Connect to the Big Idea

Use the photograph of the swimmers to start a discussion on the human circulatory and respiratory systems. Ask students how they would prepare to swim underwater. (Sample answers: I would take a deep breath; I would hold my breath.) Challenge students to explain why people can stay underwater only for a limited amount of time. (Students may describe “running out of air” after a certain amount of time.) Then, ask students to identify some of the structures and systems involved in taking in oxygen and getting oxygen to the body’s tissues. Lead students to anticipate the answer to the question, **How do the structures of the circulatory and respiratory systems allow for their close functional relationship?**

Have students read over the Chapter Mystery. Then, discuss the impact that clogged heart vessels would have on the circulatory system and the entire body. Challenge them to relate damage to circulatory system structures with impaired functioning of the system.

Have students preview the chapter vocabulary terms using the [Flash Cards](#).

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**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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**Understanding by Design**

Chapter 33 describes the circulatory, lymphatic, and respiratory systems. The graphic organizer at the right shows how these topics are connected to the chapter Essential Question and Big Idea. Together, these ideas and questions help students build toward the Unit 8 Enduring Understanding that the human body is a complex system. *The coordinated functions of its many structures support life processes and maintain homeostasis.*

**PERFORMANCE GOALS**

Students will show understanding of Chapter 33 concepts by using and discussing the many complex diagrams in this chapter. They will also gather and analyze data on their own heart rates. At the end of the chapter, students will synthesize what they have learned by writing a script for a museum tour through a larger-than-life model of the circulatory, lymphatic, or respiratory system.
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.

**What’s Online**

Extend your reach by using these and other digital assets offered at Biology.com.

**CHAPTER MYSTERY**

How could John and Lila have the same symptoms despite their very different ages and medical histories? Students can use clues to figure out the identity of this genetic disease.

**UNTAMED SCIENCE VIDEO**

Some like it cold! Students can take a video field trip that explores adaptations in animals that live in Earth’s coldest environments.

**VISUAL ANALOGY**

Explore ways in which the human circulatory system is similar to an urban transportation network.

**ART IN MOTION**

Have students use this animation to watch how blood flows through the heart.

**DATA ANALYSIS**

This activity allows students to use electrocardiography to diagnose heart conditions.

**ART REVIEW**

Use this activity to help students understand the structures of the respiratory system.

**INTERACTIVE ART**

Students can use this interactive activity to learn about breathing.
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

Getting Started

Objectives
33.1.1 Identify the functions of the human circulatory system.
33.1.2 Describe the structure of the heart and explain how it pumps blood through the body.
33.1.3 Name three types of blood vessels in the circulatory system.

Student Resources
Study Workbooks A and B, 33.1 Worksheets
Spanish Study Workbook, 33.1 Worksheets
Lab Manual B, 33.1 Hands-On Activity Worksheet

Lesson Overview • Lesson Notes
• Activities: Visual Analogy, Art in Motion, Data Analysis • Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the Foundation Edition, see pages 786–789.

Visual Analogy

A person who lives in a city needs goods and waste removal; a cell needs nutrients, oxygen, and waste removal.

Answers

FIGURE 33–1 A person who lives in a city needs goods and waste removal; a cell needs nutrients, oxygen, and waste removal.

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.

Teach for Understanding

ENDURING UNDERSTANDING The human body is a complex system. The coordinated functions of its many structures support life processes and maintain homeostasis.

GUIDING QUESTION What structures transport substances throughout the human body?

EVIDENCE OF UNDERSTANDING After completing the lesson, assign students the following assessment to show their understanding of the circulatory system. Have students work in small groups to make a poster that describes the three types of blood vessels discussed in this lesson. Have each group present its completed poster to the class.
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.

**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.

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**Vocabulary**

**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.”

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**How Science Works**

**WILLIAM HARVEY’S CONTRIBUTION**

One scientist is known above all others for his contributions to our understanding of the human circulatory system. That scientist is William Harvey, an English physician, whose 1628 book on the circulation of blood was a landmark publication. Up until Harvey’s time, there were many misconceptions about blood and the circulatory system. For example, it was thought that blood formed in the liver, that blood moved very sluggishly if at all, and that the pulmonary and systemic blood were not connected. Harvey dissected cadavers and studied living patients to disprove many of these thoughts. He determined that the heart pumps blood through the body via arteries and that blood returns to the heart through veins. Harvey described how the valves in the heart and veins keep blood flowing in just one direction.

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**Answers**

**IN YOUR NOTEBOOK** Yes, an average heart beating 72 times a minute, pumping 70 milliliters of blood with each contraction, will pump more than 2,600,000 liters of blood in a year. (70 mL/contraction × 72 contractions/min = 5040 mL/min; 5040 mL/min × 525,600 min/year = 2,649,024,000 mL, or 2,649,024 L)
**Teach** continued

**Lead a Discussion**

Use the following questions to discuss circulation.

**Ask** How is blood flowing through the heart different from the heart's own blood supply? *(When blood flows through the heart, it does not supply the cells of the heart muscle with oxygen and nutrients or remove wastes. The heart's own blood supply that comes from the coronary arteries provides heart muscle cells with oxygen and nutrients and removes cellular wastes.)*

**Ask** How is pulmonary circulation different from systemic circulation? *(Pulmonary circulation is the blood flow between the lungs and the heart; systemic circulation is blood flow between the heart and the body.)*

**DIFFERENTIATED INSTRUCTION**

**Struggling Students** Have students use Figure 33–3 to help them clarify the difference between pulmonary and systemic circulation. First, have students trace the black arrows in the diagram, which represent pulmonary circulation. Then, have them trace the white arrows in the diagram, which represent systemic circulation. Use the following questions to check students’ comprehension.

