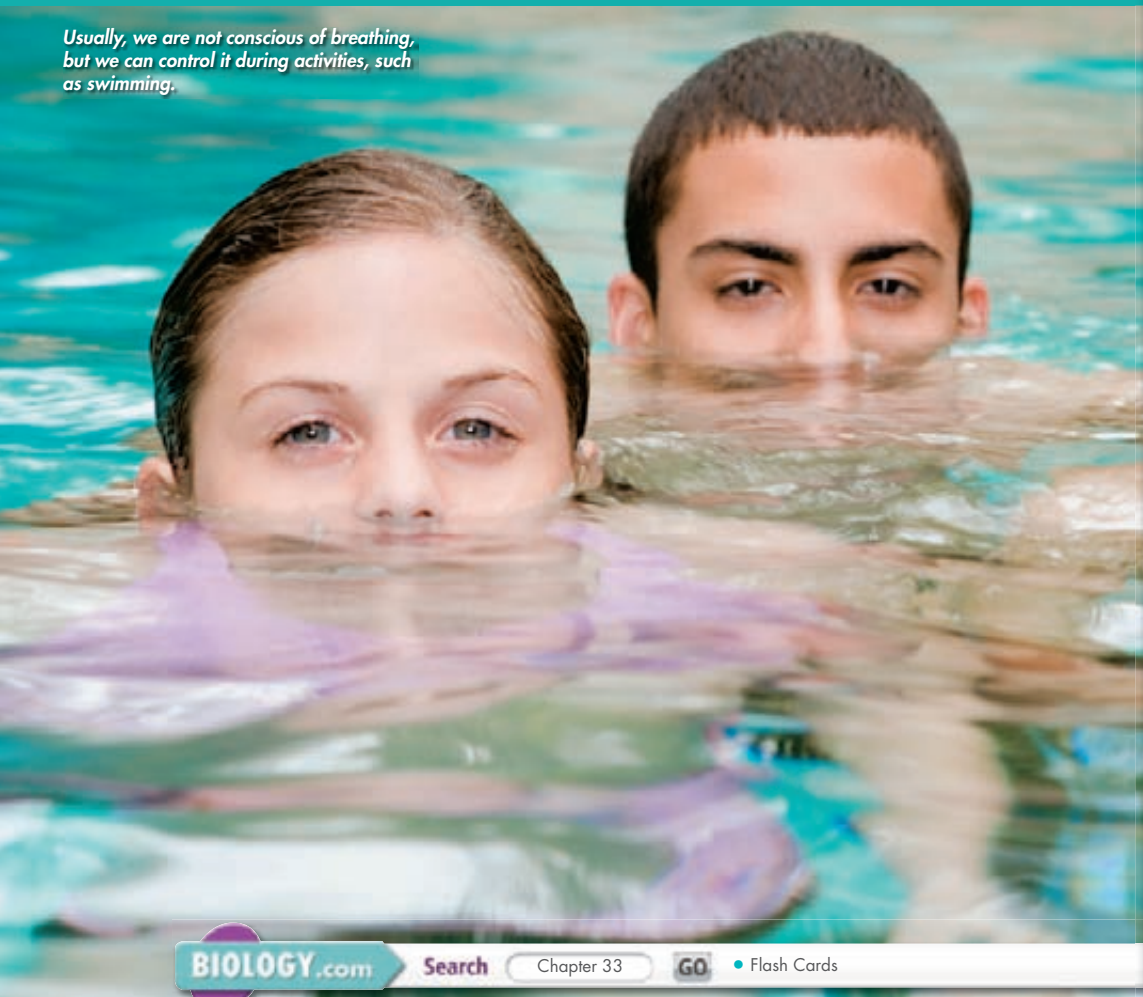
33 Circulatory and Respiratory Systems

Big idea

Structure and Function

Q: How do the structures of the circulatory and respiratory systems allow for their close functional relationship?



Usually, we are not conscious of breathing, but we can control it during activities, such as swimming.

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INSIDE:

- Untamed Science Video
- Chapter Mystery

CHAPTER MYSTERY

IN THE BLOOD

At the age of 60, John underwent surgery to reroute blood around blocked vessels in his heart. Since then, he has limited his fat intake and stuck to an exercise program. Still, today he is meeting with his doctor to talk about a new medication that would break up the fatty deposits re-forming in his heart's vessels.

Down the hall, 6-year-old Lila is seeing her doctor today, too. Her vessels are also clogged with fatty deposits, which means she is dangerously close to a heart attack, even at her young age. Both of these patients suffer from a genetic disease that affects a substance transported in blood. What is that disease? And why did it affect them at such different ages? As you read this chapter, look for clues to the identity of this genetic disease and the research that explains it. Then, solve the mystery.

Never Stop Exploring Your World. Finding the solution to the In the Blood mystery is just the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mysteries of the circulatory system lead.

Untamed Science™

33.1 The Circulatory System

Key Questions

- ***What are the functions of the circulatory system?***
- ***How does the heart pump blood through the body?***
- ***What are three types of blood vessels?***

Vocabulary

myocardium • atrium • ventricle • valve • pulmonary circulation • systemic circulation • pacemaker • artery • capillary • vein

Taking Notes

Preview Visuals Before you read, look at **Figure 33–3.** Make a list of questions about the illustration. As you read, write down the answers.

THINK ABOUT IT "I was about 47 when I collapsed one day at work. There are 22 minutes out of my life that I don't remember. I had gone into cardiac arrest." These are the words of a man who survived a heart attack. Fortunately he received prompt treatment and had successful heart surgery. He continued to live a fairly normal life. He even ran the Boston Marathon! But more than one-third of the 1.2 million Americans who suffer a heart attack each year die. This grim evidence shows that the heart and the circulatory system it powers are vital to life. Why is that so?

Functions of the Circulatory System

What are the functions of the circulatory system?

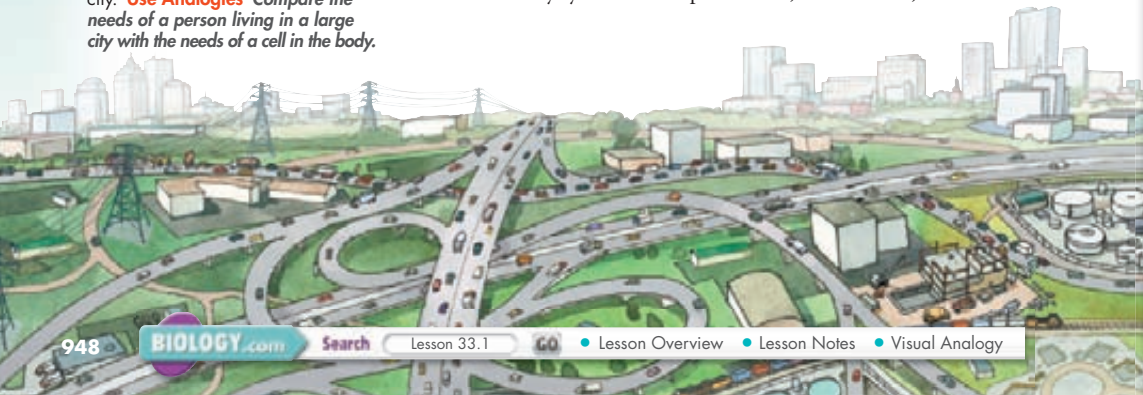
Some animals have so few cells that all of their cells are in direct contact with the environment. Diffusion and active transport across cell membranes supply the cells with oxygen and nutrients and remove waste products. The human body, however, contains millions of cells that are not in direct contact with the external environment. Because of this, humans need a circulatory system. **The circulatory system transports oxygen, nutrients, and other substances throughout the body, and removes wastes from tissues.**

People who live in large cities face a set of problems like those of the body's cells. City dwellers need food and goods that are produced elsewhere, and they need to get rid of their garbage and other wastes. People need to move around within the city. How are these needs met? By the city's transportation system—a network of streets, highways, and subway or train lines that deliver goods to the city and remove wastes from it. The human body's major transportation system is a closed circulatory system made up of a heart, blood vessels, and blood.

VISUAL ANALOGY

A CITY'S TRANSPORTATION SYSTEM

FIGURE 33–1 The human circulatory system is like the highways and streets of a large city. **Use Analogies** *Compare the needs of a person living in a large city with the needs of a cell in the body.*



The Heart

How does the heart pump blood through the body?

Much of the time, you're probably not even aware of your heart at work. But when you exercise, you can feel your heart beating near the center of your chest.

Heart Structure Your heart, which is a hollow organ about the size of a clenched fist, is composed almost entirely of muscle. The muscles begin contracting before you are born and stop only when you die. In the walls of the heart, two thin layers of epithelial and connective tissue form a sandwich around a muscle layer called the **myocardium.** **Powerful contractions of the myocardium pump blood through the circulatory system.** An adult's heart contracts on average 72 times a minute, pumping about 70 milliliters of blood with each contraction.

As **Figure 33–2** shows, the heart is divided into four chambers. A wall called the septum separates the right side of the heart from the left side. The septum prevents oxygen-poor and oxygen-rich blood from mixing. On each side of the septum are an upper and lower chamber. Each upper chamber, or **atrium** (plural: atria), receives blood from the body. Each lower chamber, or **ventricle,** pumps blood out of the heart.

In Your Notebook *An Olympic pool contains about 2,000,000 liters of water. In one year, could an average heart pump enough blood to fill an Olympic pool? Explain your answer.*

BUILD Vocabulary

WORD ORIGINS The word *cardiac,* the prefix *cardio-,* and the suffix *-cardium* are all based on the Greek word *kardia,* which means "heart."

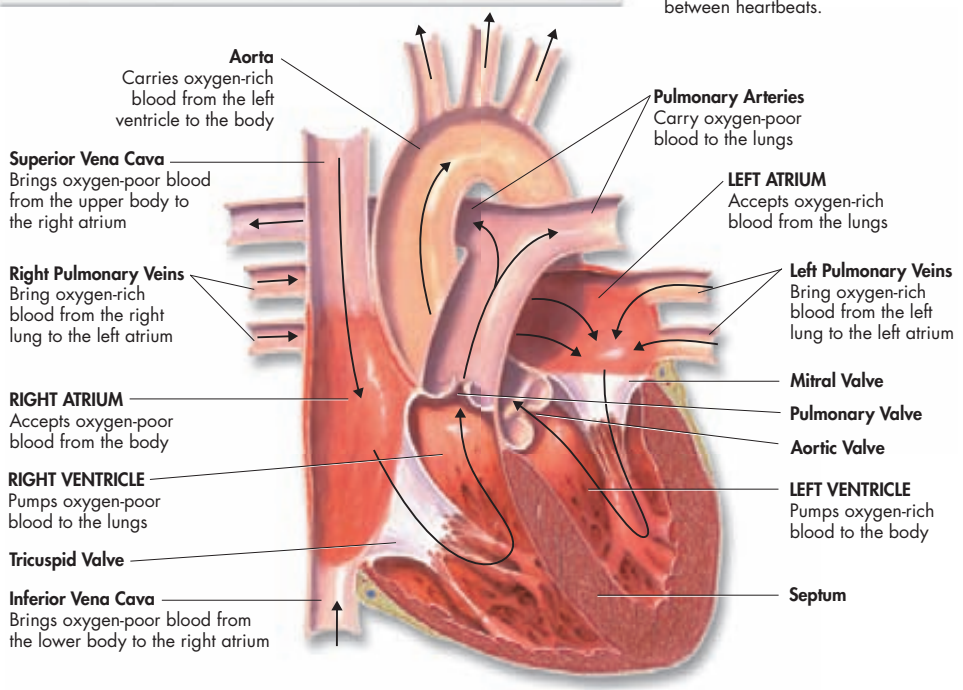
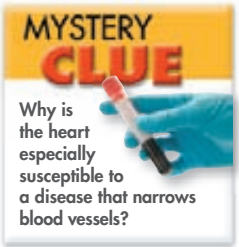


FIGURE 33–2 The Heart
The human heart has four chambers: the right atrium, the right ventricle, the left atrium, and the left ventricle. Valves located between the atria and ventricles and between the ventricles and vessels leaving the heart prevent blood from flowing backward between heartbeats.



