against pathogens? Find out by looking at ***Figure 39.9*** on the following page and by carrying out the *MiniLab* on page 1035 to observe the different types of white blood cells.

Protective proteins

When an infection is caused by a virus, your body faces a problem. Phagocytes alone cannot destroy viruses. Recall that a virus multiplies within a host cell. A phagocyte that engulfs a virus will itself be destroyed if the virus multiplies within it. One way your body can counteract viral infections is with interferons. **Interferons** are proteins that protect cells from viruses. Interferons are host-cell specific. This means that human interferons will protect human cells from viruses but cannot protect cells of other species from the same virus.

Word Origin

phagocyte from the Greek words *phagein,* meaning "to eat," and *kytos,* meaning "hollow"; A phagocyte consumes foreign particles by engulfing them.



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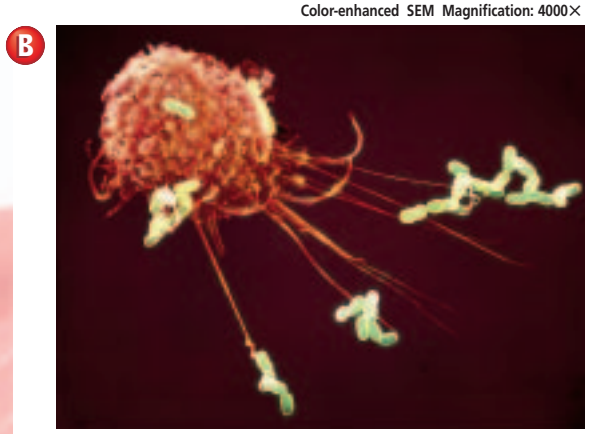

Figure 39.8
Macrophages move out of blood vessels by squeezing between the cells of the vessel walls **(A).** Macrophages will attack anything they recognize as foreign, including microorganisms and dust particles that are breathed into the lungs **(B).**

GMBH/Lennart Nilsson/Bonnier-Alba

INSIDE STORY

Immune Responses

Figure 39.9
White blood cells play a major role in protecting your body against disease. Many of these cells leave the bloodstream to fight disease organisms in the tissues. **Critical Thinking** ***Why would you not expect to see tissue macrophages in a sample of blood cells?***

An abrasion breaks the protective barrier of the skin.

A Innate immune response

Macrophages are large, phagocytic white blood cells found in the tissues. They are the first to arrive at the site of an infection. *Basophils,* found in the blood, are not phagocytic. They are filled with granules that release histamine at an infection site. *Eosinophils* are also granular and also play a role in inflammation.

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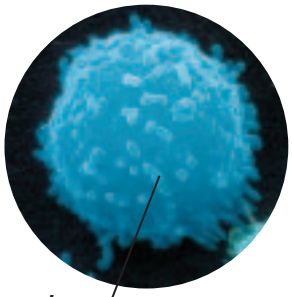

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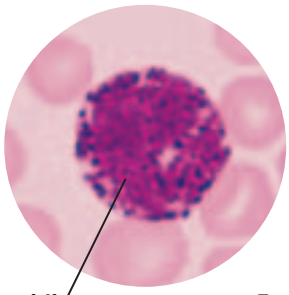

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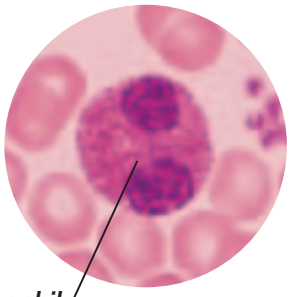

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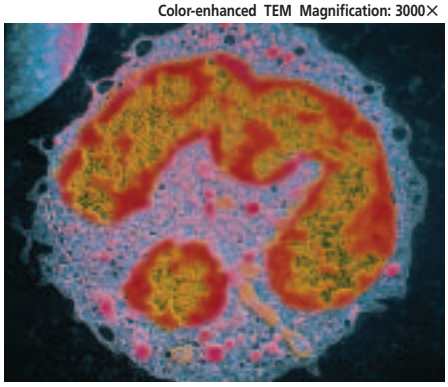
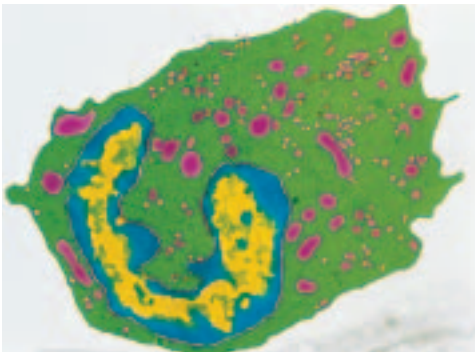


B Second wave of defenders

A *neutrophil* (above) is a phagocytic white blood cell with a nucleus that has several lobes.

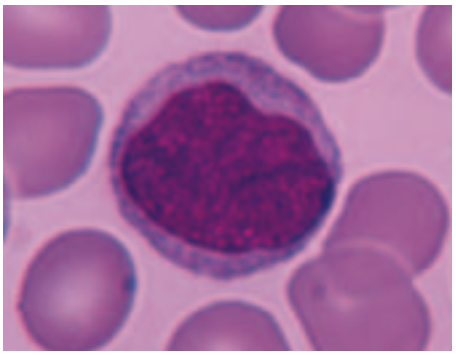
Color-enhanced TEM Magnification: 6600×



C Continued defense

After moving from the blood into an infected area, *monocytes* (above) mature into macrophages. Monocytes are two to three times larger than other blood cells and have large nuclei. They replenish the supply of tissue macrophages following an infection.

Color-enhanced LM Magnification: 750×



D Acquired immune response

Lymphocytes (above) are cells with nuclei that nearly fill the cell. They include B cells and T cells and are involved in developing immunity to specific pathogens. Lymphocytes are found in the blood, spleen, thymus, lymph nodes, tonsils, and appendix.

CONTENTS

Interferon is produced by a body cell that has been infected by the virus. The interferon diffuses to uninfected neighboring cells, which then produce antiviral proteins that can prevent the virus from multiplying.

The lymphatic system

Your lymphatic (lihm FA tihk) system not only helps the body defend itself against disease, but also maintains homeostasis by keeping body fluids at a constant level.

Acquired Immunity

The cells of your innate immune system continually survey your body for foreign invaders. When a pathogen is detected, these cells begin defending your body right away. Meanwhile, as the infection continues, another type of immune response that counteracts the invading pathogen is also mobilized. Certain white blood cells gradually develop the ability to recognize a specific foreign substance. This acquired immune response enables these white blood cells to inactivate or destroy the pathogen. Defending against a specific pathogen by gradually building up a resistance to it is called **acquired immunity.**

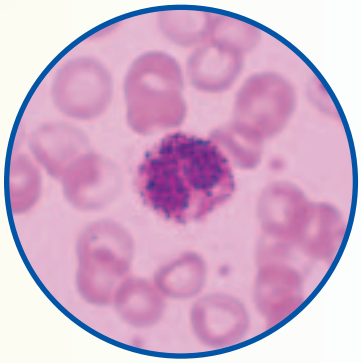
Normally, the immune system recognizes components of the body as self, and foreign substances, called antigens, as nonself. Antigens are usually proteins present on the surfaces of whole organisms, such as bacteria, or on parts of organisms, such as the pollen grains of plants. An acquired immune response occurs when the immune system recognizes an antigen and responds to it by producing antibodies against it. Antigens are foreign substances that stimulate an immune response, and antibodies are proteins in the blood that correspond specifically to each antigen. The development of acquired immunity is the job of the lymphatic system. The process of acquiring immunity to a specific disease can take days or weeks.

MiniLab 39.2

Observe and Infer

Distinguishing Blood Cells The human immune system includes five types of white blood cells in the bloodstream: basophils, neutrophils, monocytes, eosinophils, and lymphocytes.

Color-enhanced LM Magnification: 400×



A blood smear

Procedure

1. Copy the data table below.
2. Mount a prepared slide of blood cells on the microscope and focus on low power. Turn to high power and look for white blood cells. **CAUTION:** ***Use care when working with microscope slides.***
3. Find a neutrophil, monocyte, eosinophil, and lymphocyte. You may see a basophil, although they are rare. Refer to ***Figure 39.9*** for photos of these cells.
4. Count a total of 50 white blood cells, and record how many of each type you see.
5. Calculate the percentage by multiplying the number of each cell type by two. Record the percentages. Diagram each cell type.

Data Table

Type of White Blood Cell	Number Counted	Percent	Diagram
Neutrophil			
Monocyte			
Basophil			
Lymphocyte			
Eosinophil			

Analysis

1. **Summarize** Which type of white blood cell was most common? Second most common?
2. **Describe** How do red and white blood cells differ?

Fred Hossler/Visuals Unlimited

CONTENTS

Figure 39.10
The lymphatic system is spread throughout the body. **Interpret Scientific Illustrations** ***As you read about the various vessels, tissues, and organs of the lymphatic system, locate them on this diagram.***

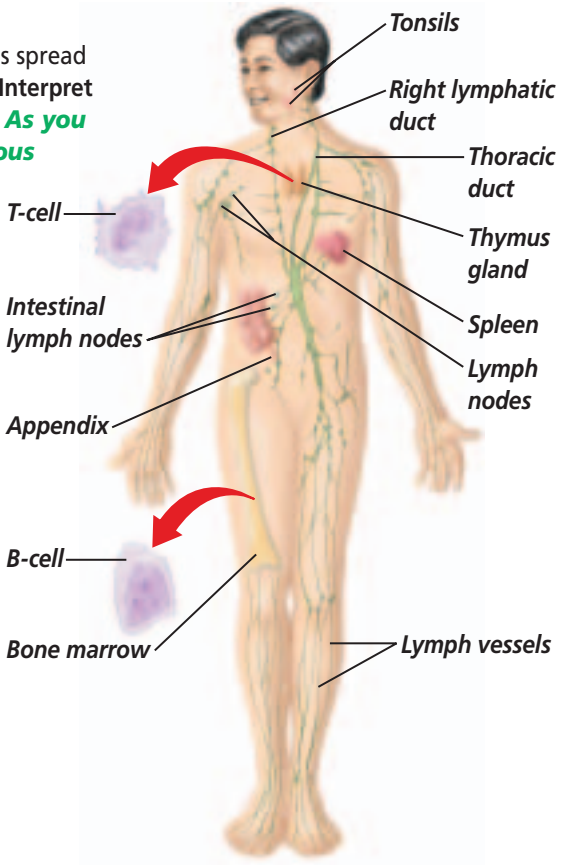


Figure 39.10 shows the major glands and vessels that make up the lymphatic system.

Your body's cells are constantly bathed with fluid. This **tissue fluid** is composed of water and dissolved substances that diffuse from the blood into the spaces between the cells that make up the surrounding tissues. This tissue fluid collects in open-ended lymph capillaries. Once the tissue fluid enters the lymph vessels, it is called **lymph.**

Lymph capillaries meet to form larger vessels called lymph veins. The flow of lymph is only toward the heart, so there are no lymph arteries. The lymph veins converge to form two major lymph ducts. These ducts return the lymph to the bloodstream in the shoulder area, after it has been filtered through various lymph glands.

Reading Check **Describe** how lymph is circulated through the body.