**Ask** In pulmonary circulation, what organs does blood flow through? *(heart and lungs)*

**Ask** What happens to blood in the capillaries of the lungs? *(The blood absorbs oxygen and gives off carbon dioxide.)*

**Ask** What structures does blood flowing through the systemic pathway serve? *(the rest of the body)*

Students should explain that the coronary arteries are already narrow. Therefore, a disease that further narrows them would affect the heart's blood supply. Students can go online to Biology.com to gather their evidence.

**Mystery Clue**

![Mystery Clue Image](image)

**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.

**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.

**UBD Check for Understanding**

**HAND SIGNALS**

Present students with the following questions, and ask them to show a thumbs-up sign if they can answer the question, a thumbs-down sign if they definitely cannot, or a waving-hand sign if they are not sure.

- What is the function of the myocardium?
- Can you describe pulmonary circulation?
- Can you describe systemic circulation?

**ADJUST INSTRUCTION**

Identify questions that are a source of confusion for at least several students. Have the class form groups to discuss these questions for approximately 5 minutes and then share their answers.

**Answers**

**FIGURE 33–3** Oxygen-rich blood leaves the lungs and returns to the heart.

**IN YOUR NOTEBOOK** Students’ cycle diagrams should include 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.

**Use Visuals**

Use **Figure 33–4** to help students understand how the heart beats. Point out that both atria contract at the same time and both ventricles contract at the same time. The result is that blood is pumped into the pulmonary circulation pathway and the systemic circulation pathway at the same time. Then, walk the class through the steps of a heartbeat.

**Ask** What happens when the sinoatrial node fires? *(The atria contract.)*

**Ask** Where in the heart does blood move when the atria contract? *(from the atria to the ventricles)*

**Ask** What signals the atrioventricular node to fire? *(It picks up the signal from the sinoatrial node.)*

**Ask** What happens when the atrioventricular node fires? *(The ventricles contract.)*

**DIFFERENTIATED INSTRUCTION**

**L.** Advanced Students Tell students artificial pacemakers are implanted in individuals whose hearts need help maintaining a normal rate of contractions. Have them do research to find out more about artificial pacemakers and why they are used. Have students share what they learned with the class.

**To watch how the heart beats,** suggest students view the animation, **Art In Motion: Heartbeat.** The **Data Analysis:** **Electrocardiography** activity allows students to use electrocardiography to diagnose heart conditions.

**Address Misconceptions**

**Heart Contraction** A common misconception among students is that oxygen-rich blood leaves the heart at a separate time from oxygen-poor blood. Explain to students that when the ventricles contract, oxygen-rich blood is pumped out of the left ventricle to the body. At the same time, oxygen-poor blood is pumped out of the right ventricle to the lungs.

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**Quick Lab**

**PURPOSE** Students will identify how standing affects heart rate.

**MATERIALS** stopwatch or clock with a second hand

**PLANNING** Have students practice locating and measuring their pulse before they begin this activity.

**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.

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**ANALYZE AND CONCLUDE**

1. Sample answer: I predict that my heart rate would increase if I stood up.

2. A person’s heart rate should increase when the person is standing versus sitting down. Evaluations and explanations will vary. Sample answer: My prediction was correct; when I stood up my heart rate increased. When I stand up, my body needs to take in more oxygen than when I am sitting down.
**Teach continued**

### Build Science Skills

Use the following questions to help students compare and contrast arteries, capillaries, and veins.

**Ask** How are the structures of veins and arteries similar? (Veins and arteries have an inner layer of endothelium, a middle layer of smooth muscle, and an outer layer of connective tissue.)

**Ask** How do the functions of arteries and veins differ? (Most arteries carry oxygen-rich blood from the heart to the tissues of the body. Most veins carry oxygen-poor blood from the body back to the heart.)

**Ask** How are capillaries similar to veins and arteries? (Sample answer: Capillaries, veins, and arteries all carry blood in the body.)

**Ask** Why does diffusion of materials between blood and body cells occur across capillary walls but not veins or arteries? (Because of capillaries’ extremely thin walls)

### DIFFERENTIATED INSTRUCTION

**LPR Less Proficient Readers** Have students use Figure 33–5 to learn about the ways in which veins, arteries, and capillaries are similar and different. Focus students’ attention on the artery, and work with them to describe its structure. Then, point out the vein, and have students describe its structure. Finally, have students examine the capillary to learn about ways capillaries are similar to and different from arteries and 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.

### Check for Understanding

#### VISUAL REPRESENTATION

Write the lesson vocabulary terms on the board: myocardium, atrium, ventricle, valve, pulmonary circulation, systemic circulation, pacemaker, artery, capillary, vein. Have students make a Concept Map that includes each of the terms.

#### ADJUST INSTRUCTION

If students have difficulty completing the concept map, or if their completed maps are incorrect, have them make a vocabulary flash card for each term, with the term on the front and its definition on the back. Have students use their flash cards to review the vocabulary terms with a partner and then revise their concept maps as needed.
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 (sig’ muh mohm soh muh soh tuh’), 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 cause the smooth muscles in vessel walls to contract. When blood pressure is low, neurotransmitters are released that cause the smooth muscles in vessel walls to relax. 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 cause the smooth muscles in vessel walls to contract. When blood pressure is low, neurotransmitters are released that cause the smooth muscles in vessel walls to relax.