Blood Flow Through the Heart Blood from the body enters the heart through the right atrium; blood from the lungs, through the left atrium. When the atria contract, blood flows into the ventricles. Flaps of connective tissue called **valves** are located between the atria and the ventricles. When blood moves from the atria into the ventricles, those valves open. When the ventricles contract, the valves close, preventing blood from flowing back into the atria. Valves are also located at the exits of each ventricle. This system of valves keeps blood moving through the heart in one direction, like traffic on a one-way street.

The Heart's Blood Supply Heart muscle needs a constant supply of oxygen and nutrients. Surprisingly, the heart gets very little oxygen and nutrients from the blood it pumps through its chambers. Instead, a pair of blood vessels called *coronary arteries,* which branch from the aorta and run through heart tissue, supply blood to the heart muscle. Coronary arteries and the vessels that branch from them are relatively narrow, considering the needs of the heart. If they are blocked, heart muscle cells run out of oxygen and could begin to die. This is what happens during a heart attack, which we discuss in Lesson 33.2.

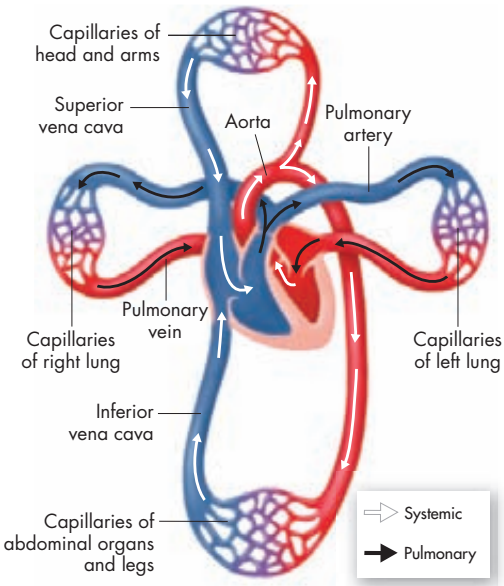


FIGURE 33–3 Circulation Pathways The circulatory system is divided into two pathways. Pulmonary circulation carries blood between the heart and the lungs. Systemic circulation carries blood between the heart and the rest of the body. **Observe** ***What kind of blood—oxygen-rich or oxygen-poor—leaves the lungs and returns to the heart?***

Circulation Although it is one organ, the heart functions as two pumps. One pump pushes blood to the lungs, while the other pump pushes blood to the rest of the body, as shown in **Figure 33–3.** The two pathways of blood through the body are called pulmonary circulation and systemic circulation.

▶ ***Pulmonary Circulation*** The right side of the heart pumps oxygen-poor blood from the heart to the lungs through what is called **pulmonary circulation.** In the lungs, carbon dioxide diffuses from the blood, and oxygen is absorbed by the blood. Oxygen-rich blood then flows to the left side of the heart.

▶ ***Systemic Circulation*** The left side of the heart pumps oxygen-rich blood to the rest of the body through what is called **systemic circulation.** Cells absorb much of the oxygen and load the blood with carbon dioxide. This now oxygen-poor blood returns to the right side of the heart for another trip to the lungs to pick up oxygen.

In Your Notebook *Draw a cycle diagram that represents both pulmonary and systemic circulation.*

Heartbeat To be an efficient pump, the heart must beat in an orderly and coordinated way. Two networks of muscle fibers coordinate the heart's pumping action—one in the atria and one in the ventricles. When a single muscle fiber in either network is stimulated, the entire network contracts.

1 Atria Contract Each contraction begins in a small group of cardiac muscle fibers—the sinoatrial node (SA node)—located in the right atrium. The SA node "sets the pace" for the heart, so it is also called the **pacemaker.** When the SA node fires, an electrical impulse spreads through the entire network of muscle fibers in the atria and the atria contract.

2 Ventricles Contract The impulse from the SA node is then picked up by another group of muscle fibers called the atrioventricular node (AV node). Here the impulse is delayed for a fraction of a second while the atria contract and pump blood into the ventricles. Then the AV node produces impulses that spread through the ventricles and cause the ventricles to contract, pumping blood out of the heart. This two-step pattern of contraction—first the atria and then the ventricles—makes the heart an efficient pump.

Control of Heart Rate Your heart rate varies depending on your body's need to take in oxygen and release carbon dioxide. During vigorous exercise, for example, your heart rate could increase to about 200 beats per minute. Heartbeat is not directly controlled by the nervous system, but the autonomic nervous system does influence the activity of the SA node. Neurotransmitters released by the sympathetic nervous system increase heart rate. Those released by the parasympathetic nervous system decrease heart rate.

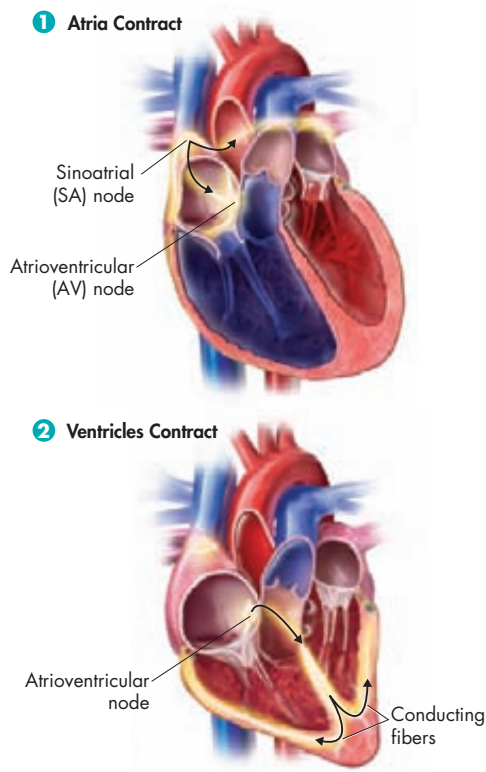


FIGURE 33–4 Heartbeat The SA node generates an impulse that spreads through the atria, causing the muscle fibers to contract and pump blood to the ventricles. The AV node picks up the signal and, after a slight delay, sends an impulse through the ventricles, causing them to contract.

Quick Lab
GUIDED INQUIRY

What Factors Affect Heart Rate?

1 While sitting, measure your heart rate. Find the pulse in one of your wrists using the first two fingers of your other hand.

2 Count the number of beats for 15 seconds, and multiply by 4. This gives you the number of beats per minute.

Analyze and Conclude

1. Predict What do you think would happen if you stood up? Would your heart rate decrease, increase, or stay the same?

2. Evaluate Test your prediction by standing up and measuring your heart rate again. Explain your results.

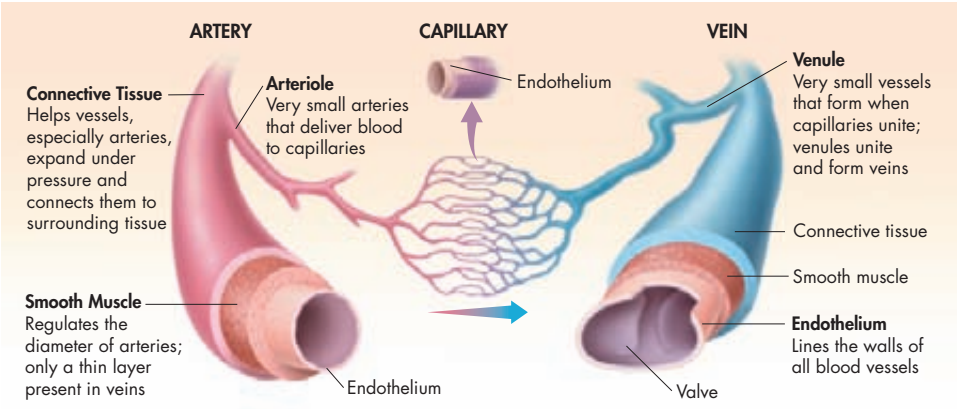


FIGURE 33–5 Structure of Blood Vessels The structure of blood vessel walls contributes to the vessels' functions.

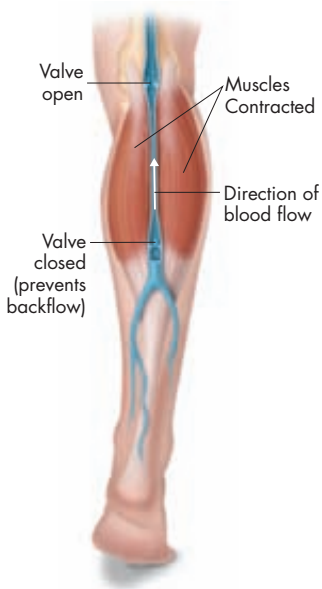


FIGURE 33–6 Blood Flow in Veins The contraction of skeletal muscles helps move blood in veins toward the heart.
Draw Conclusions ***What role do valves play in large veins?***

Blood Vessels

What are three types of blood vessels?

Oxygen-rich blood leaving the left ventricle passes into the aorta. The aorta is the first of a series of vessels that carries blood through the systemic circulation and back to the heart.

As blood flows through the circulatory system, it moves through three types of blood vessels—arteries, capillaries, and veins.

Arteries **Arteries** are large vessels that carry blood from the heart to the tissues of the body. Arteries are the superhighways of the circulatory system. Except for the pulmonary arteries, all arteries carry oxygen-rich blood. Arteries have thick elastic walls that help them withstand the powerful pressure produced when the heart contracts and pumps blood through them. **Figure 33–5** describes the three layers of tissue found in artery walls—connective tissue, smooth muscle, and endothelium.

Capillaries The smallest blood vessels are the **capillaries.** Capillaries are the side streets and alleys of the circulatory system. Most capillaries are so narrow that blood cells pass through them in single file. Their extremely thin walls allow oxygen and nutrients to diffuse from blood into tissues, and carbon dioxide and other waste products to move from tissues into blood.