Glands of the lymphatic system

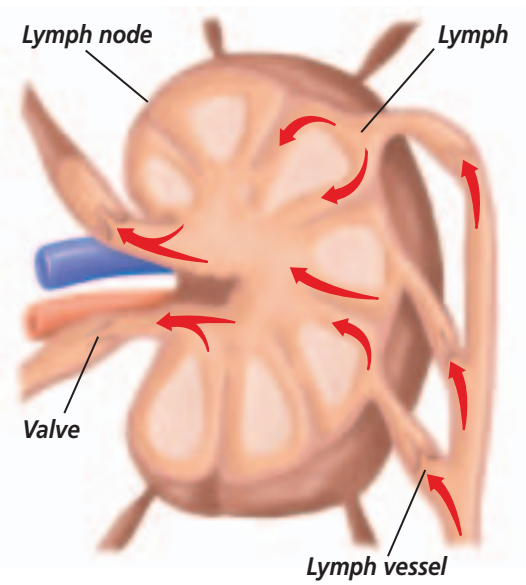
At locations along the lymphatic system, the lymph vessels pass through lymph nodes. A **lymph node** is a small mass of tissue that contains lymphocytes and filters pathogens from the lymph, as shown in *Figure 39.11.* Lymph nodes are made of an interlaced network of connective tissue fibers that holds lymphocytes. A **lymphocyte** (LIHM fuh site) is a type of white blood cell that defends the body against foreign substances.

The tonsils are large clusters of lymph tissue located at the back of the mouth cavity and at the back of the throat. They form a protective ring around the openings of the nasal and oral cavities. Tonsils provide protection against bacteria and other pathogens that enter your nose and mouth.

The spleen is an organ that stores certain types of lymphocytes. It also filters out and destroys bacteria and worn-out red blood cells, and acts as a blood reservoir. Unlike lymph nodes, the spleen does not filter lymph.

Another important component of the lymphatic system is the thymus gland, which is located above the heart. The thymus gland stores immature lymphocytes until they mature and are released into the body's defense system.

Figure 39.11
As lymph filters through a lymph node, the lymphocytes in the node trap and kill pathogens.



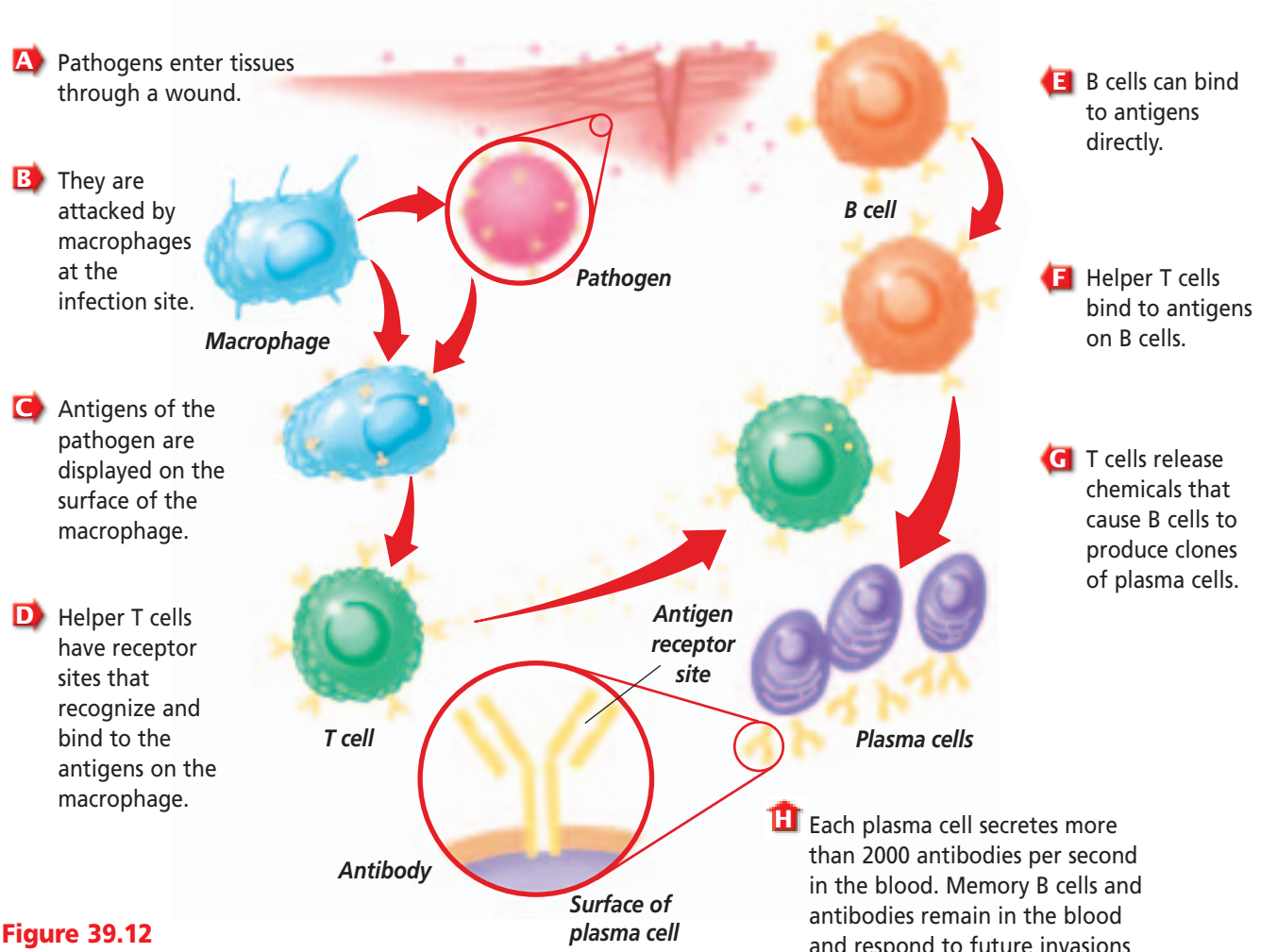


Figure 39.12
Antibody immunity utilizes B cells and antibodies in defending your body against invading pathogens.

Antibody Immunity

Acquired immunity involves the production of two kinds of immune responses: antibody immunity and cellular immunity. Antibody immunity is a type of chemical warfare within your body that involves several types of cells. Follow the steps of antibody immunity illustrated in ***Figure 39.12.***

When a pathogen invades your body, it is first attacked by the cells of your innate immune system, as shown in ***Figure 39.12A, B,*** and ***C.*** If the infection is not controlled, then your body builds up acquired immunity to the antigen by producing antibodies to it. A type of lymphocyte called a T cell becomes involved. A **T cell** is a lymphocyte that is produced in bone marrow and processed in the thymus gland. Two kinds of T cells play different roles in immunity.

One kind of T cell, called a helper T cell, interacts with B cells, shown in ***Figure 39.12D, E,*** and ***F.*** A **B cell** is a lymphocyte that, when activated by a T cell, becomes a plasma cell and produces antibodies. B cells are produced in the bone marrow. Plasma cells, shown in ***Figure 39.12G*** and ***H,*** release antibodies into the bloodstream and tissue spaces. Some activated B cells do not become plasma cells but remain in the bloodstream as memory B cells. Memory B cells are ready and armed to respond rapidly if the same pathogen invades the body at a later time. The response to a second invasion is immediate and rapid, usually without any symptoms.

CONTENTS

Cellular Immunity

Like antibody immunity, cellular immunity also involves T cells with antigens on their surfaces. The T cells involved in cellular immunity are cytotoxic, or killer, T cells. T cells stored in the lymph nodes, spleen, and tonsils transform into cytotoxic T cells that are specific for a single antigen. However, unlike B cells, they do not form antibodies. Cytotoxic T cells differentiate and produce identical clones. They travel to the infection site and release enzymes directly into the pathogens, causing them to lyse and die. The steps in cellular immunity are illustrated in ***Figure 39.13***.

The same cells that protect the body against pathogens can sometimes cause problems within the body. Sometimes the immune system overreacts to a harmless substance such as pollen. Mast cells release histamines in large amounts, causing the symptoms of an allergic reaction: sneezing, increased mucus production in the nasal passages, and redness. The immune system also can recognize its own cells as foreign and mistakenly attack the body's own tissues in what is referred to as an autoimmune disorder, such as lupus or rheumatoid arthritis. T cells and antibodies also can attack transplanted tissue, such as a transplanted kidney, that comes from a source outside the body.

Passive and Active Immunity

Acquired immunity to a disease may be either passive or active. Passive acquired immunity develops as a result of acquiring antibodies that are generated in another host. For example, prior to birth and during nursing, a human infant acquires passive immunity to disease from its mother.

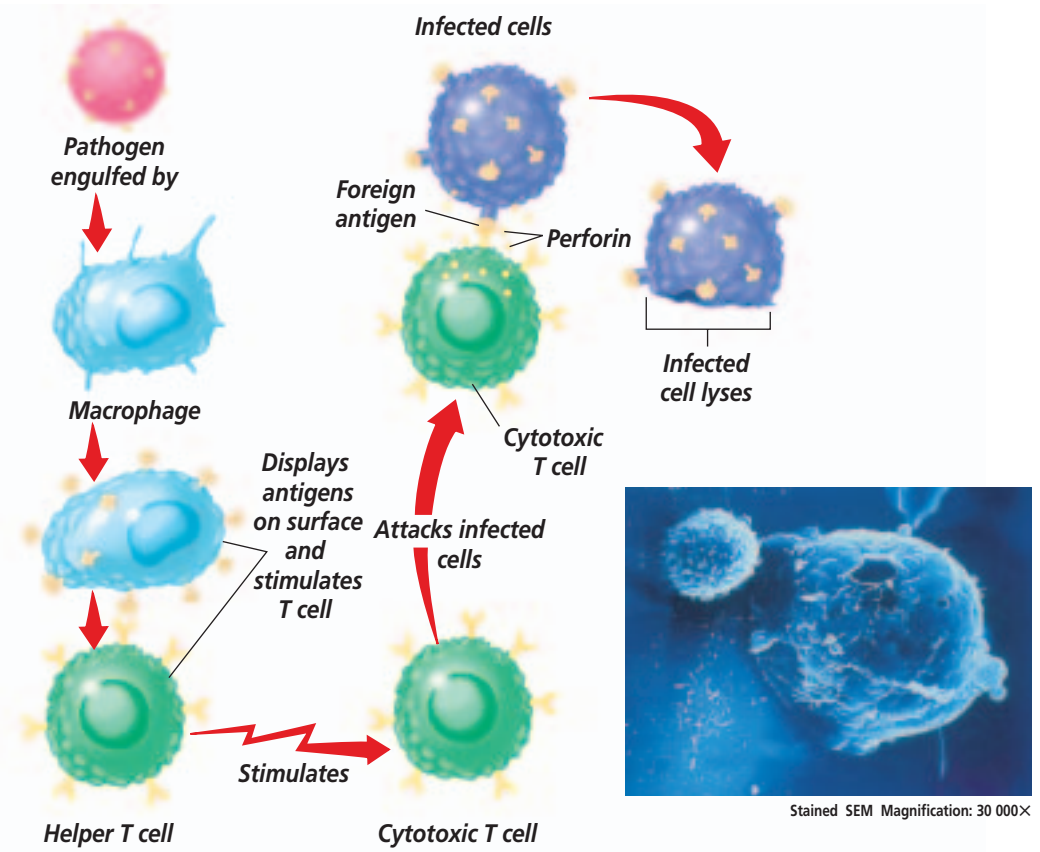


Figure 39.13
Cellular immunity involves T cells that transform into cytotoxic T cells. These T cells release perforin, which pokes holes in cells invaded by pathogens.