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.

**Assessment Answers**

1a. Heart, pumps blood throughout the body; blood vessels, carry blood throughout the body; blood, carries oxygen and nutrients to the body’s tissues and carries away the tissues’ wastes.

1b. Humans need a circulatory system because their bodies contain millions of cells that are not in direct contact with the external environment. These cells cannot exchange gases, nutrients, and wastes with the environment; they must rely on the circulatory system to do this.

2a. In pulmonary circulation, the heart pumps oxygen-poor blood to the lungs. Oxygen-rich blood from the lungs returns to the heart. In systemic circulation, the heart pumps this oxygen-rich blood to the rest of the body. The veins return oxygen-poor blood to the heart.

2b. If the sinoatrial node were damaged, the heartbeat would not be properly regulated.

3a. Arteries carry blood from the heart to the tissues; capillaries allow diffusion between the blood and body cells; veins carry blood back to the heart from the body.

3b. Blood pressure would be higher in your arm because it is closer to your heart.

4. Students’ diagrams should resemble Figure 33–2. Make sure the chambers of the heart are labeled and that students have correctly indicated the path of blood through the heart.
Lessons Overview  • Lesson Notes

Lesson 33.2

Getting Started

Objectives

33.2.1 Explain the functions of blood plasma, red blood cells, white blood cells, and platelets.
33.2.2 Describe the role of the lymphatic system.
33.2.3 List three common circulatory diseases.
33.2.4 Describe the connection between cholesterol and circulatory disease.

Student Resources

Study Workbooks A and B, 33.2 Worksheets
Spanish Study Workbook, 33.2 Worksheets
Lab Manual B, 33.2 Data Analysis Worksheet

For corresponding lesson in the Foundation Edition, see pages 790–795.

Activate Prior Knowledge

Tell students that blood serves several important functions in the body. Then, have them form small groups to discuss what they already know about blood. Call on each group to share a summary of its discussion with the rest of the class.

Blood and the Lymphatic System

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?

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 er-throh 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.

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 1866X).

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?

What is the role of the lymphatic system in the body?

ENDURING UNDERSTANDING The human body is a complex system. The coordinated functions of its many structures support life processes and maintain homeostasis.

GUIDING QUESTION What are the roles of blood and the lymphatic system in the body?

EVIDENCE OF UNDERSTANDING After completing the lesson, give students the following assessment to show their understanding of the lymphatic and circulatory systems. Have pairs of students role-play a conversation in which one student assumes the role of the lymphatic system and the other student plays the circulatory system. Suggest pairs discuss how they are similar and how they are different. Make sure students also discuss how they work together.

UBD Teach for Understanding

ENDURING UNDERSTANDING The human body is a complex system. The coordinated functions of its many structures support life processes and maintain homeostasis.

GUIDING QUESTION What are the roles of blood and the lymphatic system in the body?

EVIDENCE OF UNDERSTANDING After completing the lesson, give students the following assessment to show their understanding of the lymphatic and circulatory systems. Have pairs of students role-play a conversation in which one student assumes the role of the lymphatic system and the other student plays the circulatory system. Suggest pairs discuss how they are similar and how they are different. Make sure students also discuss how they work together.
White Blood Cells  White blood cells, or leukocytes (100 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.

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

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.

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.

Figure 33–9 How Blood Clot

Make a flowchart that describes the
blood-clotting process.

How is a blood clot like a screened porch?

LESSON 33.2

Teach

Lead a Discussion
Ask these questions to help students understand the functions of each component of blood.

Ask Which two components of blood are most directly involved in blood clotting? (plasma proteins and platelets)

Ask Anemia is a term for a group of disorders characterized by a deficiency of red blood cells. What function of blood is impaired in individuals with anemia? (delivery of oxygen to body cells)

Ask If an individual has a disorder that results in a reduction of white blood cells, what is a likely result? (reduced ability to fight infection)

DIFFERENTIATED INSTRUCTION

LPR Less Proficient Readers Distribute four index cards to each student. On the front of each card, have them write the name of one of the components of blood. On the back of the cards, have them rephrase the Key Concept about that component and add details from the reading.

ELL Focus on ELL: Access Content

ADVANCED AND ADVANCED HIGH SPEAKERS Have students write five questions about blood that can be answered from the text on the left side of a T-Chart under the heading Questions. Have them exchange charts with a partner and record the answers on the right side of the T-Chart under the heading Answers. Encourage students to use complete sentences when recording their answers. Then, have pairs discuss the completed T-Charts and review any questions that they struggled to answer.

Study Wkbsks A/B, Appendix S30, T-Chart. Transparencies, GO15.

How Science Works

MEDICINAL USES OF LEECHES

Ancient medical practices are rarely accepted in modern times. The medicinal use of leeches is an exception. Until the mid-19th century, patients were bled using leeches to treat a wide variety of ailments. For most of these disorders, the usefulness of intentional bleeding was questionable. In 2004, the Food and Drug Administration approved the use of leeches as a medical device. Modern medical uses of leeches are limited to situations in which blood needs to be extracted from a specific area of tissue—such as when blood needs to be drained from an area surrounded by damaged blood vessels before surgery can be performed. Leeches extract blood and also release a chemical that inhibits clotting, allowing for enhanced blood flow. Leeches also produce an anesthetic that numbs the area while blood is being drawn.

Answers

FIGURE 33–9 The filaments formed from fibrinogen are similar to a screen, because blood cells cannot pass through them, just as most bugs cannot pass through a screen.

