Section 37.2 The Circulatory System

Before You Read
To donate blood, you need to be in good health. If you pass the health questions and the blood test, and if you are old enough, you can donate blood. Donating blood saves lives. Some companies are trying to develop artificial blood. Artificial blood has not been able to replace human blood in most cases. Why do you think that might be?

Read to Learn

Your Blood: Fluid Transport
Blood is a tissue made of fluid, cells, and fragments of cells. The fluid portion of the blood is called plasma. Plasma is straw colored and makes up about 55 percent of the total volume of blood. Red and white blood cells and cell fragments are suspended in plasma.

What do red blood cells do?
Red blood cells are round, disk-shaped cells. Red blood cells carry oxygen to body cells. They make up 44 percent of the total volume of blood. Red blood cells are produced in the red bone marrow of your ribs, humerus, femur, sternum, and other long bones.

The red blood cells in humans have nuclei in an early stage of cell development. The nucleus is lost before the cells enter the bloodstream. Red blood cells remain active in the bloodstream for about 120 days. Then they break down and are removed as waste. Old red blood cells are destroyed in the spleen and in the liver.

How is oxygen carried by the blood?
Red blood cells have an iron-containing protein molecule called hemoglobin (HEE uh glohn buhn). Oxygen becomes loosely attached to the hemoglobin in blood cells that have entered the lungs. These oxygenated blood cells carry oxygen from the lungs to the body’s cells. As blood passes through body tissue with low oxygen concentrations, oxygen is released from the hemoglobin and diffuses into the tissue.

Hemoglobin can also carry some carbon dioxide after it releases oxygen. Remember that once biological work has been done in a cell, wastes in the form of carbon dioxide diffuse into the blood. The bloodstream carries the carbon dioxide to the lungs. About 70 percent of this carbon dioxide combines with water in the blood plasma to form bicarbonate. The remaining 30 percent travels back to the lungs dissolved in plasma or attached to the hemoglobin molecules.

What is the function of white blood cells?
White blood cells play a major role in protecting the body from foreign substances and from microscopic organisms that cause disease. White blood cells make up only one percent of the total volume of blood.

How does blood clot?
What happens if you cut yourself? If the cut is not deep, you bleed until the blood clots. It usually does not take long for the blood to clot. That’s because, in addition to red and white blood cells, blood contains small cell fragments called platelets. They help blood to clot after an injury. Platelets help connect a sticky network of protein fibers called fibrin. This forms a web over the wound that traps escaping blood cells. Then a dry, leathery substance forms. Platelets are produced from cells in the bone marrow. They have a short life span and are removed from the blood by the spleen and liver about a week after they are produced.

ABO Blood Groups
If a person is injured so severely that a large amount of blood is lost, a transfusion of blood from another person may be required. Whenever blood is transfused from one person to another, it is important to know the blood group of each person. There are four human blood groups, A, B, AB, and O. You inherited the characteristics of one of these blood groups from your parents. Sometimes the term blood type is used to describe the blood group to which a person belongs. If your blood group is O, you are said to have type O blood.
37.2 The Circulatory System, continued

Rh factor can cause complications in some pregnancies. The problem begins when an Rh- mother becomes pregnant with an Rh+ baby. Sometimes at birth, the blood cells of the baby are mixed with those of the mother. If the Rh- mother is exposed to the blood of the Rh+ baby, the mother will make anti-Rh antibodies. If the mother becomes pregnant again, the antibodies can cross the placenta and enter the fetus. If the next fetus is Rh+, the anti-Rh antibodies from the mother will destroy red blood cells in the fetus.

Prevention of the problem is possible: When the Rh+ fetus is 28 weeks old and again shortly after the Rh+ baby is born, the Rh- mother is given a substance that prevents the production of Rh antibodies in her blood. As a result, the next fetus will not be in danger.

Your Blood Vessels: Pathways of Circulation

Blood is a fluid channelled through blood vessels. The three main types of blood vessels are arteries, capillaries, and veins.

Arteries are large, thick-walled, muscular, elastic blood vessels that carry blood away from the heart. The blood that they carry is under great pressure. As the heart contracts, it pushes blood through the arteries. Each artery's elastic walls expand slightly. As the heart relaxes, the artery shrinks a bit, which helps to push the blood forward. As a result, blood surges through the arteries in pulses that correspond with the rhythm of the heartbeat.

The arteries branch off from the heart. They divide into smaller arteries that, in turn, divide into even smaller vessels called arterioles. Arterioles (at TEER e olz) enter tissues, where they branch into the smallest blood vessels, the capillaries. Capillaries (KA puh ler ez) are microscopic blood vessels with walls that are only one cell thick. These vessels are so tiny that red blood cells must move through them in single file. Capillaries form a dense network that reaches almost every cell in the body. Thin capillary walls allow nutrients and gases to diffuse easily between blood cells and surrounding tissues.