Table 39.2 Recommended Childhood Immunizations

Immunization	Agent	Protection Against
Acellular DPT or Tetrammune	Bacteria	Diphtheria, pertussis (whooping cough), tetanus (lockjaw)
MMR	Virus	Measles, mumps, rubella
OPV	Virus	Poliomyelitis (polio)
HBV	Virus	Hepatitis B
HIB or Tetrammune	Bacteria	*Haemophilus influenzae B* (spinal meningitis)

Active acquired immunity develops when your body is directly exposed to antigens and produces antibodies in response to those antigens.

Reading Check **Explain** the difference between passive acquired immunity and active acquired immunity.

Passive immunity

Passive immunity may develop in two ways. Natural passive immunity develops when antibodies are transferred from a mother to her unborn baby through the placenta or to a newborn infant through the mother's milk. Artificial passive immunity involves injecting into the body antibodies that come from an animal or a human who is already immune to the disease. For example, a person who is bitten by a snake might be injected with antibodies from a horse that is immune to the snake venom.

Active immunity

Active immunity is obtained naturally when a person is exposed to antigens. The body produces antibodies that correspond specifically to these antigens. Once the person recovers from the infection, he or she will usually be immune if exposed to the pathogen again.

Active immunity can be induced artificially by vaccines. A **vaccine** is a substance consisting of weakened, dead, or incomplete portions of pathogens or antigens that, when injected into the body, cause an immune response. Vaccines produce immunity because they prompt the body to react as if it were naturally infected. ***Table 39.2*** lists some common vaccines.

In the late 1790s, Edward Jenner, an English country doctor shown in ***Figure 39.14,*** demonstrated the first safe vaccination procedure. Jenner knew that dairy workers who acquired cowpox from infected cows were resistant to catching smallpox during epidemics. Cowpox is a disease similar to, but milder than, smallpox. To test whether immunity to cowpox also caused immunity to smallpox, Jenner infected a young boy with cowpox. The boy developed a mild cowpox infection. Six weeks later, Jenner scratched the skin of the boy with viruses from a smallpox victim.

Science VU/Visuals Unlimited

Figure 39.14
This portrait shows Jenner vaccinating a young boy against smallpox. A worldwide attack on the disease through vaccinations brought an end to it. Because of the efforts of the World Health Organization, smallpox has been eliminated.

The viruses for cowpox and smallpox are so similar that the immune system cannot tell them apart. The boy, therefore, did not get sick because he had artificially acquired active immunity to the disease. To learn more about how vaccines work, try the *Problem-Solving Lab* on this page.

Problem-Solving Lab 39.2

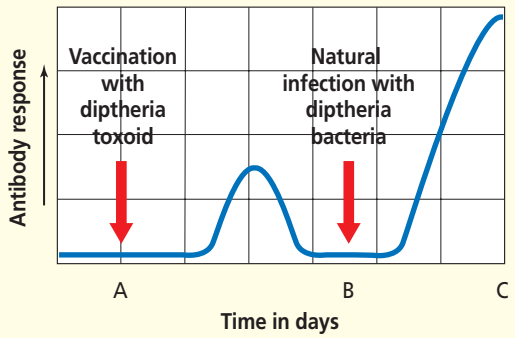
Analyze Information

Get a Shot or Get the Disease? You probably have had injections for immunization. How do these shots prevent you from catching a particular disease?

Solve the Problem

Diphtheria toxoid is an inactivated form of the toxin produced by the bacterium *Corynebacterium diphtheriae.* The toxin causes the symptoms associated with the disease diphtheria. When injected into your body, the toxoid prompts the immune system to respond as if it were being attacked by the diphtheria toxin. The graph below shows the human body's response to receiving an immunization shot of the diphtheria toxoid and then to being infected later on with diphtheria.

Antibody Response to Diptheria Antigens



Thinking Critically

1. **Explain** Are the events in the graph illustrating innate or acquired immunity?
2. **Describe** What is the difference between a toxin and a toxoid?
3. **Analyze** Which cells associated with the immune system are most likely involved with line A–B? With line B–C?

AIDS and the Immune System

In 1981, an unusual cluster of cases of a rare pneumonia caused by a protozoan appeared in the San Francisco area. Medical investigators soon related the appearance of this disease with the incidence of a rare form of skin cancer called Kaposi's sarcoma. Both diseases seemed associated with a general lack of function of the body's immune system.

By 1983, the pathogen causing this immune system disease had been identified as a retrovirus, now known as Human Immunodeficiency (ih myew noh dih FIH shun see) Virus, or HIV. HIV kills helper T cells and leads to the disorder known as Acquired Immune Deficiency Syndrome, or AIDS.

HIV is transmitted when blood or body fluids from an infected person are passed to another person through direct contact, or through contact with objects that have been contaminated by infected blood or other body fluids. Methods of transmission include intimate sexual contact, contaminated intravenous needles, and blood-to-blood contact, such as through transfusions of contaminated blood.

Since 1985, careful screening measures have been instituted by blood banks in the United States to help keep HIV-infected blood from being given to people who need transfusions. A pregnant woman infected with the virus can transmit it to her fetus. The virus can also be transmitted through breast milk.

Abstinence from intimate sexual contact provides protection from HIV and other sexually transmitted diseases. Among illegal drug users, HIV transmission can be prevented by not sharing needles.

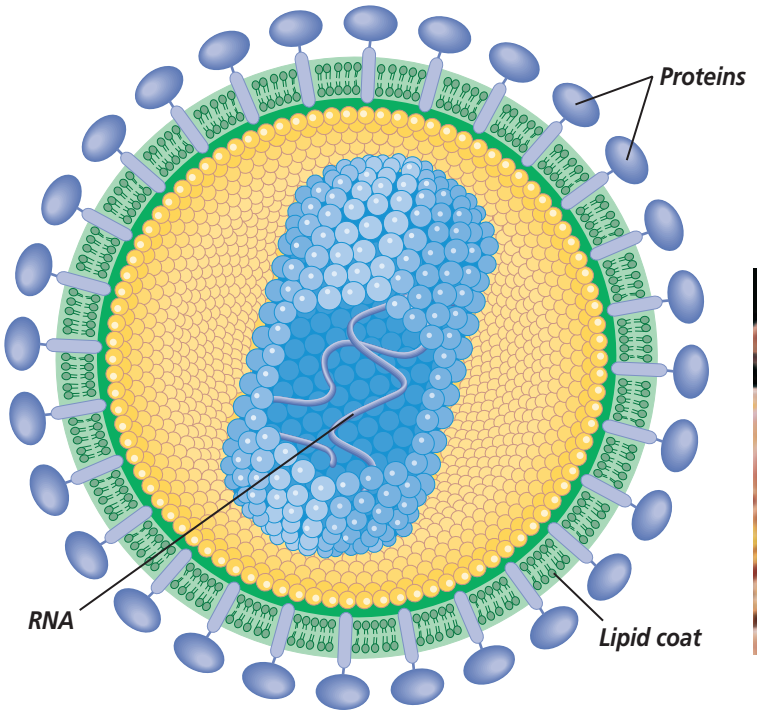
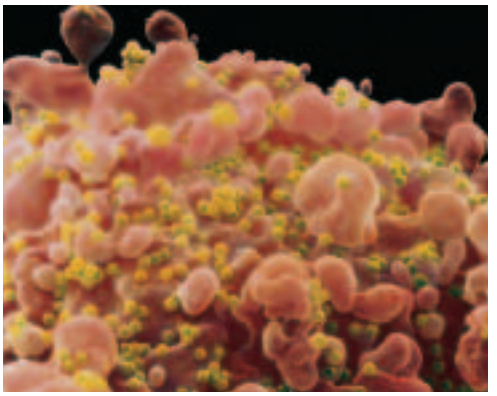


Figure 39.15
HIV is a retrovirus with an outer envelope covered with knoblike attachment proteins. Researchers are studying these proteins to find ways to stop the spread of the virus in humans. The photo shows a T-lymphocyte with yellow-green HIV particles on its surface.



Color-enhanced SEM Magnification: 40 000×

The HIV virus in ***Figure 39.15*** is basically two copies of RNA wrapped in proteins, then further wrapped in a lipid coat. The knoblike outer proteins of the virus attach to a receptor on a helper T cell. The virus can then penetrate the cell, where it may remain inactive for months. HIV contains the enzyme reverse transcriptase, which allows the virus to use its RNA to synthesize viral DNA in the host cell.

The first symptoms of AIDS may not appear for eight to ten years after initial HIV infection. During this time, the virus reproduces and infects an increasing number of T cells. Infected persons may eventually develop AIDS. During the early stages of the disease, symptoms may include swollen lymph nodes, a loss of appetite and weight, fever, rashes, night sweats, and fatigue.

It is not known what percentage of persons infected with HIV will develop AIDS, but the majority of those untreated will. In most cases, as AIDS progresses, infectious diseases or certain forms of cancer take advantage of the body's weakened immune system and homeostasis is severely disrupted.

Section Assessment

Understanding Main Ideas

1. Identify the structures of and interpret the functions of the immune system.
2. Explain the difference between innate immunity and acquired immune responses.
3. What role do phagocytes play in defending the body against disease?
4. What role does a lymph node play in defending your body against microorganisms?

Thinking Critically

5. Why is it adaptive for memory cells to remain in the immune system after an invasion by pathogens?

Skill Review

6. **Get the Big Picture** Sequence the events that occur in the formation of antibody and cellular immunity. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

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INTERNET

BioLab

Information on Emerging and Re-emerging Diseases

Before You Begin

Emerging diseases are those in which the incidence in humans has increased within the past 20 years or threatens to increase in the near future. These diseases may be new or a mutation of an existing organism, or may be an already identified disease that has spread to a new geographic area or population. Re-emerging diseases are ones that have increased in incidence after a time of decline. Disease agencies are constantly monitoring our world for these types of diseases.

PREPARATION

Problem

How can you obtain current research information on emerging and re-emerging diseases?

Objectives

In this BioLab, you will:

- **Choose** five emerging and five re-emerging diseases for study.
- **Collect** data on the ten diseases and record in a table.

Materials

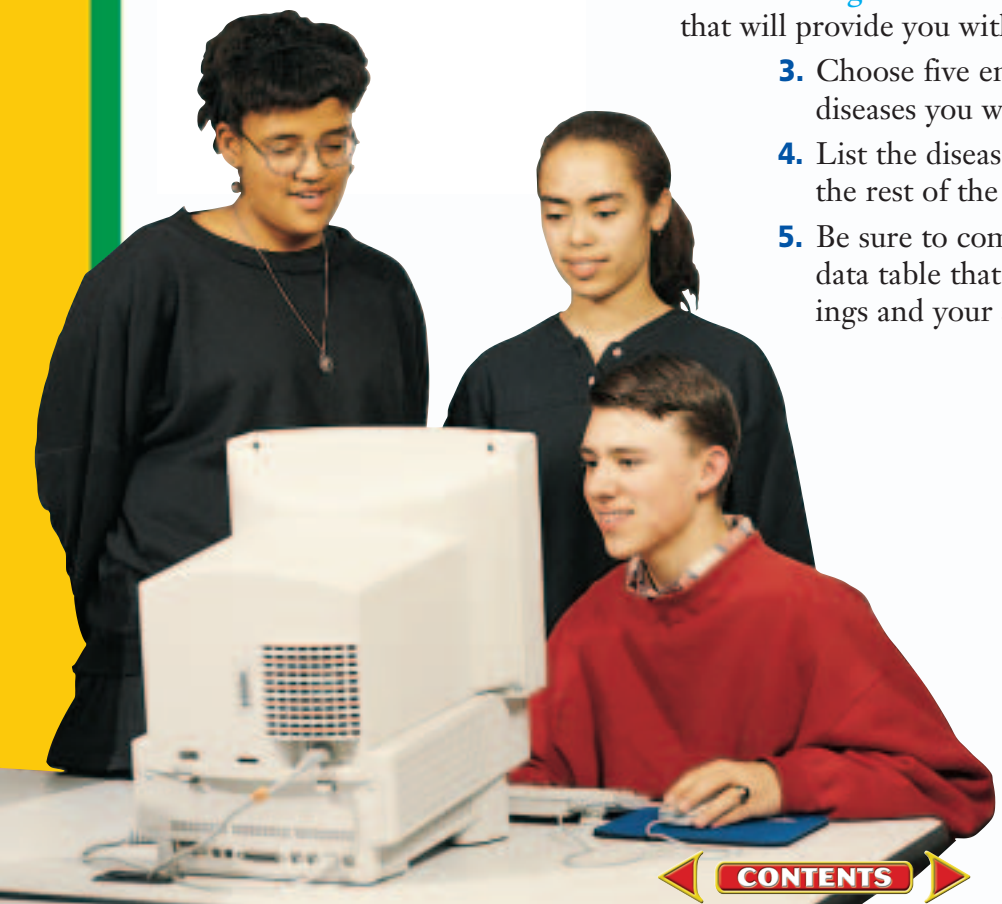
access to the Internet

Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

PROCEDURE

1. Copy the two data tables on the next page.
2. Go to **bdol.glencoe.com/internet_lab** to find links that will provide you with information for this BioLab.
3. Choose five emerging and five re-emerging diseases you wish to investigate.
4. List the diseases in your data tables and fill in the rest of the columns.
5. Be sure to complete the last two rows of your data table that ask for current research findings and your sources of information.