IN YOUR NOTEBOOK Flowcharts should include the steps shown in Figure 33–9, connected by arrows.
### LESSON 33.2

**Build Study Skills**

Have students build **Cause-and-Effect Diagrams** to describe what would happen if the lymphatic system did not perform each of its functions. *(If the lymphatic system did not collect lymph, swelling would occur. If it didn’t absorb fat, then the body would not receive the fat it needs to be healthy. If the lymph nodes did not house white blood cells and “catch” microorganisms it would be harder to fight infections.)*

**Study Wkbks A/B,** Appendix S18, Cause-and-Effect Diagram. **Transparencies, G01.**

**DIFFERENTIATED INSTRUCTION**

**ELL Struggling Students** Suggest students work in pairs to locate the information they need to complete the **Cause-and-Effect Diagrams.** Remind students that the blue heads provide clues to the main functions of the lymphatic system.

**ELL English Language Learners** Have students identify words they do not understand in the section on the lymphatic system. Have them list the words on a sheet of paper. Then, have students form small groups to find definitions for these words. Suggest they refer to this list as they fill in the **Cause-and-Effect Diagrams.**

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### 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.

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### 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.

<table>
<thead>
<tr>
<th>Blood Type of Donor</th>
<th>Blood Type of Recipient</th>
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<tbody>
<tr>
<td>A</td>
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<td>A</td>
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<td>O</td>
<td>AB</td>
</tr>
<tr>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

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.)*

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**Analyzing Data**

**PURPOSE** Students will examine and interpret data to identify how blood type affects the success of transfusions.

**PLANNING** Remind students that human blood types are an inherited trait.

**ANSWERS**

1. Type O is sometimes referred to as the “universal donor.” Type AB is sometimes referred to as the “universal recipient.”

2. Yes, because people with type A blood can safely receive type O blood, whereas people with type O blood cannot safely receive type A blood.

3. Students’ responses will vary, but should reflect an understanding of blood groups and genetics. Sample answer: People who have type O blood do not produce blood antigens and, therefore, can donate blood to any of the other blood groups safely. The alleles for type A and B are codominant; people with type AB blood can receive blood from all four blood groups.
**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.

**Circulatory System 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.*

**FIGURE 33–10 The Lymphatic System** The lymphatic system is a network of vessels, nodes, and organs that recycle 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?*

**Check for Understanding**

**ONE-MINUTE RESPONSE**

Give students about a minute to write a quick response to:

What are the structures and functions of the lymphatic system? *(Responses should include lymph vessels, lymph nodes, spleen, and thymus; and the system’s roles in circulation, nutrient absorption, and immunity.)*

**ADJUST INSTRUCTION**

If responses are incorrect or incomplete, suggest each student write a list of structures and then work with a partner to discuss the function of each.

**Use Visuals**

Have students use Figure 33–10 to learn more about the lymphatic system.

**Ask** How is the location of lymph nodes and lymph vessels throughout the body related to the role of the lymphatic system in circulation? *(Lymph can be collected throughout the body and returned to the circulatory system.)*

**Ask** Where is lymph returned to the circulatory system? *(through openings in the subclavian veins)*

**Ask** In what role of the lymphatic system are the thymus and spleen directly involved? *(immunity)*

**DIFFERENTIATED INSTRUCTION**

* Advanced Students Have students find out why doctors use a biopsy of lymph nodes from near a tumor when assessing the stage of disease in cancer patients. Have them create a poster to share what they learn with the class.

**Answers**

**FIGURE 33–10** Swollen lymph nodes indicate that a large number of microorganisms have been trapped in the lymph nodes.

**IN YOUR NOTEBOOK** Students’ responses will vary but should indicate an understanding of the main functions of both systems. The circulatory system transports oxygen, nutrients, and other substances throughout the body and removes wastes from tissues. The lymphatic system collects lymph that leaves the capillaries, and returns it to the circulatory system, picks up fat and other nutrients from the intestines, and removes microorganisms from lymph.
Use Models

Give students a hands-on demonstration of how atherosclerosis increases the work the heart has to do to pump blood. Obtain a bicycle pump and a piece of rubber tubing that fits over the air nozzle of the pump. Give students a chance to pump air through the open tube. Then, have them pump air while you squeeze the tube almost closed. Ask students to describe the difference.

**Ask** How does squeezing the tube represent atherosclerosis? (Atherosclerosis restricts blood flow through the arteries similar to how squeezing restricts air flow through the tube.)

**DIFFERENTIATED INSTRUCTION**

**L1 Struggling Students** If students struggle to understand the bike-pump model, provide them with additional guiding questions that explicitly make the connection between the model and atherosclerosis.

**Ask** What does the heart do? (It pumps blood throughout the body.)

**Ask** What does the bike pump do? (It pumps air.)

**Ask** In this model, what does the bicycle pump represent? (the heart)

**Ask** Was it easier to pump air through an open tube or through a tube that is being squeezed? (through an open tube)

**Ask** Is it easier for the heart to pump blood through an open artery or one that is blocked by plaques? (through an open artery)

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**Answers**

**FIGURE 33–11** sudden death of brain cells due to lack of oxygen
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.

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 available 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.

Quick Facts

**BLOOD PRESSURE**

Blood pressure rises and falls throughout life and even throughout the day. Babies and children usually have much lower blood pressure than adults, and blood pressure is usually lowest during sleep and highest in the morning. Blood pressure also rises during exercise and periods of emotional excitement. Weight gain is usually associated with an increase in blood pressure. Some people have a genetic predisposition for high blood pressure. For instance, for unknown reasons, people of African American descent are at higher risk than the general U.S. population for more frequent and severe high blood pressure. Knowing one’s genetic predisposition for high blood pressure may help encourage a person to take preventive measures, such as adopting a healthier lifestyle.