Veins After blood passes through the capillaries, it returns to the heart through **veins.** Blood often must flow against gravity through the large veins in your arms and legs. Many veins are located near and between skeletal muscles, as shown in **Figure 33–6.** When you move, the contracting skeletal muscles squeeze the veins, pushing blood toward the heart. Many veins contain valves. The valve that is farthest from the heart closes to ensure blood continues to flow in one direction.

Blood Pressure Like any pump, the heart produces pressure. When it contracts, it produces a wave of fluid pressure in the arteries, known as blood pressure. Although blood pressure falls when the heart relaxes between beats, the system still remains under pressure due to the elasticity of the arterial walls. It's a good thing, too. Without that pressure, blood would stop flowing through the body.

Healthcare workers measure blood pressure with a device called a sphygmomanometer (sfig moh muh NAHM uh tur), an inflatable cuff with a pump and a meter. The cuff is wrapped around the upper arm and inflated until blood flow through the artery that runs down the arm is blocked. As the pressure is released, the healthcare worker listens for a pulse with a stethoscope and records a number from the meter. This number represents the systolic pressure—the force in the arteries when the ventricles contract. When the pulse sound disappears, a second number is recorded. This number represents the diastolic pressure—the force in the arteries when the ventricles relax. A typical blood pressure reading for a healthy teen or adult is below 120/80.

The body regulates blood pressure in a number of ways. Sensory receptors in blood vessels detect blood pressure and send impulses to the brain stem. When blood pressure is high, the autonomic nervous system releases neurotransmitters that relax the smooth muscles in blood vessel walls. When blood pressure is low, neurotransmitters are released that cause the smooth muscles in vessel walls to contract.

The kidneys also regulate blood pressure by affecting the volume of blood. Triggered by hormones produced by the heart and other organs, the kidneys remove more water from the blood and eliminate it in urine when blood pressure is high or conserve more water when blood pressure is low.

FIGURE 33–7 Measuring Blood Pressure It's important to have your blood pressure measured because blood pressure that is too high or too low can have serious effects on most body systems.

33.1 Assessment

Review Key Concepts

1. a. Review List the structures of the circulatory system and explain their roles.

b. Apply Concepts Why do humans need a circulatory system?

2. a. Review Describe the two paths of blood circulation through the body.

b. Relate Cause and Effect How would damage to the sinoatrial node affect the heart's function?

3. a. Review Describe the functions of three types of blood vessels in the circulatory system.

b. Infer If you were standing, would you expect the blood pressure to be higher in your arm or in your leg? Explain your answer. (*Hint:* Think about which area of the body is closer to the source of pressure.)

VISUAL THINKING

4. Trace **Figure 33–2.** Label the four chambers of the heart. Add arrows and labels to indicate how blood flows through the heart.

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33.2 Blood and the Lymphatic System

Key Questions

- ***What is the function of each component in blood?***
- ***What is the function of the lymphatic system?***
- ***What are three common circulatory diseases?***
- ***What is the connection between cholesterol and circulatory disease?***

Vocabulary

plasma • red blood cell • hemoglobin • white blood cell • platelet • lymph • atherosclerosis

Taking Notes

Outline Before you read, make an outline of the major headings in the lesson. As you read, fill in main ideas and supporting details for each heading.

FIGURE 33–8 Blood Cells The micrograph shows red blood cells (red disks), white blood cells (gold orbs), and platelets (pink fragments) (SEM 1866×).

THINK ABOUT IT When you think about body tissues, you probably picture something with a definite shape, like muscle or skin. But blood is a tissue too—it just happens to be in liquid form! The more you think about blood, the more remarkable its many functions are. In addition to transporting oxygen and fighting disease, it carries substances your body makes and sources of energy such as sugars and fats. In fact, one of the best ways to judge a person's health is—you guessed it—a blood test. How does this unusual tissue perform so many essential functions?

Blood

What is the function of each component in blood?

You might think that the most important function of blood is to serve as the body's transportation system. But the various components of blood also help regulate body temperature, fight infections, and produce clots that help minimize the loss of body fluids from wounds.

Plasma The human body contains 4 to 6 liters of blood. About 55 percent of total blood volume is a straw-colored fluid called **plasma.** **Plasma is about 90 percent water and 10 percent dissolved gases, salts, nutrients, enzymes, hormones, waste products, plasma proteins, cholesterol, and other important compounds.**

The water in plasma helps to control body temperature. Plasma proteins consist of three types—albumin, globulins, and fibrinogen. Albumin and globulins transport substances such as fatty acids, hormones, and vitamins. Albumin also plays an important role in regulating osmotic pressure and blood volume. Some globulins fight viral and bacterial infections. Fibrinogen is necessary for blood to clot.

Red Blood Cells The most numerous cells in blood are **red blood cells,** or erythrocytes (eh RITH roh syts). **The main function of red blood cells is to transport oxygen.** They get their crimson color from the iron in **hemoglobin,** a protein that binds oxygen in the lungs and releases it in capillary networks throughout the body. Then red blood cells transport some carbon dioxide to the lungs.

Red blood cells are disks that are thinner in their center than along their edges. They are produced by cells in red bone marrow. As red blood cells mature and fill with hemoglobin, their nuclei and other organelles are forced out. Red blood cells circulate for an average of 120 days before they are destroyed in the liver and spleen.

White Blood Cells

White blood cells, or leukocytes (LOO koh syts), are the "army" of the circulatory system. **White blood cells guard against infection, fight parasites, and attack bacteria.** The body can increase the number of active white blood cells dramatically during a "battle" with foreign invaders. In fact, a sudden increase in white blood cells is a sign that the body is fighting a serious infection. White blood cells are not confined to blood vessels. Many white blood cells can slip through capillary walls to attack foreign organisms.

Different types of white blood cells perform different protective functions. For example, macrophages engulf pathogens. Lymphocytes are involved in the immune response. B lymphocytes produce antibodies that fight infection and provide immunity. T lymphocytes help fight tumors and viruses. You will learn more about lymphocytes and other white blood cells in Chapter 35.

In a healthy person, white blood cells are outnumbered by red blood cells by almost 1000 to 1. Like red blood cells, white blood cells are produced from stem cells in bone marrow. Unlike red blood cells, however, white blood cells keep their nuclei and can live for years.

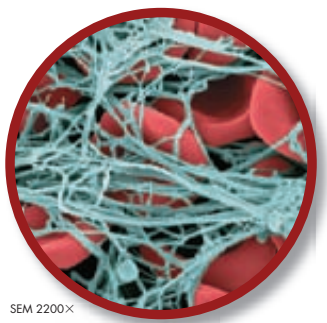
Platelets

Blood loss can be life-threatening. Fortunately, a minor cut or scrape may bleed for a bit, but then the bleeding stops. Why? Because blood clots. **Blood clotting is made possible by plasma proteins and cell fragments called platelets.** The cytoplasm of certain bone marrow cells divides into thousands of small fragments. The fragments, each enclosed in a cell membrane, break off and enter the blood as **platelets.**

When platelets come in contact with the edges of a broken blood vessel, their surface becomes sticky, and they cluster around the wound. These platelets release proteins called clotting factors that start a series of reactions. **Figure 33–9** summarizes one part of the clotting process.

In Your Notebook *Make a flowchart that describes the blood-clotting process.*

FIGURE 33–9 How Blood Clots Form This figure shows one chain reaction in the formation of a clot. When the clot is formed, strands of fibrin form a net that prevents blood from leaving the damaged vessel. **Use Analogies** ***How is a blood clot like a screened porch?***



SEM 2200×

1 Capillary Wall Breaks
A blood vessel is injured by a cut or scrape.

2 Platelets Take Action
Platelets clump at the site and release the clotting factor thromboplastin, which triggers a series of reactions. Thromboplastin converts the protein prothrombin into the enzyme thrombin.

3 Clot Forms
Thrombin converts the soluble plasma protein fibrinogen into insoluble, sticky fibrin filaments, which form the clot. The clot seals the damaged area and prevents further loss of blood.

Analyzing Data

Blood Transfusions

The first successful transfusion of human blood was carried out in 1818. But many later recipients had severe reactions to transfused blood, and a number died. Today we know why. We inherit one of four blood types—A, B, AB, or O—which are determined by antigens, or the lack of antigens, on our blood cells. Antigens are substances that trigger an immune response. People with blood type A have A antigens on their cells, those with type B have B antigens, those with AB blood have both A and B, and those with type O have neither A nor B antigens.

Transfusions work when blood types match. But they can also work in some cases even when the blood types of the donor and the recipient do not match. Use the table to answer the questions that follow.

Blood Transfusions

Blood Type of Donor	Blood Type of Recipient			
	A	B	AB	O
A	✓	x	✓	x
B	x	✓	✓	x
AB	x	x	✓	x
O	✓	✓	✓	✓

x = Unsuccessful transfusion ✓ = Successful transfusion

1. Draw Conclusions Which blood type is sometimes referred to as the "universal donor"? Which is known as the "universal recipient"?

2. Infer In a transfusion involving blood types A and O, does it matter which blood type is the recipient's and which is the donor's?

3. Apply Concepts Write a brief explanation of the results in the chart using information about phenotypes and genotypes in blood group genes. (*Hint:* Review Lesson 14.1 if needed.)

The Lymphatic System

What is the function of the lymphatic system?

As blood passes through capillaries, some blood cells and components of plasma move through capillary walls and into the fluid between cells, carrying nutrients, dissolved oxygen, and salts. Each day about 3 liters of fluid, and the small particles it contains, leaves the blood. Most of this fluid, known as **lymph,** is reabsorbed into capillaries, but not all of it. The rest goes into the lymphatic system. **The lymphatic system is a network of vessels, nodes, and organs that collects the lymph that leaves capillaries, "screens" it for microorganisms, and returns it to the circulatory system.** The lymphatic system, shown in **Figure 33–10,** is also involved in the absorption of nutrients and in immunity.

Role in Circulation Lymph collects in a system of lymphatic capillaries that slowly conducts it into larger and larger lymph vessels. The lymphatic system doesn't have a pump to move lymph along. Instead, lymph vessels have valves, similar to the valves in large veins, that prevent lymph from flowing backward. Pressure on lymph vessels from surrounding skeletal muscles helps move lymph through the system into larger and larger ducts. These ducts return lymph to the blood through openings in the subclavian veins just below the shoulders. When injury or disease blocks lymphatic vessels, lymph can accumulate in tissues, causing swelling called edema.

Role in Nutrient Absorption The lymphatic system also plays an important role in the absorption of nutrients. A system of lymph vessels runs alongside the intestines. The vessels pick up fats and fat-soluble vitamins from the digestive tract and transport these nutrients into the bloodstream.