Life Images

CONTENTS

Data Table 1

Emerging Diseases					
	1	2	3	4	5
Disease name					
Organism responsible					
Classification of organism					
Mode of transmission					
Symptoms					
Treatment					
Current research					
Source of information					

Data Table 2

Re-emerging Diseases					
	1	2	3	4	5
Disease name					
Organism responsible					
Classification of organism					
Mode of transmission					
Symptoms					
Treatment					
Current research					
Source of information					

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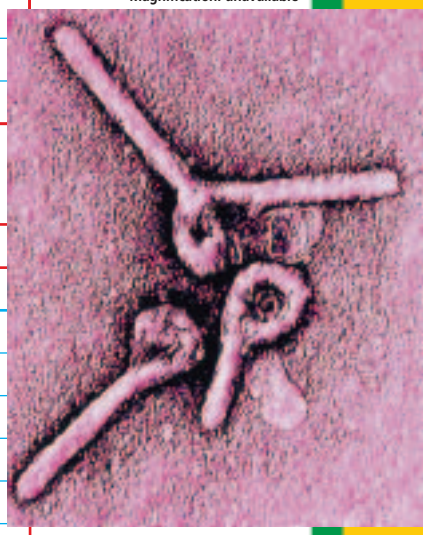

Ebola virus

Analyze and Conclude

1. **Define** What is a pathogen? Provide several examples.
2. **Contrast** Describe the difference between an emerging and a re-emerging disease. Provide several examples of each.
3. **Think Critically** Hypothesize why a disease that was once on the decline might re-emerge.
4. **Apply Concepts** Compared with travel in the 1800s, how would current worldwide travel affect the transmission of disease?
5. **Use the Internet** What are some advantages and disadvantages of getting information on disease research by way of the Internet rather than from textbooks or an encyclopedia?

Share Your Data

Interpret Data Find this BioLab using the link below, and post your data in the data table provided for this activity. Using the additional data from other students on the Internet, analyze the data and complete your data tables.

bdol.glencoe.com/internet_lab

Richard J. Green/Photo Researchers

CONTENTS

Destroy or Preserve? The Debate over Smallpox

In 1980, the World Health Organization (WHO) announced an amazing victory in the field of health care—the first disease, smallpox, had been eradicated from the human population. Throughout history, this virus has killed an estimated 500 million people. Smallpox cultures still exist in two laboratories—one in the United States and the other in Russia. Now scientists must decide: Should these cultures be destroyed or preserved?

Smallpox is a highly contagious disease that infects internal organs and can cause blindness, disfigurement, and in 30 percent of cases, death. The only natural reservoir for the virus that causes smallpox is the human body. Smallpox was the first disease for which an effective vaccine was developed. Although vaccination offers protection, the United States and other developed countries stopped their smallpox vaccination programs decades ago. As a result, many people are not protected against the deadly disease. Destroying the virus would seemingly ensure that no one would ever again be infected by smallpox.

The anti-smallpox argument Proponents of destroying the cultures raise additional points. They note that the DNA sequence of the virus has been mapped. This should allow scientists to "reconstruct" the virus in the event that unknown reserves exist either in the natural environment or in other labs. The smallpox virus itself is not used in the vaccine. Some people feel these dangerous cultures should not be kept because it increases the risk that they may accidentally—or worse, deliberately—be let loose on the world.

The pro-smallpox argument Those in favor of preserving the smallpox cultures counter that no one can be absolutely certain that the virus has indeed been contained in only two laboratories.

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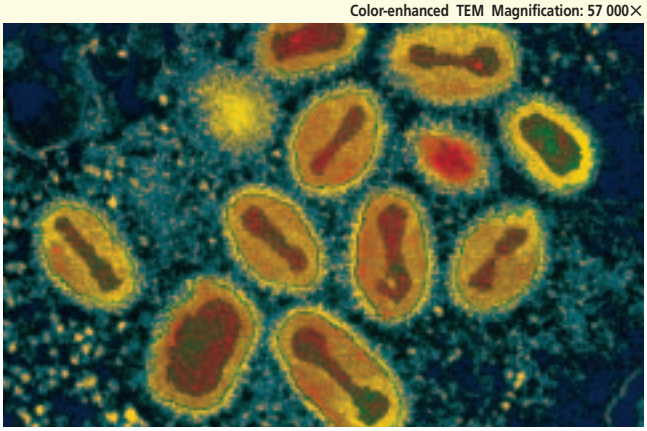


The virus that causes smallpox has an envelope.

Other hidden cultures may exist. If so, destroying the known cultures will not necessarily protect the world against a smallpox outbreak. In addition, some scientists argue that a DNA map of the virus is insufficient for study purposes. In their opinion, it is crucial to study the virus intact because that is the best way to learn about—and develop strategies against—devastating diseases that attack the human body.

Perspectives The World Health Organization recognizes the complexity of the debate. WHO is made up of global representatives who, among other tasks, offer recommendations about health-care issues that affect the world at large. Since 1986, WHO has consistently stated that the smallpox cultures should be destroyed. However, fear of bioterrorism has risen steadily since that time. In 2002, WHO reversed its stance. Now, the organization says that the remaining cultures should be preserved until new vaccines or other treatments against smallpox are developed. This will also give scientists more time to study the virus.

Forming Your Opinion

Think Critically Review the arguments for and against the complete destruction of the smallpox virus. What ethical issues are involved? In your view, should the smallpox virus be destroyed or preserved? Organize a classroom debate about the issue.

To find out more about the debate over smallpox, visit bdol.glencoe.com/biology_society

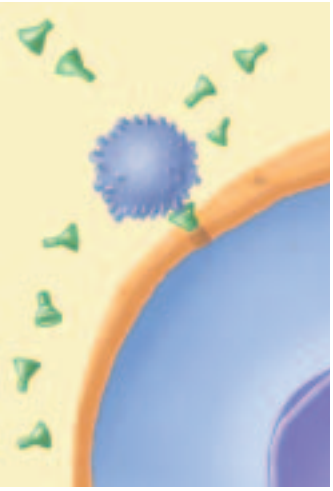
O. Meckes/e.o.s/Gelderblom/Photo Researchers

Chapter 39 Assessment

Study Guide

Section 39.1

The Nature of Disease



Key Concepts

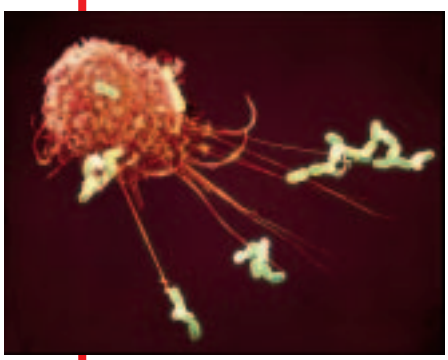
- Infectious diseases are caused by the presence of pathogens in the body.
- The cause of an infection can be established by following Koch's postulates.
- Animals, including humans, and nonliving objects can serve as reservoirs of pathogens. Pathogens can be transmitted by direct contact, by a contaminated object, through the air, or by a vector.
- Symptoms of a disease are caused by direct damage to cells or by toxins produced by the pathogen.
- Some diseases occur periodically, whereas others are endemic. Occasionally, a disease reaches epidemic proportions.
- Some infectious diseases can be treated with antibiotics, but pathogens may become resistant to these drugs.

Vocabulary

antibiotic (p. 1029)
endemic disease (p. 1029)
epidemic (p. 1029)
infectious disease (p. 1024)
Koch's postulates (p. 1025)
pathogen (p. 1023)

Section 39.2

Defense Against Infectious Diseases



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Key Concepts

- Innate immunity provides general protection against various pathogens.
- Innate immunity includes the physical barrier of the skin as well as mucus, lysozymes in sweat, oil, tears, and saliva, the inflammation response, phagocytosis, and interferons.
- Acquired immunity provides a way of fighting specific pathogens by recognizing invaders as nonself. It includes antibody and cellular immunity.
- The lymphatic system consists of the lymphatic vessels and the lymphatic organs: lymph nodes, tonsils, spleen, and thymus.
- Passive immunity develops as a result of acquiring antibodies generated in another host. Active acquired immunity develops when the body is directly exposed to antigens and produces antibodies in response.

Vocabulary

acquired immunity (p. 1035)
B cell (p. 1037)
innate immunity (p. 1031)
interferons (p. 1033)
lymph (p. 1036)
lymph node (p. 1036)
lymphocyte (p. 1036)
macrophage (p. 1032)
phagocyte (p. 1032)
pus (p. 1033)
T cell (p. 1037)
tissue fluid (p. 1036)
vaccine (p. 1039)

FOLDABLES

To help you review disease, use the Organizational Study Fold on page 1023.

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GMBH/Lennart Nilsson/Bonnier-Alba

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Chapter 39 Assessment

Vocabulary Review

Review the Chapter 39 vocabulary words listed in the Study Guide on page 1045. Determine if each statement is true or false. If false, replace the underlined word with the correct vocabulary word.

1. An antibiotic is a disease-causing agent such as a bacterium or a virus.
2. A disease that is constantly present in a population is called an epidemic.
3. Defending against a specific pathogen by gradually building up a resistance to it is called innate immunity.
4. A B cell is a lymphocyte that is produced in bone marrow and processed in the thymus gland.

Understanding Key Concepts

5. Any disease caused by the presence of pathogens in the body is called a(n) _____.
   A. infectious disease
   B. endemic disease
   C. epidemic disease
   D. harmless disease
6. Which of the following is NOT an example of transmission of a disease by a vector?

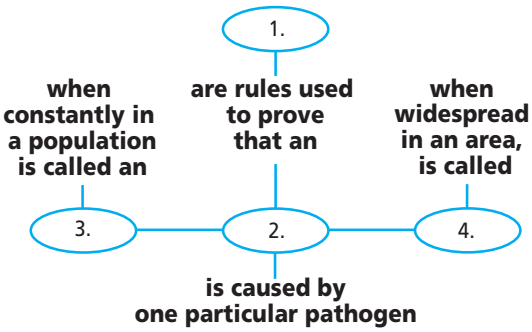
A.