**Risk Factors for Heart Disease and Stroke**

<table>
<thead>
<tr>
<th>Controllable Risk Factors</th>
<th>Uncontrollable Risk Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet</td>
<td>Age</td>
</tr>
<tr>
<td>Exercise</td>
<td>Family history</td>
</tr>
<tr>
<td>Weight</td>
<td>Gender (men have more heart attacks)</td>
</tr>
<tr>
<td>Not smoking</td>
<td></td>
</tr>
<tr>
<td>High blood cholesterol</td>
<td></td>
</tr>
<tr>
<td>High blood pressure</td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
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</table>

Connect to Health

Have students form small groups, and ask each group to examine the table showing risk factors for heart disease and stroke. Instruct groups to prepare a public service announcement (PSA) about one of the controllable risk factors. Remind students that a PSA is a concise message, usually presented on radio or television, that promotes a positive behavior. Explain that each group should do additional research to find out why the risk factor they selected can lead to heart disease and stroke and to find ways to avoid that risk factor. For example, a PSA about diet should explain how diet impacts susceptibility to heart disease and stroke. It should also include information on heart-healthy diets. Have each group share its PSA with the class.

**DIFFERENTIATED INSTRUCTION**

**Struggling Students** Students may be confused by the listing of high blood pressure as a risk factor for heart disease and stroke in the table. Make sure students understand that high blood pressure is a disorder itself, as well as a contributing factor to heart attack and stroke. Explain that high blood pressure can have many health consequences in addition to increasing the risk of heart disease and stroke.

**Mystery Clue**

Help students understand the relationship between high cholesterol levels and atherosclerosis. Point out that LDL becomes part of plaque. Then, have students describe why this may contribute to the development of atherosclerosis. Students can go online to Biology.com to gather their evidence.
Lead a Discussion

Remind students that humans obtain cholesterol from meat and dairy products—particularly if those foods are high in certain kinds of fat. Explain that many factors, including several genes, each with multiple alleles, determine the response of an individual to a high-fat diet.

Ask Recall that feedback inhibition is essential for the maintenance of homeostasis in the body. How does blood cholesterol level regulation demonstrate feedback inhibition? (When blood cholesterol levels are high, the liver absorbs cholesterol, which inhibits cholesterol production in the liver. When blood cholesterol levels are low, the liver does not absorb cholesterol from the blood, and cholesterol is produced by the liver.)

Ask How would individuals be affected if the LDL receptors on their liver cells were defective? (The individuals would have high cholesterol, because their liver cells could not remove cholesterol from the blood.)

Ask How could a person’s diet cause symptoms that were similar to an individual with faulty LDL receptors? (When an individual eats a high-fat diet, cholesterol can build up in liver cells. These cells stop making LDL receptors and, therefore, no longer remove cholesterol from the blood.)

Point out to students that both proteins and carbohydrates can be converted into fat tissue. An overabundance of Calories, regardless of the energy source, will be stored as fat.

DIFFERENTIATED INSTRUCTION

Less Proficient Readers Suggest students use Figure 33–13 to understand what happens when a person has defective LDL receptors. Point out that the figure shows two different situations. On the left, the cell has normal LDL receptors; on the right, the cell has defective LDL receptors. Have students describe what occurs in each cell.

Answers

IN YOUR NOTEBOOK Students’ feedback loops should show the following: When blood cholesterol levels rise, liver cells take cholesterol from the blood and do not produce cholesterol. When blood cholesterol levels fall, liver cells produce cholesterol.

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.

Check for Understanding

FOLLOW-UP PROBES

Ask Blood cholesterol levels are affected by more than one factor. Explain. (Sample answer: Diet can affect blood cholesterol level, as can defective LDL receptors on liver cells.)

ADJUST INSTRUCTION

If students’ responses indicate confusion about the factors that affect blood cholesterol level, write the question “What affects blood cholesterol level?” on the board. Have volunteers provide answers, and record their responses on the board. Lead students to the conclusion that blood cholesterol level is generally affected by more than one factor.
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.

Assess and Remediate
EVALUATE UNDERSTANDING
Have students work with a partner to review the definition of each vocabulary term in the lesson. Call on pairs of students to define a term for the class. Continue until each vocabulary term has been correctly defined. Then, have students complete the 33.2 Assessment.

REMEDIATION SUGGESTION
 Less Proficient Readers If students are struggling to answer Question 2b, help them locate information in the text about the function of veins and the function of lymphatic vessels. Have students write a brief summary of this information. Then, have them reread the question and use their summaries to help them develop an answer.

Students can check their understanding of lesson concepts with the Self-Test assessment. They can then take an online version of the Lesson Assessment.

Assessment Answers
1a. Plasma contains dissolved gases and salts and plasma proteins; red blood cells carry oxygen; white blood cells fight infection; platelets help blood clot.
1b. A person with hemophilia would bleed uncontrollably from a minor cut.
2a. The lymphatic system collects lymph and returns it to the circulatory system, removes microorganisms from the blood, and helps absorb fats and fat-soluble vitamins from the digestive tract.
2b. Sample answer: Veins and lymphatic vessels both carry fluid in one direction only due to valves. Lymphatic vessels do not carry blood.
3a. high-fat diet, lack of exercise, being overweight, smoking, having diabetes, age, family history, gender
3b. The heart must exert more pressure to push blood through stiff veins, leading to hypertension.
4a. The two types are HDL and LDL.
4b. In an individual with a genetic disorder, the liver cells cannot take up LDL from the blood, so they keep producing cholesterol. In an individual who eats a high-fat diet, excess cholesterol builds up in the liver cells, which stop making LDL receptors and no longer remove cholesterol from the blood.
5. Students’ commentaries should be based on reliable resources.
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.