Role in Immunity Hundreds of small bean-shaped enlargements—called lymph nodes—are scattered along lymph vessels throughout the body. Lymph nodes act as filters, trapping microorganisms, stray cancer cells, and debris as lymph flows through them. Fleets of white blood cells inside lymph nodes engulf or otherwise destroy this cellular "trash." When large numbers of microorganisms are trapped in lymph nodes, the nodes become enlarged. The "swollen glands" that are symptoms of certain kinds of infections are actually swollen lymph nodes.

The thymus and spleen also play important roles in the immune functions of the lymphatic system. The thymus is located beneath the sternum. T lymphocytes mature in the thymus before they can function in the immune system. The functions of the spleen are similar to those of lymph nodes. However, instead of lymph, blood flows through the spleen, where it is cleansed of microorganisms and other debris. The spleen also removes old or damaged blood cells and stores platelets.

In Your Notebook *Compare and contrast the functions of the circulatory system and the lymphatic system.*

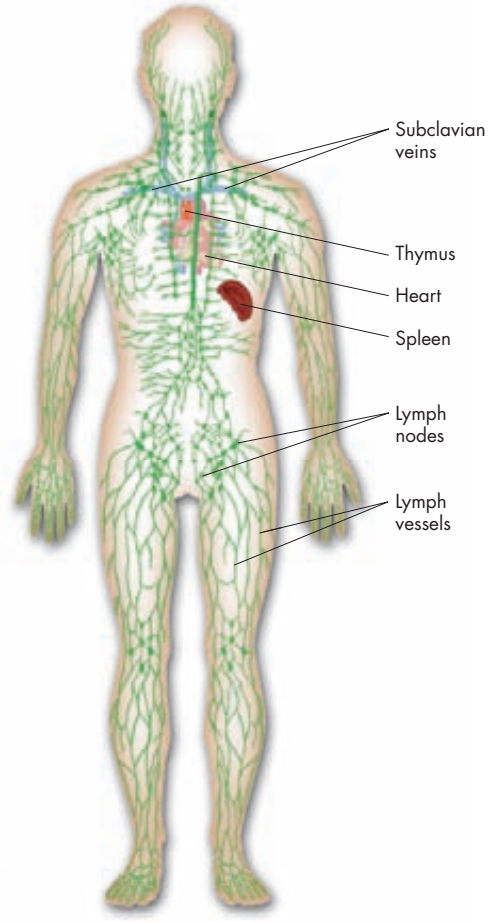


FIGURE 33–10 The Lymphatic System The lymphatic system is a network of vessels, nodes, and organs that recycles fluids from tissues and plays a role in nutrient absorption and immunity. **Infer** ***Why do you think your doctor feels your neck for swollen lymph nodes when you are sick?***

Circulatory System Diseases

What are three common circulatory diseases?

Diseases of the circulatory system can progress for many years before they are discovered. Often the first sign of circulatory problems is an event that affects the heart or brain. Why? Tissues in these vital organs begin to die within moments if their oxygen supply is interrupted.

Three common and serious diseases of the circulatory system are heart disease, stroke, and high blood pressure. Damage to heart muscle from a heart attack or to the brain from a stroke can be fatal. Individuals with high blood pressure are at higher risk for both heart disease and stroke. Heart disease is the leading cause of death in the United States.

Heart Disease Heart muscle requires a constant supply of oxygen. Yet the heart is supplied with blood by just two coronary arteries and their smaller branches. There are many types of heart disease, but the most common occur when blood flow through these vessels is obstructed.

One example is **atherosclerosis,** a condition in which fatty deposits called plaques build up in artery walls and eventually cause the arteries to stiffen. Over time, plaques often bulge into the center of a vessel and restrict blood flow to heart muscle. Chest pain, known as angina, can be a sign of restricted blood flow. Eventually, the heart can be weakened or damaged by oxygen deprivation, leading to a condition called heart failure.

If the cap on a plaque ruptures, a blood clot may form that completely blocks an artery, as shown in **Figure 33–11.** A heart attack occurs as heart muscle cells become damaged and possibly die. Heart attacks can also damage the SA or AV nodes, which can affect the heart's ability to beat in a coordinated way. Arteries severely narrowed by atherosclerosis, the use of drugs such as cocaine, and cigarette smoking can also lead to a heart attack.

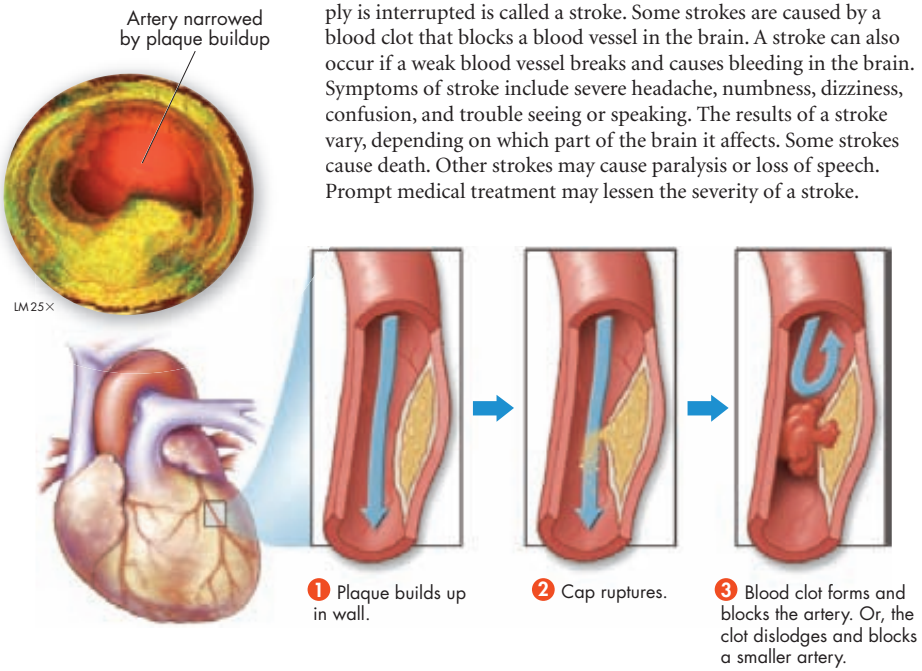
Heart attack symptoms include nausea; shortness of breath; chest pain; and pain in the neck, jaw, or left arm. People with these symptoms need *immediate* medical attention. Medication needs to be given quickly to increase blood flow and save heart muscle.

Stroke The sudden death of brain cells when their blood supply is interrupted is called a stroke. Some strokes are caused by a blood clot that blocks a blood vessel in the brain. A stroke can also occur if a weak blood vessel breaks and causes bleeding in the brain. Symptoms of stroke include severe headache, numbness, dizziness, confusion, and trouble seeing or speaking. The results of a stroke vary, depending on which part of the brain it affects. Some strokes cause death. Other strokes may cause paralysis or loss of speech. Prompt medical treatment may lessen the severity of a stroke.

BUILD Vocabulary

WORD ORIGINS **Atherosclerosis** comes from the Greek words *athero* (gruel or paste) and *sclerosis* (hardness). Atherosclerosis is hardening of the arteries that results from fatty deposits.

FIGURE 33–11 Atherosclerosis Most heart attacks occur when a plaque ruptures in a coronary artery and a clot forms. Clots can also form in large vessels in other parts of the body, break off, and block vessels in the heart that are narrowed by atherosclerosis. **Predict** ***What do you think would happen if a clot broke off from an artery and blocked a vessel in the brain?***



High Blood Pressure High blood pressure, or hypertension, is usually defined as a reading of 140/90 or higher. Because hypertension often has no symptoms, people may have it for years and not know. Meanwhile, heart damage occurs as the heart struggles to push blood through vessels. Hypertension also causes small tears in blood vessels, which sets the stage for atherosclerosis. Likewise, the stiffened arteries that result from atherosclerosis can contribute to high blood pressure. Diet, exercise, and prescription drugs can help control hypertension. Uncontrolled hypertension can lead to heart attack, stroke, and kidney damage.

Risk Factors for Heart Disease and Stroke

Controllable Risk Factors	Uncontrollable Risk Factors
Diet	Age
Exercise	Family history
Weight	Gender (men have more heart attacks)
Not smoking	
High blood cholesterol	
High blood pressure	
Diabetes	

FIGURE 33–12 Risk Factors for Heart Disease and Stroke Some risk factors for heart disease can be controlled because they are related to behavior. For example, people can control their diets and their exercise levels and many can take medication to control diabetes. But other risk factors, such as age and family history, cannot be controlled.

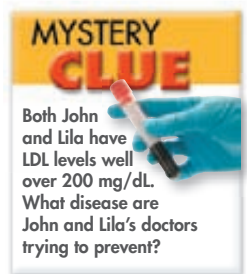
Understanding Circulatory Disease

What is the connection between cholesterol and circulatory disease?

Diseases of the circulatory system do not have a single cause. **Figure 33–12** lists several factors that increase the risk of heart and stroke. Although many risk factors can be controlled, this can be difficult. In some cases, medications may not be accessible or may not be effective. For example, blood cholesterol levels can be difficult to control. But researchers have learned a lot about blood cholesterol levels, their connection to atherosclerosis, and how the condition can be managed.

What Is Cholesterol? Cholesterol is a lipid that is part of animal cell membranes. It is also used in the synthesis of some hormones, bile, and vitamin D. Cholesterol is transported in the blood primarily by two types of lipoproteins—low-density lipoprotein (LDL) and high-density lipoprotein (HDL). LDL is the cholesterol carrier that is most likely to cause trouble in the circulatory system because it becomes part of plaque. HDL, often called good cholesterol, generally transports excess cholesterol from tissues and arteries to the liver for removal from the body.

Measures of a person's blood cholesterol actually are measures of lipoproteins. Normal total blood cholesterol levels range from 100 to 200 milligrams per deciliter (mg/dL). A person's LDL level should be less than 100 mg/dL. A man's HDL level should be greater than 40 mg/dL; a woman's HDL level should be greater than 50 mg/dL.



Sources of Cholesterol The liver manufactures cholesterol, which is then transported through the blood to tissues. Humans also consume cholesterol in meat, eggs, dairy products, and fried foods, especially if those foods are high in saturated or trans fats.