Your Heart: The Vital Pump

As the blood leaves the tissues, the capillaries join to form slightly larger vessels called veins. The veins merge to form veins, the large blood vessels that carry blood from the tissues back toward the heart. Blood in veins is not under pressure as great as blood in arteries. In some veins, especially those in your arms and legs, blood has to travel uphill against gravity. These veins, shown at left, are equipped with valves that prevent the blood from flowing backward. The veins work with skeletal muscles to open and close the valves. When the skeletal muscles contract, the top valves open, and blood is forced toward the heart. When the skeletal muscles relax, the top valves close to prevent blood from flowing backward, away from the heart.

Your Heart: The Vital Pump

The thousands of blood vessels in your body would be of little use if there were not a way to move blood through them. The heart moves blood through the vessels. In fact, the main function of the heart is to keep blood moving constantly through the body. The heart is well adapted for its job. It is a large organ made of cardiac muscle cells that are rich in energy-producing mitochondria.

All mammals, including humans, have hearts with four chambers. The two upper chambers of the heart are the atria. The two lower chambers are the ventricles. The walls of each atrium are thinner and less muscular than those of each ventricle. That's because the ventricles perform more work than the atria. Each atrium pumps blood into the corresponding ventricle. The left ventricle pumps blood to the entire body. So its muscles are thicker than those of the right ventricle. The right ventricle pumps blood to the lungs. As a result, the heart is somewhat lopsided.
37.1 The Respiratory System

Before You Read
Breathing happens automatically. We do not think about every breath we take. Look at the clock and see how many breaths you take in a minute. Write that number on the lines below. Then write one sentence describing a time that you did think about your breathing, such as after stopping to catch your breath after running.

Read to Learn

Passageways and Lungs
Your respiratory system is made of a pair of lungs and a series of passageways. The passageways include the nasal passages, the throat, the windpipe, and the bronchi. You probably think of breathing when you hear the term respiratory system. Breathing is just one of the functions that the respiratory system carries out. Gas exchange, or respiration, is another important function performed by the respiratory system. Respiration includes all of the steps involved in getting oxygen to the cells of your body and getting rid of carbon dioxide. Recall that cellular respiration also involves the formation of ATP within the cells.

The first step in the process of respiration involves taking air into your body. Air enters through the nose or mouth. It flows into the pharynx, or throat, passes the epiglottis, and moves through the larynx. The air then travels down the windpipe, or trachea (TRAY kee uh), a tubelike passageway that leads to two tubes or bronchi (BRAHN kii) (singular, bronchus), which lead into the lungs. Use the illustration on page 463 to trace the steps. When you swallow food, the epiglottis covers the entrance to the trachea, which prevents food from getting into the air passages.

Where does gas exchange happen?
Like the branches of a tree, each bronchus branches into bronchioles. The bronchioles branch into many microscopic tubules that eventually open into thousands of thin-walled sacs called alveoli. Alveoli (at VEE oh lee), are the sites of the lungs where oxygen and carbon dioxide are exchanged by diffusion between air and blood. The clusters of alveoli are surrounded by networks of tiny blood vessels, or capillaries. Blood in these vessels has come from the cells of the body and contains wastes from cellular respiration. Diffusion of gases takes place easily because the wall of each alveolus and the wall of each capillary are only one cell thick. External respiration involves the exchange of oxygen and carbon dioxide between the air in the alveoli and the blood that circulates through the walls of the alveoli.

Once oxygen diffuses into the blood vessels surrounding the alveoli, the heart pumps it to the body cells. There it is used for cellular respiration. Remember that cellular respiration is the process by which cells use oxygen to break down glucose and release energy in the form of ATP. Carbon dioxide is a waste product of this process. The carbon dioxide diffuses into the blood, which carries it back to the lungs.
37.1 The Respiratory System, continued

Control of Respiration

Breathing is usually an involuntary process. It is partially controlled by an internal feedback mechanism. The medulla oblongata receives signals about the chemistry of your blood. It responds to higher levels of carbon dioxide in your blood by sending nerve signals to the rib muscles and diaphragm. The nerve signals cause the muscles to contract and you inhale. During exercise you breathe faster. This causes a more rapid exchange of gases between air and blood.

After You Read

Mini Glossary

alveol (AHL-VEE-uh-uhl): sacs in the lungs where oxygen diffuses into the blood and carbon dioxide diffuses into the air

trachea (TRAY-kee-uh): tube-like passageway for air flow that connects with two bronchi tubes that lead into the lungs

1. Read the terms and their definitions in the Mini Glossary above. On the lines below, write each term in a sentence:

2. Place the list of respiratory structures below in the order an oxygen molecule would pass them as it moves from the outside air into a blood vessel.

bronchiole
bronchi
pharynx
trachea
nose/mouth
larynx
capillary
alveolus

3. Describe the process by which carbon dioxide leaves the body.

Visit the Glencoe Science Web site at science.glencoe.com to find your biology book and learn more about the respiratory system.
### 39.2 Defense Against Infectious Diseases

#### Before You Read

Have you ever been around someone who was sneezing and coughing? Did you later get sick, or were you able to fight off the infection? Why do you think that you sometimes catch other people's bugs and other times you don't? On the lines below, write a sentence about the last time you got sick. Then explain why you think your body was unable to defend itself.