In a paragraph, explain which technique would most likely be used to detect unhealthy heart tissue? (MRI)

Answers

WRITING

Students’ responses should identify the CT scan as the most likely technique for detecting atherosclerosis in a coronary artery and offer a reasonable explanation for this choice.

Biology In-Depth

PET SCANS

PET, or positron emission tomography, scanning is an additional imaging method that can contribute to the diagnosis of heart disease. PET scans reveal more information about the functioning of an organ or tissue than the other methods described above, which provide more structural information. A PET scan uses a radioactive tracer to generate images representing the functioning of the tissue or organ being studied. PET scans are often combined with CT scans to provide information about both the structure and function of the heart.
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.
Teach

Build Study Skills

Use a Two-Column Table to enhance students’ understanding of the structures of the respiratory system and their functions. In the left column, have students record the structures through which air passes as it moves through the respiratory system. In the right column, have them write a brief description of the function of each structure. After students have completed their own tables, draw a two-column table on the board. Have volunteers come forward one at a time to add information to the table on the board. Continue until all structures mentioned in the lesson and their functions have been entered.

Study Wkbks A/B, Appendix S31, Two-Column Table. Transparencies, GO16.

DIFFERENTIATED INSTRUCTION

**Special Needs** Students may need to work with a partner to complete the Two-Column Table summarizing the structures and functions of the respiratory system. Have students use single words or short phrases to describe the functions of each structure.

**Advanced Learners** Have students work in a group to develop mnemonic devices to help other students remember the functions of the various structures of the respiratory system. After the class has worked together to complete the two-column table on the board, draw a third column and ask advanced learners to share the mnemonic devices they developed.

DIFFERENTIATED INSTRUCTION

**Special Needs** Students may need to work with a partner to complete the Two-Column Table summarizing the structures and functions of the respiratory system. Have students use single words or short phrases to describe the functions of each structure.

**Advanced Learners** Have students work in a group to develop mnemonic devices to help other students remember the functions of the various structures of the respiratory system. After the class has worked together to complete the two-column table on the board, draw a third column and ask advanced learners to share the mnemonic devices they developed.

Quick Lab

**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?

Quick Lab

**PURPOSE** Students will compare the number of particles in air from several different locations and infer how mucus acts to help keep particles from entering the lungs.

**MATERIALS** graph paper, microscope slides, petroleum jelly, microscope

**PLANNING** Identify, in advance, locations in which slides can sit undisturbed for 24 hours.

**ANALYZE AND CONCLUDE**

1. Answers will vary depending on the location chosen.
2. Answers will vary. Accept all reasonable responses.
3. Cilia lining the trachea keep particles from entering the lungs.

Answers

**FIGURE 33-14** If the cilia were damaged by pollutants, more particles would enter the lungs, possibly inhibiting gas exchange.

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

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

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.

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.

DIFFERENTIATED INSTRUCTION

Focus on ELL: Extend Language

BEGINNING SPEAKERS
Have students create a Vocabulary Word Map for each of the following terms: pharynx, larynx, trachea, bronchus, alveolus, and diaphragm. For each term, encourage them to draw an illustration in one of the boxes and write a definition of the term in another. They can fill in the remaining boxes with attributes or concepts that help them remember the term. Then, have students work in pairs to practice using the terms in conversation.


Address Misconceptions

The Color of Blood
A common misconception among students is that oxygen-poor blood is blue. Explain that, in illustrations, the color blue is often used to represent oxygen-poor blood but this does not reflect the actual color of oxygen-poor blood. Oxygen-rich blood is bright red and oxygen-poor blood is deeper red. Although veins look blue in some people, the blood flowing in them is not.
**Lead a Discussion**

Make sure students understand the process of gas exchange in the lungs.

**Ask** In which lung structures does gas exchange take place? (alveoli)

**Ask** How is diffusion involved in this process? (Oxygen diffuses from the alveoli into blood, and carbon dioxide diffuses from blood into the alveoli.)

**Ask** How does hemoglobin increase the efficiency of gas exchange? (Hemoglobin actively binds oxygen, taking it out of the plasma. This helps keep the oxygen concentration in the blood lower than in the alveoli, which makes gas exchange more efficient.)

**Differen**

**Struggling Students** For students who are having difficulty understanding gas exchange, have them work in pairs to summarize the lower panel of Figure 33–16. For example, “Oxygen in the alveolus diffuses into blood cells in the capillary.” “Carbon dioxide from the blood diffuses into the alveolus.” Then, have the students share their sentences with the class.

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

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**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?

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**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.**

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**Biology In-Depth**

**Asthma**

Asthma is a potentially fatal respiratory illness characterized by repeated episodes of contractions in the muscles surrounding the airways. This constriction of the air passages makes it difficult to get enough air. Episodes of asthma symptoms can be severe enough to cause death; approximately 4000 deaths per year in the U.S. are attributable to asthma. The percentage of individuals who have asthma is on the rise. Some scientists think the increase is due to air pollution. Asthma risk is greater for Latinos and African Americans than it is for Caucasians. Urban children have a higher risk of asthma than those who live outside cities.
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.