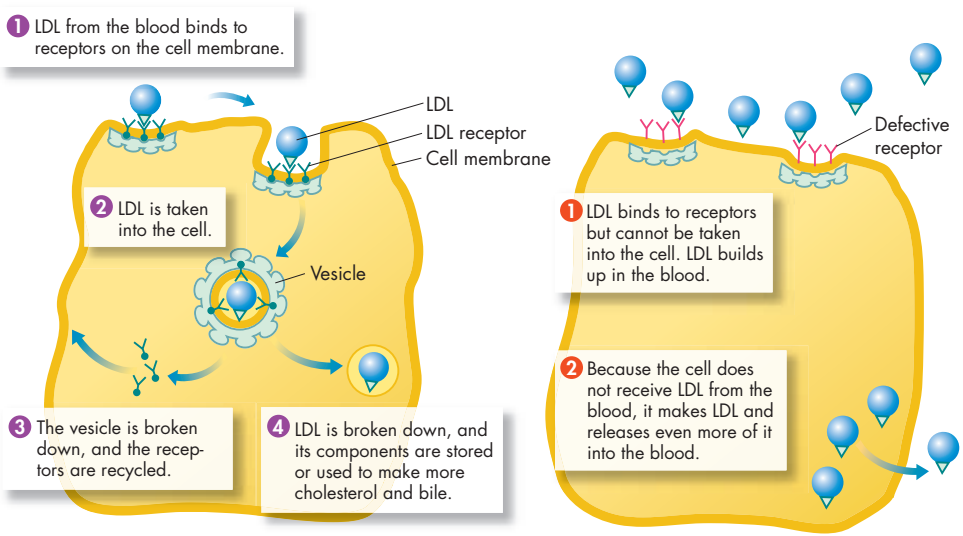
Cholesterol and Atherosclerosis Years ago researchers compared cholesterol levels and heart attack rates in different groups of people. In certain villages in Japan and Yugoslavia, the average cholesterol level was 160. In those populations, the heart attack rate was very low—fewer than five attacks for every 1000 men over a ten-year period. In parts of Finland, researchers found mean cholesterol levels of 265. In that population, the heart attack rate was 14 times higher! **Research indicates that high cholesterol levels, along with other risk factors, lead to atherosclerosis and higher risk of heart attack.**

What controls the level of cholesterol in blood? Is there any medical treatment that can lower cholesterol and reduce the risk of atherosclerosis? These questions led researchers Michael Brown and Joseph Goldstein to studies that earned them a Nobel Prize in 1985.

Identifying the LDL Receptor Brown and Goldstein discovered LDL receptors on the cell membrane of liver cells, as shown in **Figure 33–13.** LDL binds to these receptors and then is taken into the cells. Once inside, cholesterol is broken down and then stored or used for making bile or more cholesterol. When blood cholesterol levels are high, liver cells take cholesterol from the blood and do not make it. When blood cholesterol levels are low, the liver produces it.

In Your Notebook *Make a feedback loop to demonstrate the relationship between blood cholesterol levels and healthy liver cells.*

FIGURE 33–13 LDL Receptors
When blood LDL levels are high, liver cells with normal LDL receptors take up LDL and use it or store it. However, the liver cells of some people have defective LDL receptors. Those cells cannot remove cholesterol from the blood and do not stop producing cholesterol.



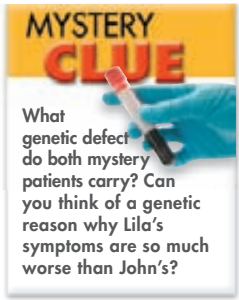
Cell With Normal LDL Receptors **Cell With Defective LDL Receptors**

Brown and Goldstein also found that some people carry genes that produce defective LDL receptors. This causes two problems. First, without working LDL receptors, liver cells can't remove cholesterol from blood. Second, these liver cells don't get the signal to stop producing cholesterol. People with defective LDL receptors have very high cholesterol levels, even if they don't eat much cholesterol or fat.

From Genetic Disease to the Public Does understanding this genetic defect help us understand high cholesterol in the general public? Brown and Goldstein learned that people who eat high-fat diets store excess cholesterol in their liver cells. Those cells then stop making LDL receptors and removing cholesterol from blood. The excess cholesterol is then deposited in arteries. So a diet that is high in cholesterol can cause symptoms similar to those of a genetic disease!

Brown and Goldstein's work led to the development of drugs that can help people with high cholesterol. For example, statins block the synthesis of cholesterol in liver cells. This stimulates the liver to produce more LDL receptors, which then remove excess cholesterol from the blood.

Keeping Your Circulatory System Healthy It is much easier to prevent heart disease than to cure it. Prevention starts when you're young, with healthy habits that include a balanced diet, regular exercise, and not smoking. A healthy diet may protect your arteries from atherosclerosis. Exercise strengthens your heart and helps your circulatory system work efficiently. Never starting to smoke will protect your circulatory system from the many dangerous chemicals in tobacco smoke.



33.2 Assessment

Review Key Concepts

1. a. Review List the main function of plasma, red blood cells, white blood cells, and platelets.

b. Infer Hemophilia is a genetic disorder that results from a defective protein in the clotting pathway. What do you think happens to a person with hemophilia who has a minor cut?

2. a. Review Describe the role of the lymphatic system.

b. Compare and Contrast How are the functions of veins and lymphatic vessels similar? How are they different?

3. a. Review What are the risk factors for the three common diseases of the circulatory system?

b. Form a Hypothesis Why do you think atherosclerosis may lead to hypertension?

4. a. Review What are two types of cholesterol carriers found in the blood?

b. Compare and Contrast Explain how high blood cholesterol develops in someone with a genetic disorder versus someone who eats a high-fat diet.

WRITE ABOUT SCIENCE

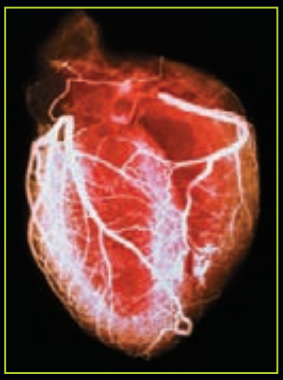
Creative Writing

5. Use library or Internet resources to research the connection between diet and circulatory disease. Write a short commentary that could be used on a television news program that explains the connection. (*Hint:* Prepare a cause-and-effect diagram to organize your ideas.)

BIOLOGY.com Search Lesson 33.2 GO • Self-Test • Lesson Assessment

Testing for Heart Disease

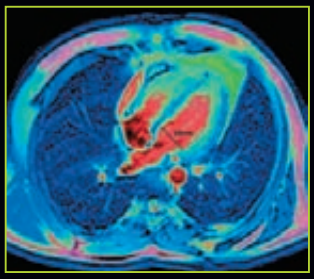
Ever-improving imaging techniques make it possible for doctors to diagnose heart disease and disorders quickly and without the risk of invasive procedures. None of these tests involves inserting instruments into the body, but they reveal the inner workings of the heart with remarkable accuracy.



Computed Tomography Angiography
A patient is injected with an iodine-based dye. Then the CT scanner rotates over the patient and takes multiple X-rays of the heart, which a computer uses to form three-dimensional images. The test can show if parts of blood vessels are blocked or damaged. The results can be used to determine what further tests are needed or as a guide for planning surgery.

WRITING **In a paragraph, explain which technique would most likely be used to check for advanced atherosclerosis in a coronary artery.**

Echocardiography
High-frequency sound waves, transmitted through the chest, are fed into a computer, which analyzes the "echoes" to produce moving images of the heart. This is an especially safe test because it doesn't involve radiation or dyes. The test allows doctors to see the heart in action. It can reveal an enlarged heart, reduced pumping action, and structural problems.



Magnetic Resonance Imaging (MRI)
MRI uses powerful magnets to produce images that are particularly good for examining muscle and other soft tissue. Professionals analyzing MRI images can see the difference between healthy tissue and unhealthy tissue. MRI does not involve radiation or iodine-based dyes. It can be used to assess heart muscle damage caused by a heart attack, birth defects, or abnormal growths.

33.3 The Respiratory System

THINK ABOUT IT When medics examine an unconscious accident victim, one of the first things they do is check whether the person is breathing. This is one way to determine whether there is still a life to save. Why do we make such a close connection between breathing and life? For that matter, why do we need to breathe? All cells in our body, especially brain cells, require a constant supply of oxygen for cellular respiration. Without oxygen, many cells begin to die within minutes. The respiratory system works together with the circulatory system to provide our cells with oxygen. Any interruption in that vital function can be fatal.

Structures of the Respiratory System

What is the function of the respiratory system?

For organisms, rather than single cells, *respiration* means the process of gas exchange between a body and the environment. **The human respiratory system picks up oxygen from the air we inhale and releases carbon dioxide into the air we exhale.** With each breath, air enters the body through the air passageways and fills the lungs, where gas exchange takes place. The circulatory system links this exchange of gases in the lungs with our body tissues. The respiratory system consists of the nose, pharynx, larynx, trachea, bronchi, and lungs.

Nose The respiratory passageways transport air into some of the most delicate tissues in the body. To keep lung tissue healthy, air entering the respiratory system must be filtered, moistened, and warmed. Hairs lining the entrance to the nasal cavity start the filtering process by trapping large particles. Incoming air is warmed in the inner nasal cavity and sinuses. These areas produce mucus that moistens the air and catches even more dust particles. If you've ever blown your nose after spending time in a dusty environment, you've seen evidence of the way nasal hairs and mucus protect the lungs.

In Your Notebook *In your own words, compare and contrast cellular respiration and respiration at the organism level.*

Key Questions

- ***What is the function of the respiratory system?***
- ***How are oxygen and carbon dioxide exchanged and transported throughout the body?***
- ***What mechanisms are involved in breathing?***
- ***How does smoking affect the respiratory system?***

Vocabulary

pharynx
trachea
larynx
bronchus
alveolus
diaphragm

Taking Notes

Flowchart Make a flowchart that shows the path of air through the respiratory system.

SEM 670×

FIGURE 33–14 Cilia Cilia in the trachea sweep mucus and debris away from the lungs. **Infer** *What would likely happen to a person's respiratory system if the cilia were damaged by pollutants?*

Pharynx, Larynx, and Trachea Air moves through the nose to a cavity at the back of the mouth called the **pharynx,** or throat. The pharynx serves as a passageway for both air and food. Air moves from the pharynx into the **trachea,** or windpipe. When you swallow food or liquid, a flap of tissue called the epiglottis covers the entrance to the trachea, ensuring that the food or liquid goes into the esophagus.

Between the pharynx and the trachea is the larynx. The **larynx** contains two highly elastic folds of tissue known as the vocal cords. When muscles pull the vocal cords together, the air moving between them causes the cords to vibrate and produce sounds. Your ability to speak, shout, and sing comes from these tissues.

Mucus produced in the trachea continues to trap inhaled particles. Cilia lining the trachea sweep both mucus and trapped particles away from the lungs toward the pharynx. From there, the mucus and particles can be swallowed or spit out. This process helps keep the lungs clean and open for the important work of gas exchange.

Lungs From the trachea, air moves into two large tubes in the chest cavity called **bronchi** (singular: bronchus). Each bronchus leads to one lung. Within each lung, the large bronchus divides into smaller bronchi, which lead to even smaller passageways called bronchioles. Bronchi and bronchioles are surrounded by smooth muscles controlled by the autonomic nervous system. As the muscles contract and relax, they regulate the size of air passageways.

The bronchioles continue to divide until they reach a series of dead ends—millions of tiny air sacs called **alveoli** (singular: alveolus). Air moving through these tubes can be compared to a motorist who takes an exit off an eight-lane highway onto a four-lane highway, makes a turn onto a two-lane road, and then proceeds onto a narrow country lane—which dead-ends. Alveoli are grouped in clusters, like bunches of grapes. A delicate network of capillaries surrounds each alveolus.