C.


B.


D.


7. _____ is a body response to an injury, characterized by redness, swelling, pain, and heat.
   A. Inflammation
   B. Fever
   C. Sweating
   D. Headache
8. A person is given an injection that contains antibodies against the hepatitis A virus. This is an example of which type of immunity?
   A. natural passive immunity
   B. artificial passive immunity
   C. natural active immunity
   D. artificial active immunity
9. Complete the concept map by using the following vocabulary terms: infectious disease, endemic, Koch's postulates, epidemic.



Constructed Response

10. **Open Ended** Summarize the role of microorganisms such as bacteria in maintaining and disrupting homeostasis in humans.
11. **Open Ended** Explain how disease is a failure of homeostasis. Include a specific example in your response.
12. **Open Ended** A new mother had chicken pox as a child. Why doesn't her newborn infant get the disease, even after being exposed to the virus that causes it?

Thinking Critically

13. **Infer** Why would it be helpful to an infected person's survival to receive an injection of blood serum from someone who has survived the same disease?
14. **REAL WORLD BIOCHALLENGE** Visit bdol.glencoe.com to research past episodes in which biological agents for warfare or terrorism have been used. What type of bioterrorism threats is the world currently preparing for? Give a multimedia presentation about your results to your class.

15. Design an Experiment Several weeks after buying a new pet parakeet, Johann became ill with flu-like symptoms. When he visited the pet store again, many of the parakeets were ill. Design an experiment that would determine if Johann had the same disease as the birds.

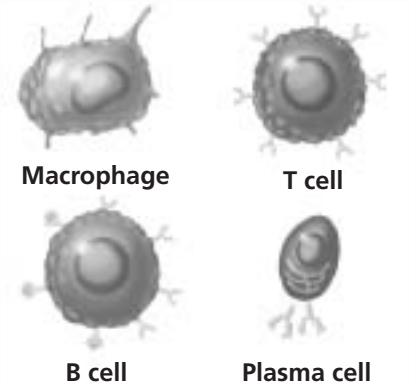
16. Infer Some hereditary disorders result in a person being unable to produce B cells or T cells. What effects would this have on a person's immunity? How would this affect the body overall?

Standardized Test Practice

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

Use the diagram to answer questions 17–19.

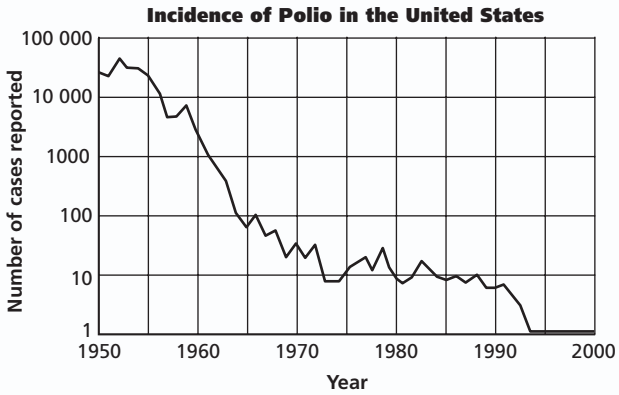


17. When a pathogen enters the body, which cells usually are the first to attack it?
A. macrophages
B. T cells
C. B cells
D. plasma cells

18. Which of the above cells are responsible for antibody production?
A. macrophages
B. T cells
C. B cells
D. plasma cells

19. Which of the following cells are destroyed in an AIDS infection?
A. macrophages
B. helper T cells
C. B cells
D. memory B cells

Study the graph and answer questions 20–22.



20. During which ten-year period were the highest numbers of polio cases reported?
A. 1950s **C.** 1970s
B. 1960s **D.** 1980s

21. How many more cases of polio were reported in the year 1980 than in the year 2000?
A. 100 **C.** 9
B. 50 **D.** 0

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

22. Open Ended Children in the United States began to get vaccinated against polio in 1954. A second type of polio vaccine began to be used in 1963. Explain how vaccines provide immunity against disease. What could account for the cases of polio still occurring after the use of the vaccines?

23. Open Ended If the bacterium that causes tetanus is easily killed by penicillin, why doesn't penicillin cure the disease tetanus?

bdol.glencoe.com/standardized_test

The Human Body

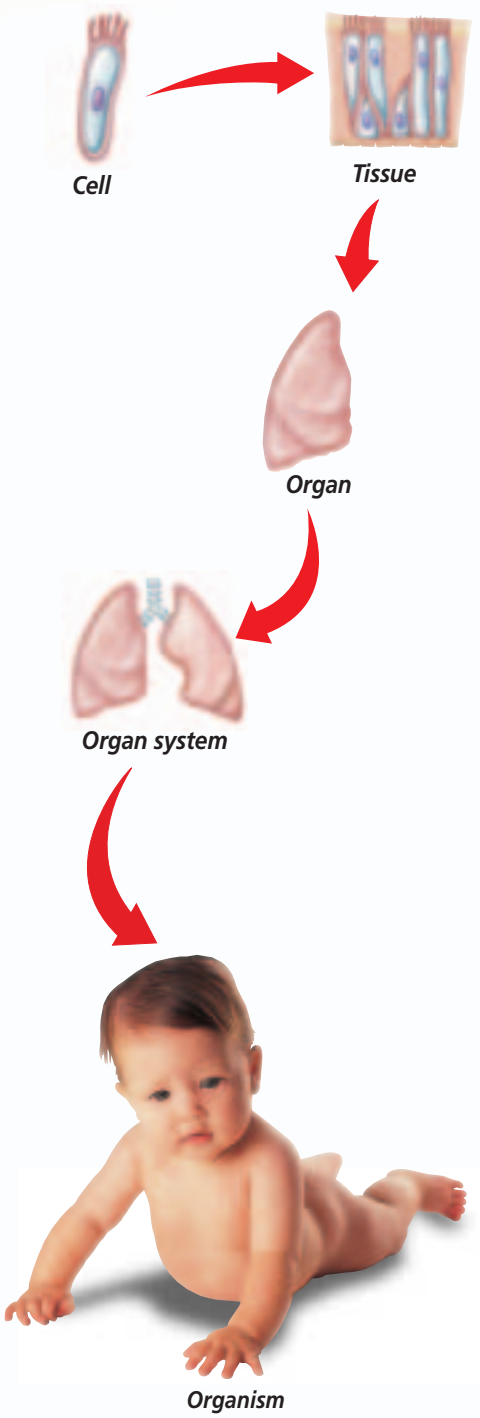
How do the human body systems function together? When an Olympic ice-skater performs on the ice, the cells, tissues, organs, and organ systems of the skater's body function together to help the athlete perform at his or her best and perhaps win a gold medal. All body systems must work together to make an award-winning performance possible.

Levels of Organization

All organisms are made of cells. In complex organisms, such as humans, most cells are organized into functional units called tissues. The four basic tissues of the human body are epithelium, muscle, connective, and nervous tissues. Epithelium covers the body and lines organs, vessels, and body cavities. Muscle tissue is contractile and is found attached to bones and in the walls of organs, such as the heart. Connective tissue is widely distributed throughout the body. It produces blood and provides support, binding, and storage. Nervous tissue transmits impulses that coordinate, regulate, and integrate body systems.

Tissues to Systems

Groups of tissues that perform specialized functions are called organs. Your stomach and eyes are examples of organs. Most organs contain all four basic tissue types. Each of the body's organs is part of an organ system. An organ system contains a group of organs that work together to carry out a major life function. The major organ systems of the human body are described in this BioDigest.



Levels of organization: cell, tissue, organ, organ system, organism

David Pollack/The Stock Market

CONTENTS

Skin

The skin and its associated structures, including hair, nails, sweat glands, and oil glands, are important in maintaining homeostasis in the body. The skin protects tissues and organs, helps regulate body temperature, produces vitamin D, and contains sensory receptors.

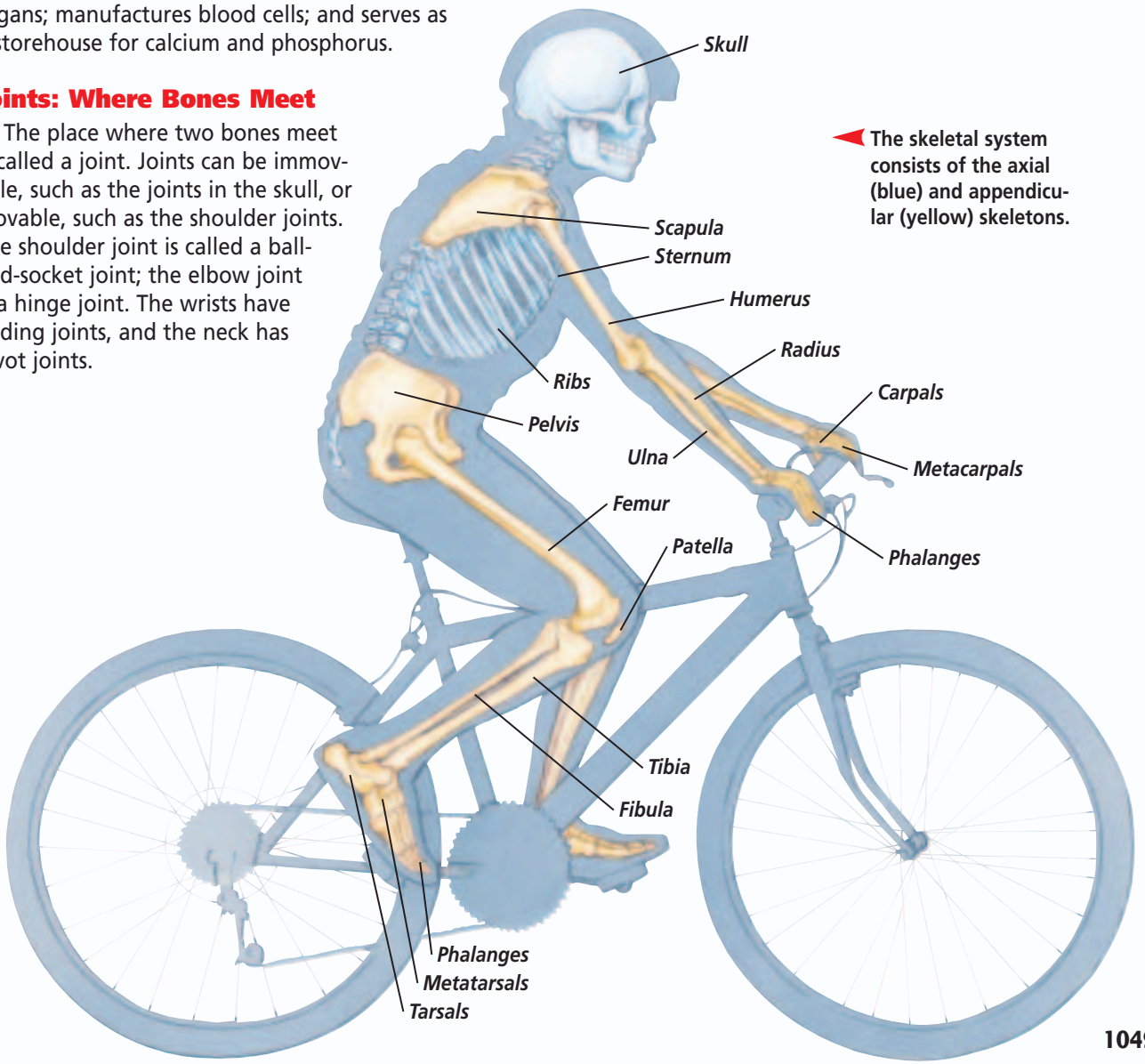
Skin structure varies somewhat from place to place on the body.