DIFFERENTIATED INSTRUCTION

English Language Learners  Write the words inhalation and exhalation on the board. Underline the word parts in- and ex-. Tell students that in-means “in” and ex-means “out, or out of.” Have students relate the meaning of these word parts to the meanings of the words inhale and exhale.

Students can use the InterActive Art: Breathing to explore the concepts described on this page.
**LESSON 33.3**

**Connect to Health**

Invite the school nurse (or other medical professional) to speak to the class about the harmful effects of smoking and smoking cessation programs available in your area. Have students read the information on this page before the nurse’s visit. Ask them to prepare written questions about smoking that they would like to ask. Have them submit their questions anonymously to you in advance. Have the nurse respond to as many of the students’ questions as possible.

**DIFFERENTIATED INSTRUCTION**

**ELL Struggling Students** Help struggling students prepare for the nurse’s visit by asking them questions that will help them comprehend the information on this page.

**Ask** What are three of the most dangerous substances in tobacco smoke? *(nicotine, carbon monoxide, tar)*

**Ask** Why do smokers often have a “smoker’s cough”? *(Tobacco smoke paralyzes the cilia, which leads to an increase in particles stuck to the walls of the respiratory tract. The cough is the body’s attempt to clear away these particles.)*

**Ask** What are some diseases caused by smoking? *(chronic bronchitis, emphysema, lung cancer)*

**ELL English Language Learners** To help students generate questions, have them start by organizing information in the text in a Cause-and-Effect Diagram. For example, they may list the cause “nicotine” and the effects “increases heart rate” and “increases blood pressure.” Have students work independently or in pairs to complete their diagrams. Then, ask students to summarize the contents of their diagram in spoken sentences. Finally, have students work independently or with a partner to develop questions for the nurse.

**Study Wkbs A/B, Appendix S18, Cause-and-Effect Diagram. Transparencies, GO1.**

**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.

**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.

**Quick Facts**

**SMOKING, CANCER, AND DEATH**

An individual who smokes cigarettes is 10 to 20 times more likely to develop lung cancer than a nonsmoker. The more cigarettes an individual smokes, the greater the chances of developing lung cancer and the more likely the individual is to die from lung cancer. In individuals who smoke two or more packs of cigarettes a day, the risk of dying from lung cancer is 20 to 25 times greater than in a nonsmoker. Three of every four deaths from lung cancer in women can be attributed to smoking. Cancer is not the only risk that smokers face. Smokers are also three times more likely to die from a heart attack than are nonsmokers. People who smoke die on average 13–14 years earlier than nonsmokers.
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.

Assessment Answers

1a. It takes in oxygen and releases carbon dioxide.

1b. Commuters drive on progressively smaller roads as they travel from work to home. An oxygen molecule moves through progressively smaller passageways.

2a. Oxygen diffuses from air in alveoli to blood cells. Carbon dioxide diffuses from blood to air in alveoli.

2b. Carbon monoxide prevents the body from getting the oxygen it needs. Carbon monoxide detectors alert people to high levels of carbon monoxide.

3a. The diaphragm contracts and the rib cage rises, increasing the size of the chest cavity and drawing air into the lungs. Then, the rib cage and diaphragm relax, the volume of the chest cavity decreases, and air is pushed out of the lungs.

3b. Individuals might not get enough oxygen, because the brain’s breathing center is not stimulated by blood oxygen levels.

4a. Students should summarize the effects of nicotine, carbon monoxide, and tar.

4b. Sample answer: If too much carbon dioxide remains in the alveoli, then the body cannot inhale enough oxygen to meet its needs.

5. Students’ responses should identify similarities and differences in the process of respiration of humans, birds, and fish.
Pre-Lab

Introduce students to the concepts they will explore in the chapter lab by assigning the Pre-Lab questions.

Lab

Tell students they will perform the chapter lab Tidal Volume and Vital Capacity described in Lab Manual A.

Struggling Students A simpler version of the chapter lab is provided in Lab Manual B.

Safety

Students should not start their experiments until their plans have been approved. Necessary safety precautions will vary based on students’ experimental design. Do not let students with latex allergies handle the balloons.

Look online for Editable Lab Worksheets.

For corresponding pre-lab in the Foundation Edition, see page 802.

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?

Pre-Lab Answers

Background Questions
a. nose, pharynx, larynx, trachea, bronchi, bronchioles, alveoli
b. The concentration of oxygen is greater in the inhaled air in the alveoli than it is in the blood.
c. Respiration is the process of gas exchange between the body and its external environment. Cellular respiration is the process that releases energy from food in the presence of oxygen.

Pre-Lab Questions

1. In Part A, the subject takes a normal breath before exhaling normally. In Part B, the subject takes a deep breath before exhaling as much air as possible.
2. Sample answer: It would not be possible to measure the diameter of the balloons with a ruler if the balloons had a different shape.

3. Students may say that the estimated vital capacity will be larger because they will not be able to capture all the exhaled air in the balloon. Some students may expect their measured capacity to be greater because they have done considerable aerobic training.
### 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.

<table>
<thead>
<tr>
<th>myocardium (949)</th>
<th>systemic circulation (950)</th>
</tr>
</thead>
<tbody>
<tr>
<td>atrium (949)</td>
<td>pacemaker (951)</td>
</tr>
<tr>
<td>ventricle (949)</td>
<td>artery (952)</td>
</tr>
<tr>
<td>valve (950)</td>
<td>capillary (952)</td>
</tr>
<tr>
<td>pulmonary circulation (950)</td>
<td>vein (952)</td>
</tr>
</tbody>
</table>

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**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.