BUILD Vocabulary

MULTIPLE MEANINGS **Alveolus** is also the term for a honeycomb cell in a beehive or a tooth socket in the jaw.

Quick Lab
GUIDED INQUIRY

What's in the Air?

1. Trace the outline of a microscope slide on graph paper. Repeat four times.
2. Cut out the outlines and tape them to the bottom of five slides.
3. Pick indoor and outdoor spots to place your slides. On the back of each slide, write your initials, the date, and where you will put the slide.
4. Cover the front of each slide with a thin coat of petroleum jelly.
5. Leave the slides in the locations you chose for at least 24 hours.
6. Collect the slides, place them under a microscope, and count the number of particles in ten of the squares on each slide. Record your results.

Analyze and Conclude

1. Observe On which slide did you count the most particles? The fewest?

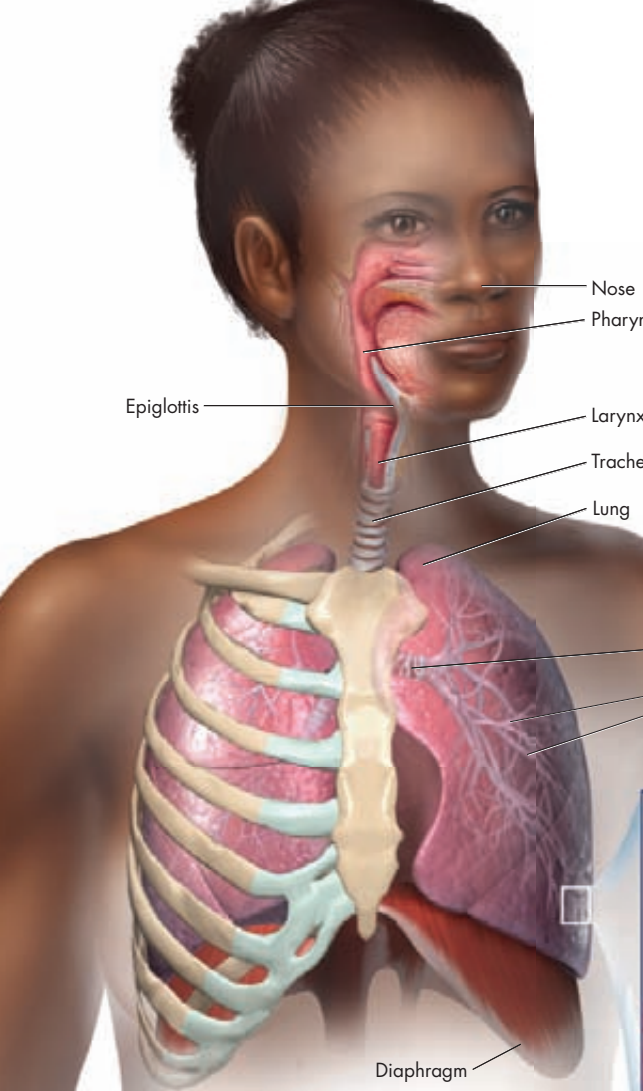
2. Draw Conclusions Were you surprised by the results? Why or why not?

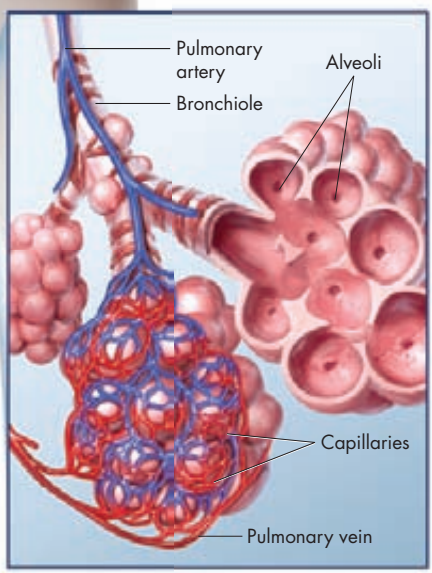
3. Apply Concepts What structures in your body prevent most of these particles from entering your lungs?

VISUAL SUMMARY

THE RESPIRATORY SYSTEM

FIGURE 33–15 Air moves through the nose, pharynx, larynx, trachea, and bronchi into the lungs.





1. **Nose** Air enters the body through the nose, where it is filtered, moistened, and warmed.

2. **Pharynx, Larynx, and Trachea** From the nose, air moves into the pharynx. Then, it passes through the larynx, which contains the vocal cords, and through the trachea.

3. **Lungs** From the trachea, air moves into the bronchi. Each bronchus leads to one lung. The bronchi divide into bronchioles, which eventually end at alveoli.

Gas Exchange and Transport

How are oxygen and carbon dioxide exchanged and transported throughout the body?

Each healthy lung contains about 150 million alveoli, which provide an enormous surface area for gas exchange. **Oxygen and carbon dioxide are exchanged across the walls of alveoli and capillaries. Chemical properties of blood and red blood cells allow for efficient transport of gases throughout the body.**

Gas Exchange When air enters alveoli, oxygen dissolves in the moisture on their inner surface and then diffuses across thin capillary walls into the blood. Oxygen diffuses in this direction because the oxygen concentration is greater in the air within the alveoli than it is in the blood within the capillaries. Meanwhile, carbon dioxide diffuses from blood into the alveoli because its concentration is greater in the blood than it is in the air in the alveoli. The process of gas exchange is illustrated in **Figure 33–16.**

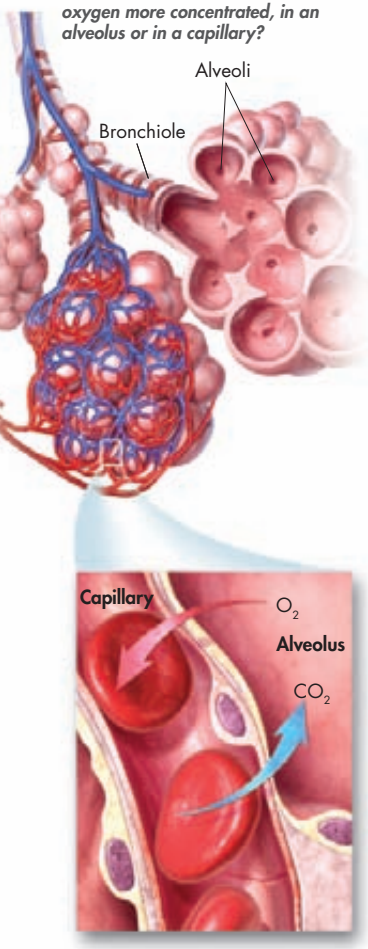
The air you inhale usually contains 21 percent oxygen and 0.04 percent carbon dioxide. Exhaled air usually contains less than 15 percent oxygen and 4 percent carbon dioxide. This means your lungs remove about a fourth of the oxygen in the air you inhale and increase the carbon dioxide content of that air by a factor of 100.

Transport Hemoglobin binds with and transports oxygen that diffuses from alveoli to capillaries. It also increases the efficiency of gas exchange. Diffusion of oxygen from alveoli into capillaries is a passive process. That process stops when oxygen concentration in the blood and alveoli is the same. But hemoglobin actively binds to dissolved oxygen, removing it from plasma and enabling diffusion from the alveoli to continue. Hemoglobin binds with so much oxygen that it increases blood's oxygen-carrying capacity more than 60 times.

When carbon dioxide diffuses from body tissues to capillaries, it is transported in the blood in three different ways. Most carbon dioxide enters red blood cells and combines with water, forming carbonic acid. The rest of it dissolves in plasma or binds to hemoglobin and proteins in plasma. These processes are reversed in the lungs, where carbon dioxide is released into alveoli and exhaled.

In Your Notebook *What would happen to the surface area for gas exchange if a disease caused the walls between alveoli to break down?*

FIGURE 33–16 Gas Exchange Carbon dioxide and oxygen diffuse across capillary and alveolus walls. **Draw Conclusions** *Where is oxygen more concentrated, in an alveolus or in a capillary?*



Breathing

What mechanisms are involved in breathing?

Surprisingly, there are no muscles in our lungs or connected directly to them that participate in breathing. The force that drives air into the lungs comes from ordinary air pressure, the diaphragm, and muscles associated with the ribs. **Movements of the diaphragm and rib cage change air pressure in the chest cavity during inhalation and exhalation.**

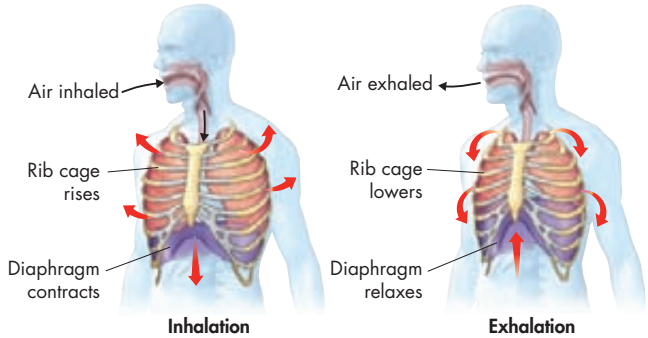


FIGURE 33–17 Breathing During inhalation, the rib cage rises and the diaphragm contracts, increasing the size of the chest cavity. During exhalation, the rib cage lowers and the diaphragm relaxes, decreasing the size of the chest cavity. Humans have some conscious control over breathing—when they swim or play an instrument, for example.

Inhalation The lungs are sealed in two sacs, called pleural membranes, inside the chest cavity. At the bottom of the chest cavity is a large dome-shaped muscle known as the **diaphragm.**

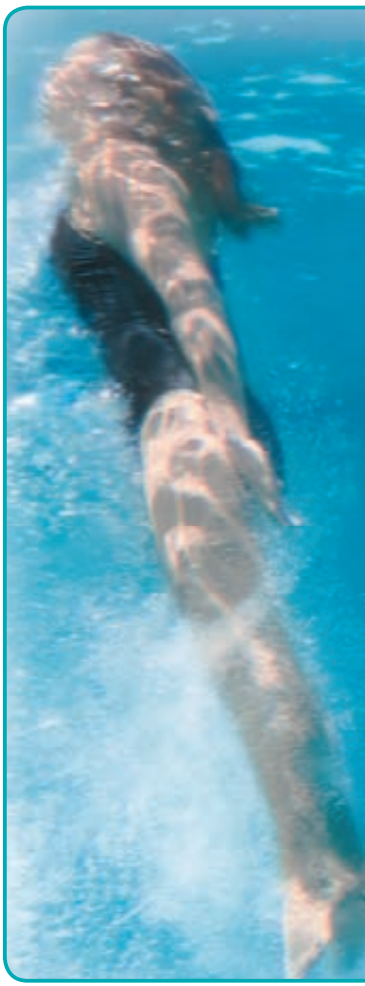
As **Figure 33–17** shows, when you inhale, the diaphragm contracts and flattens. Muscles between the ribs also contract, raising the rib cage. These actions increase the volume of the chest cavity. Because the chest cavity is tightly sealed, this creates a partial vacuum inside the cavity. Atmospheric pressure does the rest, filling the lungs as air rushes into the breathing passages.