Skeletal System

The skeletal system consists of the axial skeleton and appendicular skeleton. The axial skeleton supports the head and includes the skull and the bones of the back and chest. The appendicular skeleton contains the bones associated with the limbs. The entire skeleton, which is made up of 206 bones, has many functions. It provides support for the softer, underlying tissues; provides a place for muscle attachment; protects vital organs; manufactures blood cells; and serves as a storehouse for calcium and phosphorus.

Joints: Where Bones Meet

The place where two bones meet is called a joint. Joints can be immovable, such as the joints in the skull, or movable, such as the shoulder joints. The shoulder joint is called a ball-and-socket joint; the elbow joint is a hinge joint. The wrists have gliding joints, and the neck has pivot joints.



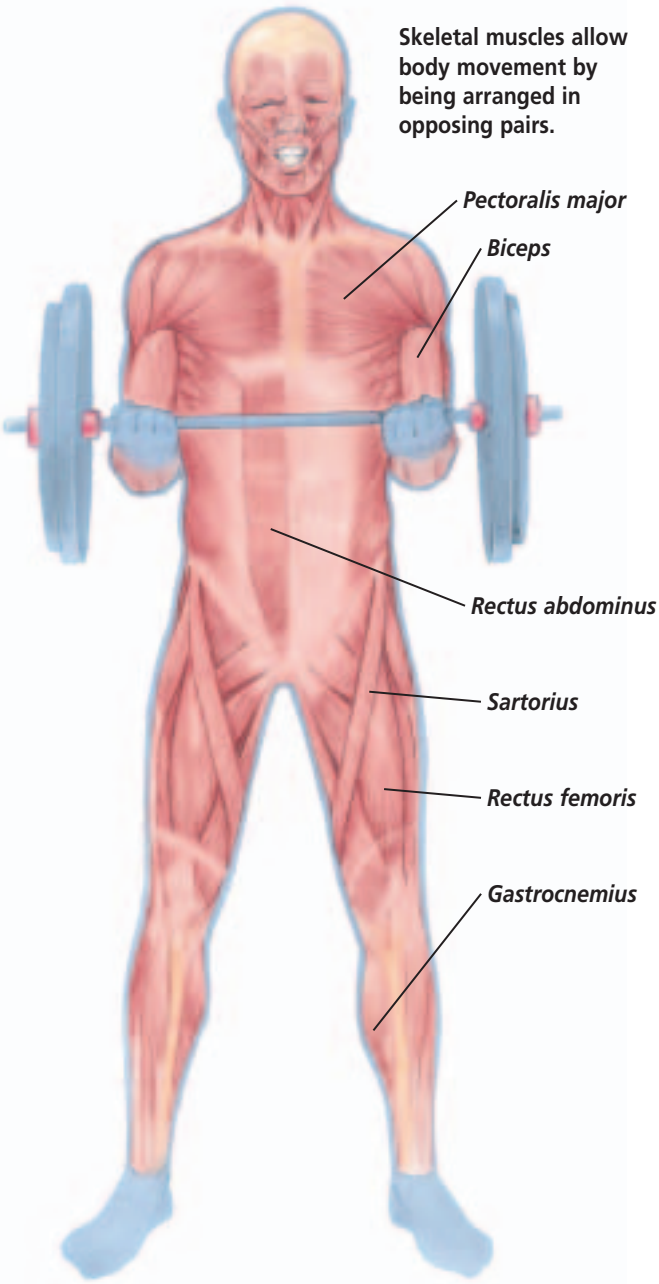
The skeletal system consists of the axial (blue) and appendicular (yellow) skeletons.

Muscular System

The muscular system includes three types of muscles: smooth, cardiac, and skeletal.

Smooth Muscle

Smooth muscles are found in the walls of hollow internal organs, such as inside the stomach or blood vessels. These muscles are not under conscious control and are called involuntary muscles. Smooth muscle contracts to exert pressure on the space inside the tube or organ it surrounds in order to move material through it.



Skeletal muscles allow body movement by being arranged in opposing pairs.

During physical activity, almost every muscle can be involved, either voluntarily or by reflex actions.

Skeletal Muscle

Skeletal muscles are usually attached to bones and allow body movement. They can be controlled by conscious effort so they are called voluntary muscles. Skeletal muscle tissue is made up of long, threadlike cells, called fibers, which have alternating dark and light striations. Each fiber has many nuclei.

Heart Muscle

Cardiac muscle tissue is found only in the heart. These cells contain a single nucleus and have striations made up of organized protein filaments that are involved in contraction of the muscle. Like smooth muscle, cardiac muscle is involuntary muscle. Cardiac muscle has the unique ability to contract without first being stimulated by nervous tissue.

Vital Statistics

Muscles

Most powerful skeletal muscle: The muscle you sit on is the gluteus maximus; it moves the thighbone away from the body and straightens the hip joint.

Longest muscle: The sartorius muscle runs from the waist to the knee and flexes the hip and knee.

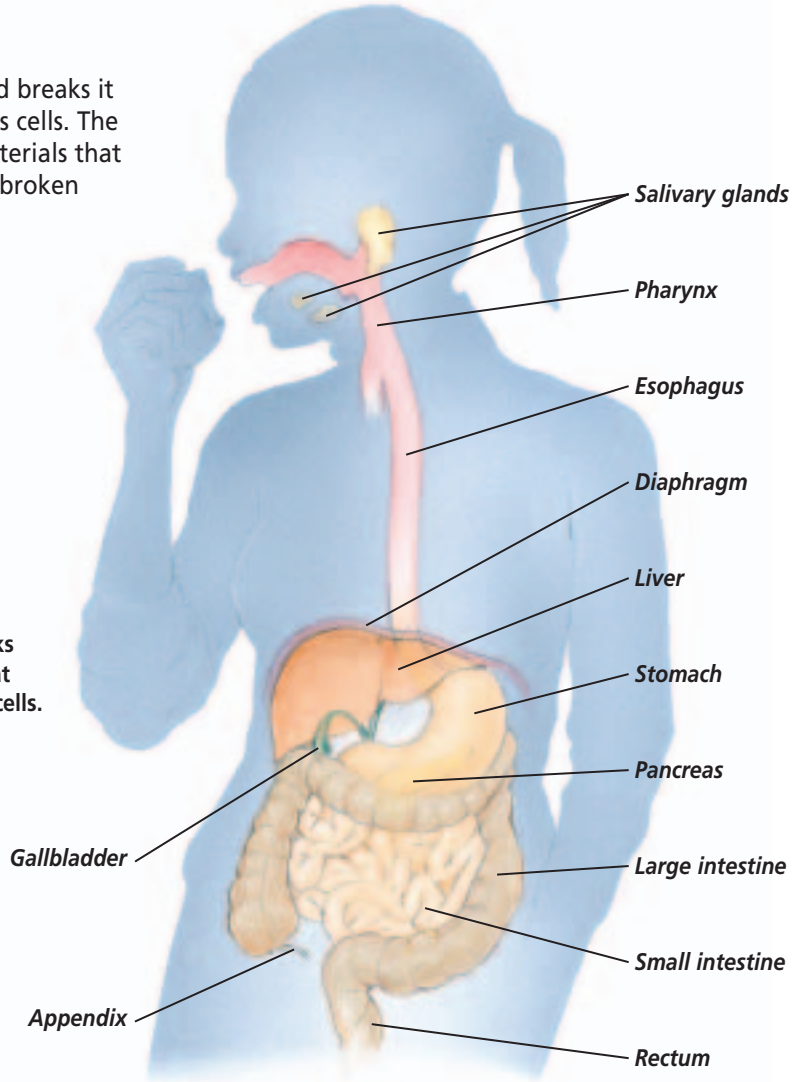
A broad smile: A smile uses 17 facial muscles; a frown uses more than 40.

Allsport Concepts

CONTENTS

Digestive System

The digestive system receives food and breaks it down so it can be absorbed by the body's cells. The digestive system also eliminates food materials that are not digested or absorbed. Foods are broken down into simpler molecules that can move through cell membranes and be transported to all parts of the body by the bloodstream or the lymphatic vessels. The digestive system includes the mouth, tongue, teeth, salivary glands, pharynx, esophagus, stomach, liver, gallbladder, pancreas, and small and large intestines.



The digestive system breaks down food particles so that they can enter the body's cells.

Focus on Health

Blood Glucose Levels

Blood glucose levels rise as carbohydrates are digested and absorbed into the blood.

Levels of glucose in the blood are maintained all day long by hormones secreted by the pancreas. After a meal, the sugars from the food are transported into the blood, raising the blood glucose level. The sugars are either used immediately for activity or stored in the liver for later use. The pancreas secretes insulin, which helps the body's cells take up the sugar or convert it to glycogen in the liver for storage.

Between meals, when blood glucose levels go down, the pancreas secretes glucagon. Glucagon causes the glycogen in the liver to be broken down into glucose, which is then released into the bloodstream and made available to the body's cells. The control of blood sugar levels in the body is an example of a feedback mechanism that is vital for maintaining homeostasis.

Digital Stock

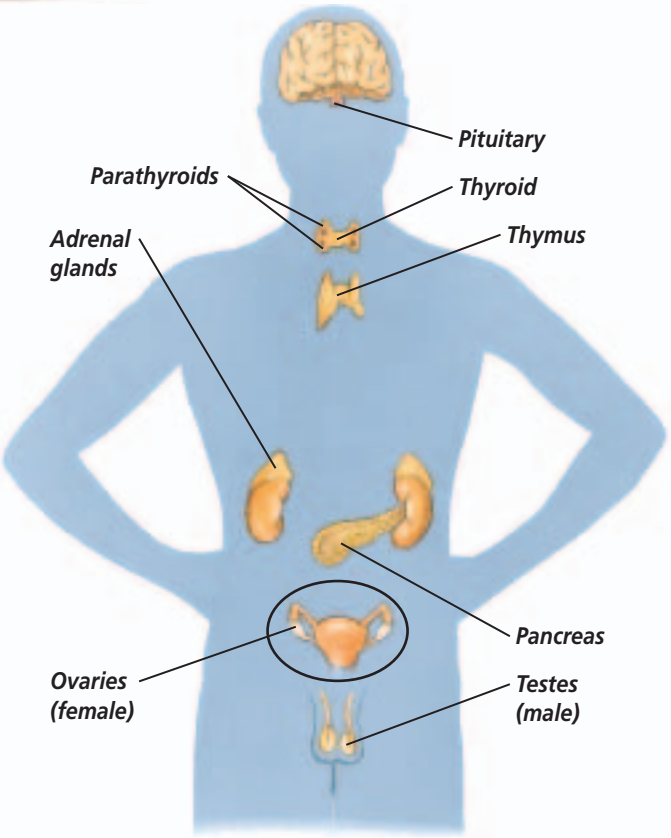
Endocrine System

The endocrine system controls all of the metabolic activities of body structures. This system includes all of the glands in the body that secrete chemical messengers called hormones. Hormones travel in the bloodstream to target cells, where they alter the metabolism of the target cell. Some of the major endocrine glands include the pituitary, thyroid, parathyroids, adrenals, pancreas, ovaries, and testes.

Nervous System

The organs of the nervous system include the brain, spinal cord, nerves, and sensory receptors. These organs contain nerve cells, called neurons, that conduct impulses. Nerve impulses allow the neurons to communicate with each other and with the cells of muscles and glands. Each impulse consists of an electrical charge that travels the length of a neuron's cell membrane.