#### Read to Learn

**Innate Immunity**

Your body produces a variety of white blood cells. These cells defend your body against invasion by pathogens. No matter what pathogens are present, a healthy immune system is always ready. The body's innate immunity is always present and defends the body against any and all pathogens.

**How do skin and body secretions protect you?**

When a potential pathogen comes in contact with your body, often the first barrier it meets is your skin. Skin keeps many microorganisms from entering the body.

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. 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. There, acidic gastric juice destroys most bacteria and their toxins. Sweat, tears, and saliva contain the enzyme lysozyme, which is capable of breaking down the cell walls of some bacteria.

**What causes inflammation of body tissues?**

If a pathogen gets past the skin and body secretions, your body has several other nonspecific defense mechanisms. These 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 (ihm-fluh MAY shun) results. Inflammation has four symptoms—redness, swelling, pain, and heat. The figure to the right shows what happens when inflammation begins:

First, damaged tissue cells called mast cells and white blood cells called basophils release histamine (HIHS tah mehn).

Histamine causes blood vessels in the injured area to dilate, or enlarge. 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 helps restore homeostasis. This increase in tissue fluid causes swelling and pain, and may also cause the area to become warmer. Inflammation can occur with other types of injuries as well as infections. Physical force, chemical substances, extreme temperatures, and radiation can cause inflammation.

**What is phagocytosis of pathogens?**

Pathogens that enter your body may encounter cells that engulf and destroy them, a process known as phagocytosis. Phagocytes (PA-guh-sites) are white blood cells that destroy pathogens by surrounding and engulfing them. They are like fighter cells attacking and devouring the invaders they encounter. Phagocytes also include monocytes. Monocytes develop into macrophages. Phagocytes also include neutrophils and eosinophils. Macrophages are white blood cells that provide the first defense against pathogens that have entered the tissues. Macrophages are sometimes called giant scavengers or bug eaters because of the manner in which they engulf pathogens or damaged cells. They will attack anything they recognize as foreign. Enzymes inside the macrophage digest the particles it has engulfed.
39.2 Defense Against Infectious Diseases, continued

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

If the infection is still not stopped, a third type of phagocyte arrives 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 into macrophages. They begin consuming pathogens and dead neutrophils. Once the infection is over, some monocytes mature into tissue macrophages. They remain in the area and prepare to guard against new infections.

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

What are protective proteins?

When an infection is caused by a virus, the body faces a problem. Phagocytes alone cannot destroy viruses. Recall that a virus multiplies within a host cell. A phagocyte that swallows a virus will 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 a type of interferon protects human cells from viruses but cannot protect cells of other species from the same virus.

Acquired Immunity

The cells of your innate immune system continually check your body for foreign invaders. When a pathogen is detected, these cells defend your body. As the infection continues, another type of immune response that fights the invading pathogens is activated. Certain white blood cells gradually develop the ability to recognize a specific foreign substance. This acquired immune response causes these white blood cells to 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 something that belongs to the body. It recognizes foreign substances, called antigens, as not belonging. An acquired immune response begins when the immune system recognizes an antigen. It responds by producing antibodies against it. Antibodies are foreign substances that stimulate an immune response. 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.

The illustration at right shows the lymphatic system.

What is the lymphatic system?

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

Body cells are constantly bathed in 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.

What are the 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. It filters pathogens from the lymph.

A lymphocyte (lih'hm fuh site) is a type of white blood cell that defends the body against foreign substances.

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 barrier around the openings of the nasal and oral cavities. Tonsils protect against bacteria and other pathogens that enter your nose and throat.
39.2 Defense Against Infectious Diseases, continued

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 in your body that involves several types of cells. The illustration below shows how antibody immunity defends your body against pathogens.

Cellular 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. They are specific for a single antigen. However, unlike B cells, they do not form antibodies. Cytotoxic T cells produce identical clones. They travel to the infection site and release enzymes directly into the pathogen, which die.

The cells that protect the body against pathogens sometimes can cause problems within the body. The immune system may overreact to a harmless substance such as pollen. Mast cells release histamines in large amounts. This causes the symptoms of an allergic reaction: sneezing, increased mucus production in the nasal passages, and redness. The immune system can attack its own cells. This attack of the body's own tissue is called an autoimmune disorder. Lupus and rheumatoid arthritis are autoimmune disorders. T cells and antibodies also can attack transplanted tissue, such as a kidney or heart, which comes from outside the body.

Passive and Active Immunity

Acquired immunity to a disease may be passive or active. Passive acquired immunity develops by acquiring antibodies that are generated in another host. Active acquired immunity develops when your body produces antibodies in response to being exposed to an antigen.