Exhalation During ordinary breathing, exhalation is usually passive. Both the rib cage and the diaphragm relax. This relaxation decreases the volume of the chest cavity and makes air pressure in the chest cavity greater than atmospheric pressure. Air rushes back out of the lungs. To blow out a candle, speak, sing, or yell, however, you need more force than passive exhalation provides. The extra force is provided by muscles between the ribs and abdominal muscles, which contract vigorously as the diaphragm relaxes.

The system works only because the chest cavity is sealed. If a wound punctures the chest—even if it does not affect the lungs directly—air may leak into the chest cavity and make breathing impossible. This is one reason chest wounds are always serious.

Breathing and Homeostasis You can control your breathing almost any time you want, to blow up a balloon or to play a trumpet. But this doesn't mean that breathing is purely voluntary. Your nervous system has final control of your breathing muscles whether you are conscious or not. This is why people who drown have water in their lungs. When they lose consciousness, they "breathe" water into their lungs.

Breathing is initiated by the breathing center in the part of the brain stem called the medulla oblongata. Sensory neurons in or near the medulla and in some large blood vessels gather information about carbon dioxide levels in the body and send the information to the breathing center. When stimulated, the breathing center sends nerve impulses that cause the diaphragm and chest muscles to contract, bringing air into the lungs. The higher the blood carbon dioxide level, the stronger the impulses. If the blood carbon dioxide level reaches a critical point, the impulses become so powerful that you cannot keep from breathing.



Smoking and the Respiratory System

How does smoking affect the respiratory system?

The upper respiratory tract filters out many particles that could damage the lungs. But some particles and certain kinds of chemicals can bypass those defenses, enter the lungs, and cause serious problems.

Chemicals in tobacco smoke damage structures throughout the respiratory system and have other negative health effects, too.

Effects on the Respiratory System Three of the most dangerous substances in tobacco smoke are nicotine, carbon monoxide, and tar. Nicotine is an addictive stimulant that increases heart rate and blood pressure. Carbon monoxide is a poisonous gas that blocks hemoglobin from binding with oxygen, thus interfering with oxygen transport in blood. Tar contains at least 60 compounds known to cause cancer.

Tobacco smoke also paralyzes cilia in the trachea. With the cilia out of action, inhaled particles stick to the walls of the respiratory tract or enter the lungs, and smoke-laden mucus is trapped along the airways. Irritation from accumulated particles and mucus triggers a cough—called a smoker's cough—to clear the airways. Smoking also causes the lining of the respiratory tract to swell, which reduces airflow to the alveoli.

FIGURE 33–18 Effect of Smoking on Lungs Chemicals in cigarette smoke damage cilia in the lungs. Over time, particles build up and lead to respiratory diseases such as chronic bronchitis, emphysema, and lung cancer. The damage that smoking can cause to lungs is visible in the bottom photograph.

Healthy Lungs

Smoker's Lungs

Diseases Caused by Smoking Damage to the respiratory system from smoking can become permanent and lead to diseases such as chronic bronchitis, emphysema, and lung cancer. Only 30 percent of male smokers live to age 80, but 55 percent of male nonsmokers live to that age. Clearly, smoking reduces life expectancy. The effect of smoking on the lungs can be seen in **Figure 33–18.**

▶ ***Chronic Bronchitis*** In chronic bronchitis, the bronchi become inflamed and clogged with mucus. Smoking even a moderate number of cigarettes on a regular basis can produce chronic bronchitis. Affected people often find simple activities, like climbing stairs, difficult. Treatments can control symptoms, but there is no cure.

▶ ***Emphysema*** Long-term smoking can lead to emphysema (em fuh SEE muh). Emphysema is the loss of elasticity and eventual breakdown of lung tissue. This condition makes breathing difficult. People with emphysema cannot get enough oxygen to the body tissues or rid the body of excess carbon dioxide. There is no cure for emphysema, but it can be treated with medication.

▶ ***Lung Cancer*** Lung cancer is particularly deadly because, by the time it is detected, it usually has spread to other areas of the body. Few people diagnosed with lung cancer live more than five years. About 87 percent of lung cancer deaths are due to smoking.

What Secondhand Smoke Does
Exposes people to cancer-causing chemicals such as formaldehyde, arsenic, and ammonia
Aggravates asthma
Increases incidence of ear infections
Causes sticky platelets and damaged blood vessels
Causes up to 70,000 deaths from heart disease each year

FIGURE 33–19 Secondhand Smoke Effects Smokers not only put their own health at risk, but also the health of their family and friends exposed to their smoke.

Other Effects of Smoking Smoking also has very negative effects on the circulatory system. For example, it raises blood pressure by constricting blood vessels, which forces the heart to work harder to deliver enough oxygen.

Nonsmokers exposed to high levels of secondhand smoke are also at greater risk for respiratory and circulatory system disease. Inhaling the smoke of others is particularly dangerous for young children because their lungs are still developing. Studies now indicate that children of smokers are twice as likely as children of nonsmokers to develop asthma or other respiratory problems. Pregnant women who smoke place their babies at risk for many complications, some of which can lead to lifelong problems.

Whatever the age of a smoker, and no matter how long that person has smoked, his or her health can be improved by quitting. Nicotine is a powerful drug with strong addictive qualities that make it very difficult to quit smoking. Considering the medical dangers and the powerful addiction, the best solution is not to start smoking.

MYSTERY CLUE

John's doctor told him that if he hadn't stopped smoking, he probably would never have lived past age 50. Explain the doctor's reasoning.

33.2 Assessment

Review Key Concepts

1. a. Review Explain the function of the respiratory system.

b. Use Analogies Explain how a molecule of oxygen flowing through the respiratory system is like a commuter driving home from work.

2. a. Review Describe the process of gas exchange in the lungs.

b. Relate Cause and Effect Carbon monoxide, a poisonous gas, binds to hemoglobin more easily than oxygen does. Based on this information, why do you think that carbon monoxide alarms in homes have saved many lives?

3. a. Review Explain the process of breathing.

b. Infer The brain's breathing center responds to the level of carbon dioxide in the blood, not the level of oxygen. What consequences could this have for people at high altitudes, where oxygen levels are low?

4. a. Review Describe the effects of smoking on the respiratory system.

b. Apply Concepts People with emphysema cannot exhale as much carbon dioxide as people with healthy lungs can. Why do you think this leaves them short of breath?

Apply the Big idea

Structure and Function

5. Compare and contrast human respiration with what you learned about respiration in birds and fish in Chapter 27.

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Pre-Lab: Tidal Volume and Lung Capacity

Problem What factors can affect lung capacity?

Materials round balloons, metric ruler, meter stick

Lab Manual Chapter 33 Lab

Skills Focus Measure, Form a Hypothesis, Design an Experiment, Interpret Graphs

Connect to the Big idea Your lungs and circulatory system work together to provide the oxygen your cells need for cellular respiration. In your lungs, oxygen diffuses from the air you inhale into your blood. Carbon dioxide, a waste product of cellular respiration, diffuses from your blood into the inhaled air. Your lungs must have a large enough volume, or capacity, to supply all your cells with the oxygen they need.

Most of the time your lungs do not fill to capacity. But they can take in more air when you want to dive underwater or when you want to sing a long phrase without having to take another breath. In this lab, you will measure the volume of air you exhale when you are breathing normally and the volume of air you exhale after you take a deep breath.

Background Questions

a. Sequence List in order, from exterior to interior, the parts of the respiratory system that air passes through as you inhale.

b. Review Why does oxygen diffuse from inhaled air in the alveoli into the capillaries?

c. Compare and Contrast What is the difference between respiration and cellular respiration?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. Control Variables What is the one difference between the procedures in Part A and Part B?

2. Design an Experiment Why must you use round balloons for this experiment?

3. Predict Which do you think will be greater—your estimated vital capacity or your measured vital capacity? Why?

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Visit Chapter 33 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Bundle up as the Untamed Science crew journeys to cold climates to show us how some animals handle extreme environments.

Art in Motion View a short animation that shows the beating of the heart as well as the transmission of impulses from the SA and AV nodes.

Art Review Review your understanding of the different parts of the respiratory system.

InterActive Art Watch an animation that shows the process of breathing and the production of sound.

Data Analysis Use electrocardiography to diagnose various heart conditions.

Visual Analogy Compare the structure and function of the circulatory system to a system of highways and secondary roads.

33 Study Guide

Big idea Structure and Function

The functions of the circulatory and respiratory systems are closely connected. Without the circulatory system, oxygen could not be transported from the lungs to the rest of the body. Without the respiratory system, the powerful cardiac muscles would not receive the oxygen they need to drive the circulatory system.

33.1 The Circulatory System

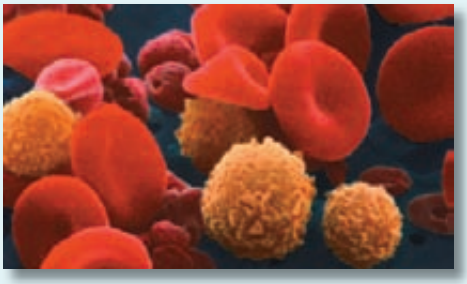
- The circulatory system transports oxygen, nutrients, and other substances throughout the body, and removes wastes from tissues.
- Powerful contractions of the myocardium pump blood through the circulatory system.
- As blood flows through the circulatory system, it moves through three types of blood vessels—arteries, capillaries, and veins.

myocardium (949)
atrium (949)
ventricle (949)
valve (950)
pulmonary circulation (950)
systemic circulation (950)
pacemaker (951)
artery (952)
capillary (952)
vein (952)

33.2 Blood and the Lymphatic System

- Plasma is about 90 percent water and 10 percent dissolved gases, salts, nutrients, enzymes, hormones, waste products, plasma proteins, cholesterol, and other important compounds.
- The main function of red blood cells is to transport oxygen.
- White blood cells guard against infection, fight parasites, and attack bacteria.
- Blood clotting is made possible by plasma proteins and cell fragments called platelets.
- The lymphatic system is a network of vessels, nodes, and organs that collects the lymph that leaves capillaries, "screens" it for microorganisms, and returns it to the circulatory system.
- Three common and serious diseases of the circulatory system are heart disease, stroke, and high blood pressure.
- Research indicates that high cholesterol levels, along with other risk factors, lead to atherosclerosis and higher risk of heart attack.

plasma (954)
red blood cell (954)
hemoglobin (954)
white blood cell (955)
platelet (955)
lymph (956)
atherosclerosis (958)



33.3 The Respiratory System

- The human respiratory system picks up oxygen from the air we inhale and releases carbon dioxide into the air we exhale.
- Oxygen and carbon dioxide are exchanged across the walls of alveoli and capillaries. Chemical properties of blood and red blood cells allow for efficient transport of gases throughout the body.
- Movements of the diaphragm and rib cage change air pressure in the chest cavity during inhalation and exhalation.
- Chemicals in tobacco smoke damage structures throughout the respiratory system and have other negative health effects, too.

pharynx (964)
trachea (964)
larynx (964)
bronchus (964)
alveolus (964)
diaphragm (967)

Think Visually

Make a two-column table. Title the first column Structure and the second column Function. Fill in the table with the structures described in this chapter—from both circulatory and respiratory systems—and their functions.