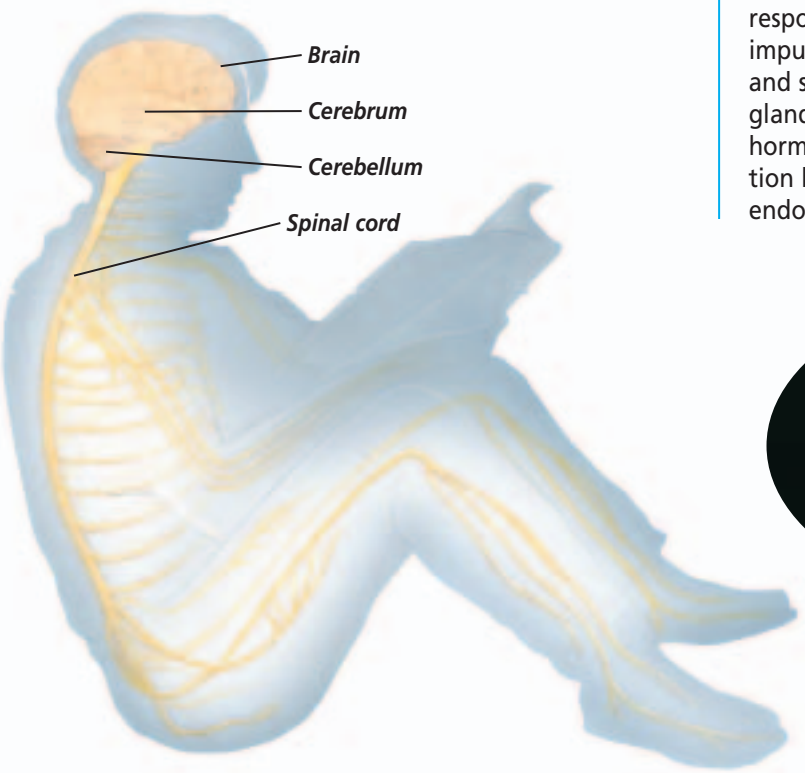
Between two neurons there is a small gap called a synapse. When one neuron is stimulated, it releases chemicals called neurotransmitters into the synapse, which stimulates a change in electrical charge in the next neuron. Nerve impulses travel through the body this way, from neuron to neuron.



The major glands of the endocrine system secrete hormones that regulate growth, development, and metabolism.

Sensory Receptors

Some nerve cells act as sensory receptors that detect both external and internal stimuli. In response to a stimulus, these neurons carry impulses to the spinal cord and brain. The brain and spinal cord then send impulses to muscles or glands, stimulating them to contract or secrete hormones. This interconnection provides coordination between the nervous system and the endocrine system.



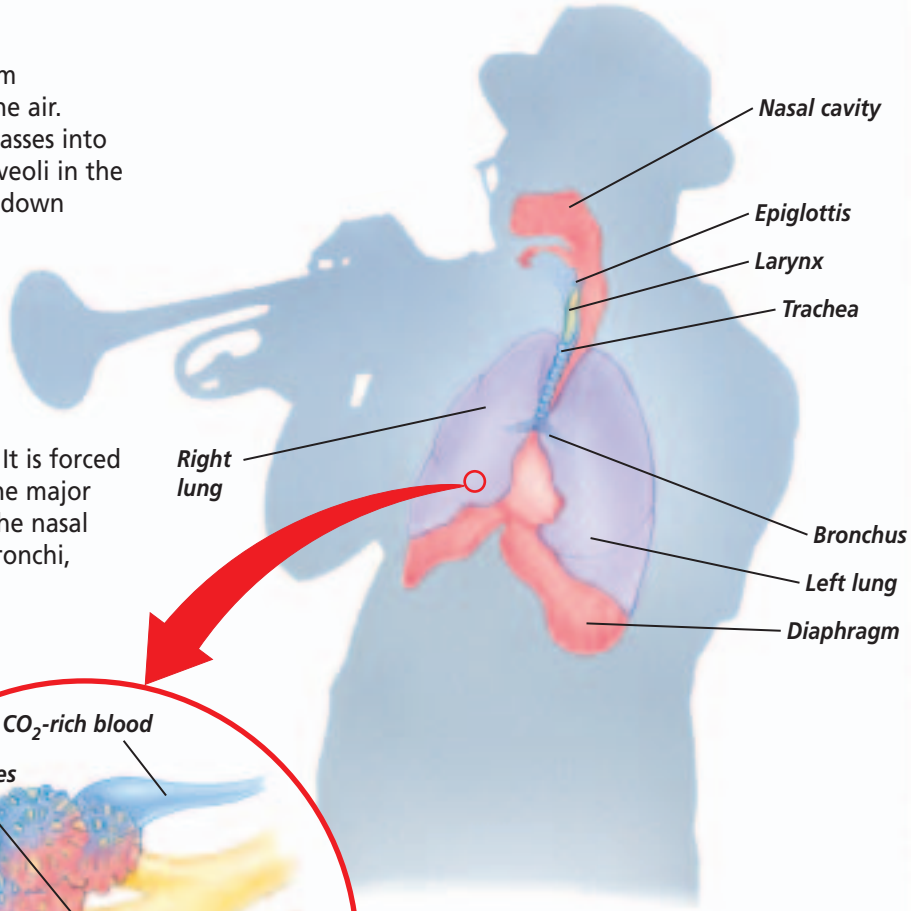
The central nervous system (brain and spinal cord) interprets and acts on information it receives from sensory neurons found throughout the body.

Jerry Wachter/Photo Researchers

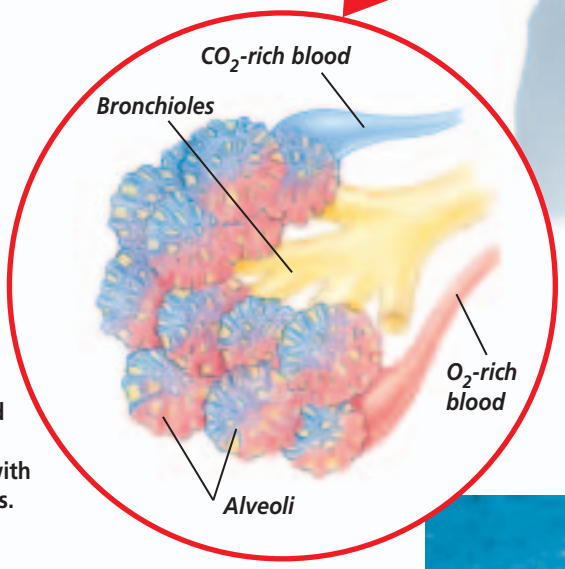
Respiratory System

The organs of the respiratory system exchange gases between blood and the air. During inhalation, oxygen in the air passes into the blood from small air sacs called alveoli in the lungs. Body cells use oxygen to break down glucose to make ATP needed for metabolism.

Carbon dioxide (CO_2) is produced by the breakdown of glucose and is transported to the lungs by the blood. In the lungs, carbon dioxide diffuses out of the blood and into the alveoli. It is forced out of the lungs during exhalation. The major organs of the respiratory system are the nasal cavity, the pharynx, larynx, trachea, bronchi, and lungs.



The respiratory system filters air as it passes into the nose, down the air passages, and into the lungs.



The lungs contain many small sacs called alveoli, where gas exchange with the blood occurs.

Vital Statistics

Respiration

Breathing: At rest, humans inhale and exhale about 12 to 20 times per minute, moving about 15 L of air per minute, and inhaling 21.6 cubic meters of air each day.

Lungs: Lungs weigh about 2.2 kg each. The right lung has three lobes and the left lung has two lobes. There are 300 million alveoli in the lungs. Flattened out, they would cover 360 square meters.

Sneezes: A sneeze ejects particles at 165.76 km/hr.

A swimmer comes up for air between strokes.

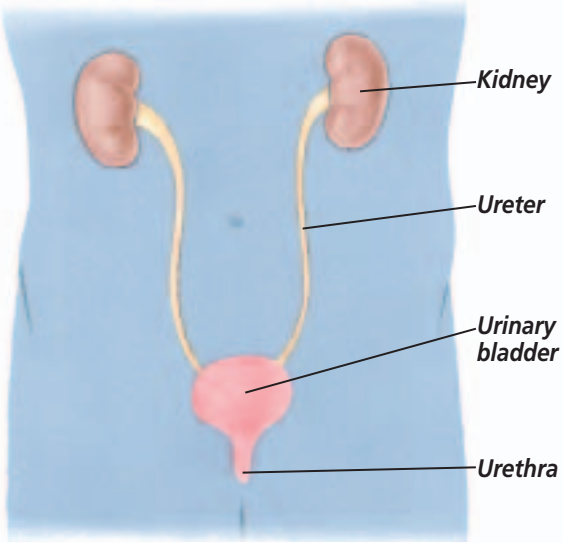
Stephen Dunn/AllSport

Circulatory System

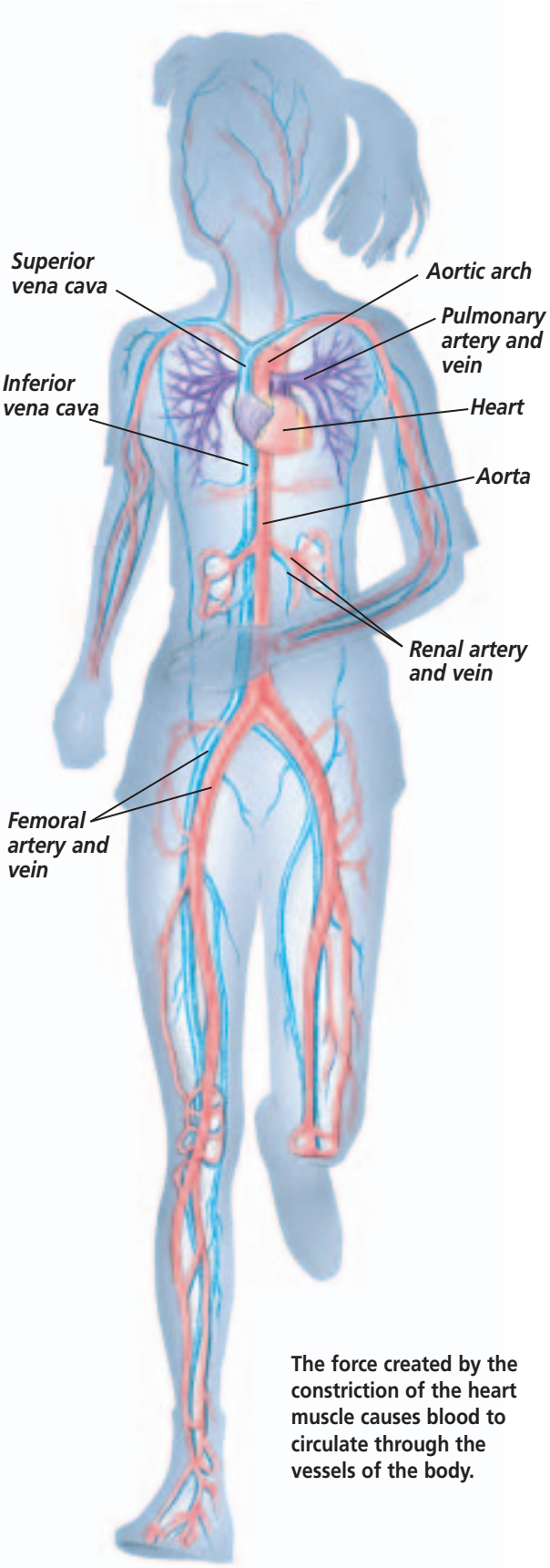
The circulatory system includes the heart, blood vessels (arteries, veins, and capillaries), and blood. The muscular heart pumps blood through the blood vessels. The blood carries oxygen from the lungs and nutrients from the digestive tract to all body cells. Blood also carries hormones to their target cells, carbon dioxide back to the lungs, and other waste products to the excretory system.