33 Assessment

33.1 The Circulatory System

Understand Key Concepts

1. The circulatory system includes the
   a. lungs, heart, and brain.
   b. lungs, blood vessels, and heart.
   c. heart, blood, and blood vessels.
   d. heart, arteries, and veins.

2. The upper chambers of the heart are the
   a. ventricles.
   b. septa.
   c. myocardia.
   d. atria.

3. Blood leaving the heart for the body passes through a large blood vessel called the
   a. aorta.
   b. vena cava.
   c. pulmonary vein.
   d. pulmonary artery.

4. Compare pulmonary circulation and systemic circulation.

5. Trace the flow of blood through the heart starting with the right atrium.

6. What is the function of valves in the heart? In what other structures of the circulatory system are valves found?

7. Describe the function of the pacemaker.

8. Describe how the heart beats.

9. Compare the size and structure of arteries, capillaries, and veins.

10. Distinguish between systolic pressure and diastolic pressure.

Think Critically

11. **Design an Experiment** Design an experiment that determines the amount of time needed for a person's heart rate to return to an at-rest rate after exercise.

12. **Draw Conclusions** Some large veins have one-way valves, which keep blood flowing in one direction. Why don't arteries need similar valves?

33.2 Blood and the Lymphatic System

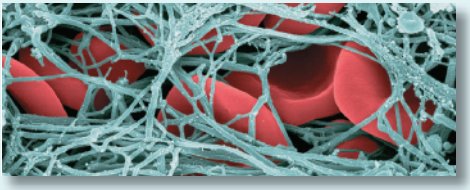
Understand Key Concepts

13. Cells that protect the body by engulfing foreign cells or producing antibodies are
   a. red blood cells. **c.** platelets.
   b. cilia. **d.** white blood cells.

14. Nutrients and wastes are exchanged with body cells through the walls of
   a. veins. **c.** arteries.
   b. capillaries. **d.** atria.

15. The protein found in red blood cells that transports oxygen is called
   a. hemoglobin. **c.** prothrombin.
   b. fibrinogen. **d.** thrombin.

16. The process shown below is made possible by plasma proteins and cell fragments called
   a. fibrins. **c.** platelets.
   b. thrombins. **d.** lymphocytes.



17. Describe the functions of each major component in blood.

18. What are the primary functions of the lymphatic system?

19. Why is LDL known as "bad" cholesterol? Why is HDL known as "good" cholesterol?

Think Critically

20. **Apply Concepts** Why would a person with a low red blood cell count feel tired?

21. **Infer** Aspirin reduces the clot-forming ability of the blood. Why would a doctor prescribe aspirin for someone who has had a stroke?

22. **Predict** Explain how the removal of someone's lymph nodes can affect his or her ability to fight disease.

Understand Key Concepts

23. The tiny hollow air sacs in the lungs where gas exchange takes place are the
a. alveoli. **c.** capillaries.
b. lymph nodes. **d.** bronchioles.

24. Two highly elastic folds of tissue known as the vocal cords are found in the
a. larynx. **c.** trachea.
b. pharynx. **d.** bronchi.

25. The large flat muscle that moves up and down and alters the volume of the chest cavity is the
a. trachea. **c.** diaphragm.
b. epiglottis. **d.** larynx.

26. What part of the brain controls involuntary breathing?

27. What are three dangerous substances in tobacco smoke? Describe how each affects the body.

28. How does emphysema affect the respiratory system?

Think Critically

29. Infer Tobacco smoke can kill white blood cells in the respiratory tract, the cells that help keep the respiratory system clean by consuming debris. How do you think this contributes to the development of smoker's cough?

30. Analyze Data The table shows the relative blood flow through some organs in the human body—that is, the percentage of blood that flows through a given organ. Through which organ(s) does all of the blood flow? Explain the effect of exercise on blood flow to skeletal muscles.

Blood Flow Through Human Organs

Organ	Percentage of Total Flow
Brain	14%
Heart	5%
Kidneys	22%
Liver	13%
Lungs	100%
Skeletal muscles	18%
Skeletal muscles during exercise	75%

solve the CHAPTER MYSTERY

IN THE BLOOD

Both John and Lila have a genetic disease called familial hypercholesterolemia, which is caused by a gene defect on chromosome 19. John is heterozygous for the disorder. Although his liver cells make a mixture of normal and defective LDL receptors, his blood cholesterol levels were so high that he had serious atherosclerosis by age 35. Most people with this disease have had a heart attack by age 60.

Lila is homozygous for the defective allele—a very rare condition. Her liver cells do not produce any functional LDL receptors. Her atherosclerosis became apparent when she was only 4 years old. Fatty deposits can be seen in the corneas of her eyes and beneath the skin near her elbows and knees.

Research on this genetic defect helped uncover the role of liver cell LDL receptors in regulating blood cholesterol. Researchers then applied that information to cases of high cholesterol among the general public. The result was the development of several new classes of drugs that are helping some people live longer.

1. Apply Concepts Is familial hypercholesterolemia a dominant or recessive disorder? Explain your answer.

2. Infer Most heterozygous patients can keep their LDL levels under control with medication that prevents their liver from making cholesterol. But these medications generally do not lower the LDL levels of homozygous patients. Why do you think that is so?

3. Connect to the Big idea If an individual knows that hypercholesterolemia runs in his or her family, what steps can he or she take to live a long and healthy life?

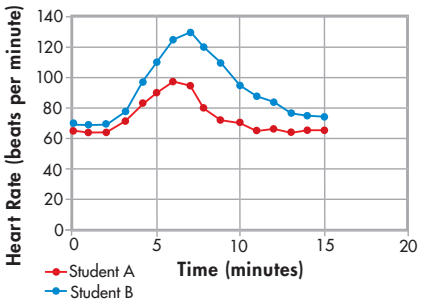
31. Use Models Construct a simple stethoscope out of rubber tubing and a metal funnel. Listen for the sounds of air rushing into and out of your lungs and record a description. How does the sound change when you cough?

Connecting Concepts

Use Science Graphics

The following graph is based on pulse rates taken each minute for two students doing the same exercises. The exercises begin at minute 1 and end at minute 8. Use the graph to answer questions 32–34.

Pulse Rate and Exercise



32. Interpret Graphs At about which minute did each student reach his or her highest heart rate?

33. Draw Conclusions Which of the two students is most likely in better physical condition? What evidence from the graph supports your answer?

34. Predict What other changes in the circulatory and respiratory systems would you expect to take place in the time interval shown?

Write About Science

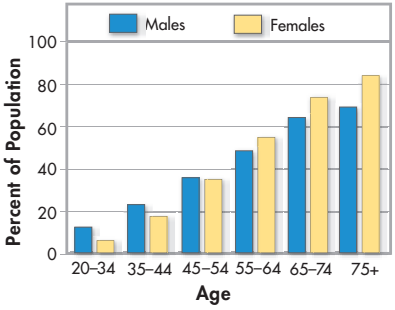
35. Explanation Make a list of the things you do that affect your circulatory and respiratory systems. After completing your list, place a check mark next to those that are harmful. Pick one harmful habit and write a paragraph explaining how you could change or break it.

36. Assess the Big idea Describe the relationship between the human circulatory system and the respiratory system. How does the proper functioning of those systems affect other body systems?

Analyzing Data

High blood pressure is a major risk factor for heart disease in the United States. By age 44, about 25 percent of Americans have high blood pressure, and many of them do not know it. Use the graph to answer questions 37 and 38.

Prevalence of High Blood Pressure in the United States (1999–2004)



37. Interpret Graphs In what age group do women start to have a higher incidence of high blood pressure than men?

38. Calculate Between which age groups do you find the largest percentage increase in cases of high blood pressure? MATH

a. women between 20–34 and 35–44 years of age
b. men between 20–34 and 35–44 years of age
c. women between 55–64 and 65–74 years of age
d. men between 45–54 and 55–64 years of age

Standardized Test Prep

Multiple Choice

1. In the human heart, oxygen-rich blood would be found in the
- **A** right atrium and the right ventricle.
- **B** right atrium and the left atrium.
- **C** left atrium and the left ventricle.
- **D** right ventricle and the left ventricle.

2. Which statement BEST describes an interaction between the circulatory system and the respiratory system that helps maintain homeostasis?
- **A** Blood plasma transports salts, nutrients, and proteins through the body to keep it healthy.
- **B** The diaphragm and rib cage work together to move air into and out of the lungs.
- **C** Lymph nodes filter out bacteria that could cause disease.
- **D** Blood cells pick up and carry oxygen from the lungs to the body's cells.

3. A heartbeat begins with an impulse from the
- **A** nervous system.
- **B** sinoatrial node.
- **C** atrioventricular node.
- **D** aorta.

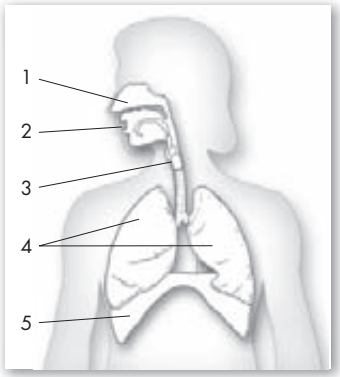
4. All of the following are components of human blood EXCEPT
- **A** plasma.
- **B** mucus.
- **C** phagocytes.
- **D** platelets.

5. Nicotine in tobacco
- **A** is not addictive.
- **B** lowers blood pressure.
- **C** blocks the transport of oxygen.
- **D** increases heart rate.

6. Antibodies are produced by
- **A** red blood cells.
- **B** platelets.
- **C** B lymphocytes.
- **D** hormones.

Questions 7–10

Use the diagram below to answer the questions that follow.



7. Which structure's primary function is to warm and moisten inhaled air?
- **A** 1
- **B** 3
- **C** 4
- **D** 5

8. Which structure contains the vocal cords?
- **A** 1
- **B** 2
- **C** 3
- **D** 4

9. Damage to which structure can lead to emphysema?
- **A** 2
- **B** 3
- **C** 4
- **D** 5

10. Which structure contains alveoli?
- **A** 2
- **B** 3
- **C** 4
- **D** 5

Open-Ended Response

11. Explain why the risk factors for heart disease and strokes are similar.

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10	11
See Lesson	33.1	33.3	33.1	33.2	33.3	33.2	33.3	33.3	33.3	33.3	33.2