Urinary System

Metabolic waste products are created during the breakdown of amino acids. The urinary system removes these metabolic wastes from the blood, maintains the balance of water and salts in the blood, stores wastes in the form of urine, and transports urine out of the body.



The urinary system filters the blood, collects urine, and excretes urine from the body.

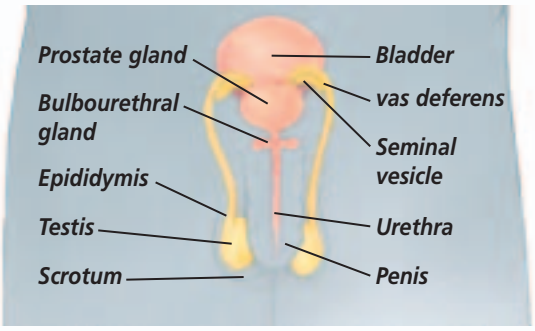


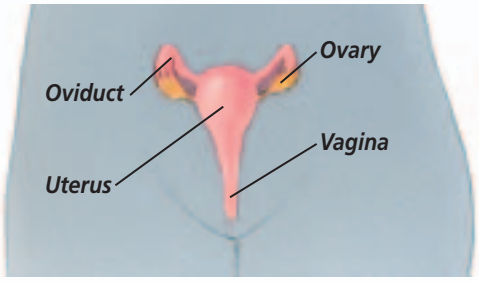
The force created by the constriction of the heart muscle causes blood to circulate through the vessels of the body.

Reproductive System

The reproductive system is involved in the production of gametes. The male reproductive system produces and maintains sperm cells and transfers them into the female reproductive tract. The female reproductive system produces and maintains egg cells, receives sperm cells, and supports the development of the fetus.

The male reproductive system





The female reproductive system

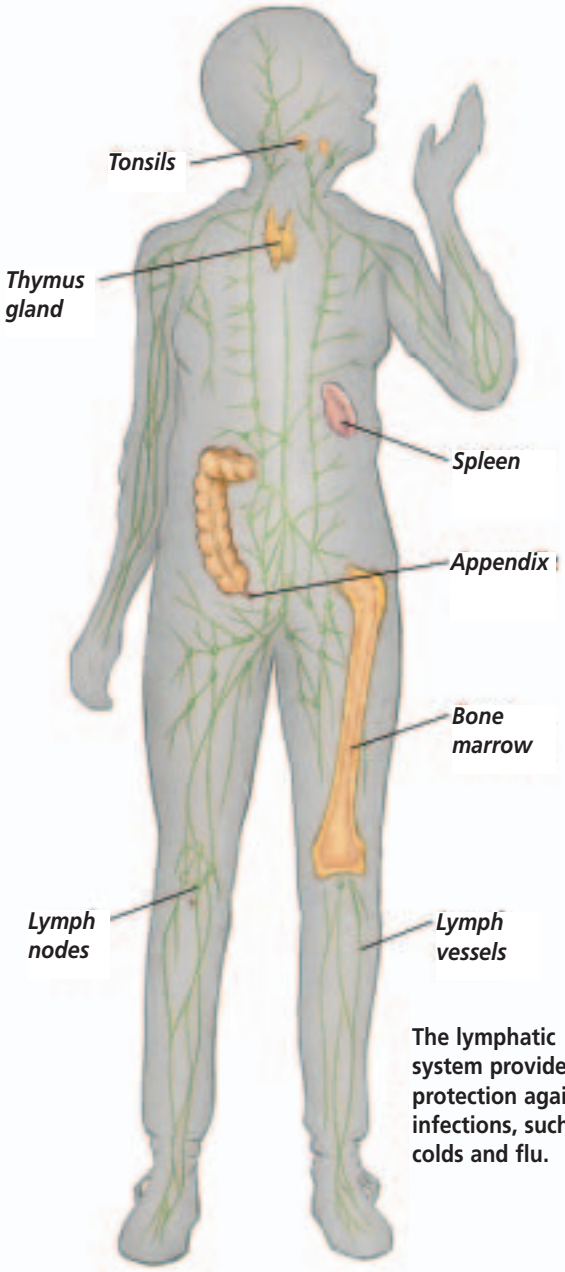
Lymphatic System

Fluids leak out of capillaries and bathe body tissues. The lymphatic system transports this tissue fluid back into the bloodstream. The lymphatic system also plays an important role in immunity. As tissue fluids pass through lymphatic vessels and lymph nodes, disease-causing pathogens and other foreign substances are filtered out and destroyed.

Innate immunity involves the action of several types of white blood cells that protect the body against any type of pathogen. Macrophages and neutrophils engulf foreign substances that enter the body. If the infection persists, the lymphatic system becomes involved. The body develops an acquired immune response that defends against the specific pathogen.

Acquired immunity involves helper T cells that pass on chemical information about the pathogen to B cells. B cells produce antibodies that disarm or destroy the invaders. Some B cells remain in the body as memory B cells that recognize the antigens if they ever invade the body again. This process provides the body with acquired natural immunity against disease.

The lymphatic system includes lymph nodes, tonsils, the thymus gland, and spleen. T cells mature in the thymus. The spleen stores both T cells and B cells.



The lymphatic system provides protection against infections, such as colds and flu.

Standardized Test Practice

The Princeton Review — TEST-TAKING TIP

Read the Instructions

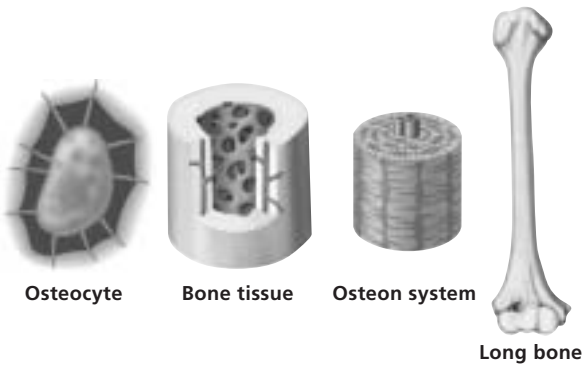
No matter how many times you've taken a particular test or practiced for an exam, it's always a good idea to read through the directions provided at the beginning of each section. It only takes a moment.

Part 1 Multiple Choice

1. Which of the following is the correct sequence of increasing complexity when describing the levels of organization in the human body?

A. organs, cells, tissues, organism, organ systems
B. cells, organ systems, tissues, organism, organs
C. cells, tissues, organs, organ systems, organism
D. tissues, cells, organs, organ systems, organism

Use the figure below to answer question 2.



2. Place the structures of the human body in order from least to most complex.

A. osteocyte, bone tissue, osteon system, long bone
B. osteocyte, osteon system, bone tissue, long bone
C. long bone, osteon system, bone tissue, osteocyte
D. long bone, bone tissue, osteon system, osteocyte

3. Which of the following statements is NOT true regarding the skeletal system?

A. The skeletal system and the circulatory system interrelate because red blood cells, white blood cells, and platelets are produced in red bone marrow.
B. The skeletal system and the muscular system interrelate because skeletal muscles are attached to bones in order to produce movement of the body.
C. The skeletal system and the digestive system interrelate because bones release digestive juices that help break down food.
D. The skeletal system functions to support the entire body and protect vital organs, such as the brain, heart, and lungs.

4. The functions of the digestive system include _____.

A. digesting food, absorbing nutrients, and eliminating undigested food and other wastes
B. secreting hormones to control the metabolic activities of the body
C. producing antibodies in response to antigens present in the body
D. circulating blood containing oxygen throughout the body

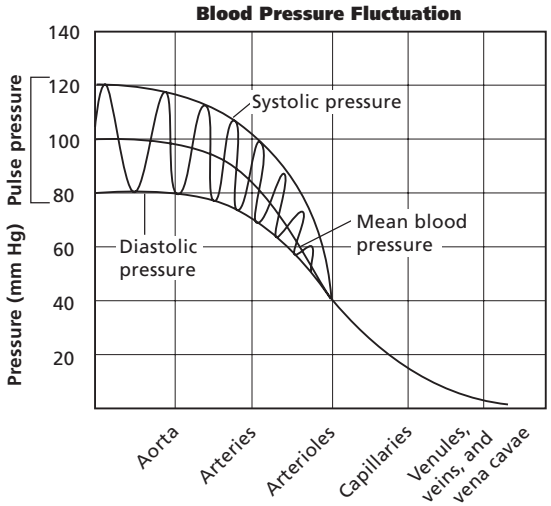
5. Which of the following processes does NOT involve an internal feedback mechanism?

A. The release of insulin from the pancreas to maintain blood glucose levels.
B. The release of antidiuretic hormone in response to a reduced concentration of water level in the blood.
C. The release of calcitonin and parathyroid hormone to maintain proper levels of calcium in the blood.
D. The release of carbon dioxide from the lungs during breathing.

6. In order for an impulse to be transmitted from one neuron to another, nerve cells release _____ at a synapse.

A. hemoglobin
B. luteinizing hormone
C. neurotransmitters
D. antibodies

Use the information below and your knowledge of science to answer questions 7–9.



7. In which blood vessel is blood pressure the greatest?
- **A.** the aorta
- **B.** the arteries
- **C.** the capillaries
- **D.** the veins

8. Which of the variables shown on the graph is the dependent variable?
- **A.** type of blood vessel
- **B.** systolic pressure
- **C.** diastolic pressure
- **D.** blood pressure

9. The rate of blood flow would decrease if the _____ of the blood increased.
- **A.** momentum
- **B.** conduction
- **C.** viscosity
- **D.** polarization

10. Which structure of the male reproductive system produces sperm?
- **A.** epididymis
- **B.** scrotum
- **C.** testis
- **D.** vas deferens

11. In which structure of the female reproductive system does a human embryo normally develop?
- **A.** ovary
- **B.** oviduct
- **C.** placenta
- **D.** uterus

12. Failure of the urinary system to maintain homeostasis in the body could result in all of the following except _____.
- **A.** high levels of nitrogenous waste products in the blood
- **B.** not enough nutrients reaching body cells
- **C.** the pH of the blood being abnormal
- **D.** irregularities in blood osmotic pressure

13. The lymphatic system performs which of the following functions?
- **A.** transports tissue fluid back into the bloodstream
- **B.** carries oxygen and carbon dioxide to and from body cells
- **C.** controls the metabolic activities of body structures
- **D.** exchanges gases between blood and the air

14. Which of the following statements regarding B cells is NOT true?
- **A.** B cells are part of innate immunity.
- **B.** B cells can form plasma cells that produce antibodies to attack foreign cells that invade the body.
- **C.** B cells can form memory cells that recognize antigens if they invade the body a second time.
- **D.** B cells are produced in the spleen.

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

15. Open Ended Describe the differences between skeletal, smooth, and cardiac muscle. Include the functions of each in your response.

16. Open Ended Explain how gas exchange occurs in the lungs. How does the respiratory system interrelate with the circulatory system?

17. Open Ended Explain the functions of the male and female reproductive systems. How does fertilization occur?

18. Open Ended Describe the structures and processes involved in innate immunity. How do these differ from structures and processes involved in acquired immunity?