<table>
<thead>
<tr>
<th>plasma (954)</th>
<th>platelet (955)</th>
</tr>
</thead>
<tbody>
<tr>
<td>red blood cell (954)</td>
<td>lymph (956)</td>
</tr>
<tr>
<td>hemoglobin (954)</td>
<td>atherosclerosis (958)</td>
</tr>
<tr>
<td>white blood cell (955)</td>
<td></td>
</tr>
</tbody>
</table>

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**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.

<table>
<thead>
<tr>
<th>pharynx (964)</th>
<th>bronchus (964)</th>
</tr>
</thead>
<tbody>
<tr>
<td>trachea (964)</td>
<td>alveolus (964)</td>
</tr>
<tr>
<td>larynx (964)</td>
<td>diaphragm (967)</td>
</tr>
</tbody>
</table>

**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.

**Performance Tasks**

**SUMMATIVE TASK** Have students work in pairs to make a pamphlet entitled *Your Circulatory and Respiratory Systems—An Owner’s Manual*. Explain that the pamphlet should be directed to a teen audience and contain information about the care of these body systems. Pamphlets should include specific tips for keeping these body systems healthy, both now and in the future. Encourage students to use an attractive format for their pamphlets and to include illustrations.

**TRANSFER TASK** Have students imagine a museum display that allows visitors to walk through a larger-than-life model of the circulatory, respiratory, or lymphatic system. Have them work in pairs to write a guidebook for use by museum guests as they walk through this exhibit. The guidebook should include structures of the system, functions of those structures, and diseases that can strike the system. Suggest that they draw a floor plan or diagram of the display.

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**Answers**

**THINK VISUALLY**

The left column of students’ tables should list structures of the circulatory and respiratory systems, such as arteries, veins, aorta, heart, lungs, larynx, trachea, pharynx, and alveoli. In the right column, the functions of each structure should be described.
Lesson 33.1

UNDERSTAND KEY CONCEPTS

1. c  2. d  3. a
4. Pulmonary circulation carries blood between the heart and the lungs. Systemic circulation carries blood between heart and the rest of the body.
5. Blood from the body enters the right atrium. It moves from the right atrium to the right ventricle. Blood is pumped from the right ventricle to the lungs. It returns to the heart in the left atrium. From the left atrium, it moves to the left ventricle and is then pumped to the body.
6. Heart valves allow blood to flow in only one direction. Valves are also found in veins.
7. The pacemaker controls the rate at which the heart beats.
8. The heart beats in a two-step pattern of contraction; first the atria contract, and then the ventricles contract.
9. Arteries are wide vessels with thick walls. Capillaries are narrow vessels with walls just one cell thick. Veins are wide vessels with walls that are thicker than capillary walls but thinner than artery walls.
10. Systolic pressure is the force of the blood in the arteries when the ventricles contract. Diastolic pressure is the force of the blood in the arteries when the ventricles relax.

THINK CRITICALLY

11. The most likely experimental design is to measure each subject’s heart rate at rest to determine the normal heart rate and then again at frequent, timed intervals after the subject has exercised, until the heart rate returns to normal.
12. The powerful pressure produced when the heart contracts keeps blood moving in one direction in the arteries.

Lesson 33.2

UNDERSTAND KEY CONCEPTS

13. d  14. b  15. a  16. c
17. Plasma is the fluid that carries other blood components and contains proteins involved in immune reactions and blood clotting. Platelets cluster around wounds and release proteins that start a series of reactions resulting in blood clots. White blood cells attack foreign substances and organisms. Red blood cells transport oxygen.
18. Functions of the lymphatic system are to collect fluid lost by the blood and return it to the circulatory system, filter bacteria and other microorganisms from the fluid, house white blood cells, and absorb fat and fat-soluble vitamins from the digestive tract.
19. LDL is known as “bad cholesterol” because it often becomes part of plaque, causing trouble in the circulatory system. HDL, on the other hand, helps remove excess cholesterol from the body, so it is known as “good cholesterol.”

THINK CRITICALLY

20. A person with a low red blood cell count has fewer red blood cells to transport oxygen to cells. Without adequate oxygen, the production of energy by cellular respiration is reduced.
21. Some strokes are caused by clots, so individuals who have had a stroke may decrease their chance of having another one by taking aspirin.
22. Removal of the lymph nodes can lessen the body’s ability to fight disease. The lymph nodes filter many pathogens from the lymph before it is returned to the circulatory system. The lymph nodes also house white blood cells, called lymphocytes, which help fight infection.
Lesson 33.3

UNDERSTAND KEY CONCEPTS

23. a 24. a 25. c

26. Involuntary breathing is controlled by the breathing center in a part of the brain stem called the medulla oblongata.

27. Three of the most dangerous substances in tobacco smoke are nicotine, carbon monoxide, and tar. Nicotine increases heart rate and blood pressure. Carbon monoxide blocks the transport of oxygen by hemoglobin in the blood. Tar contains compounds that cause cancer.

28. Emphysema is a loss of elasticity in lung tissue. This makes it difficult for the lungs to bring in enough oxygen and eliminate enough carbon dioxide.

THINK CRITICALLY

29. When tobacco smoke kills white blood cells in the respiratory tract, the amount of debris found in the respiratory system increases. This leads to increased coughing as the body attempts to clear the debris.

30. All of the blood flows through the lungs to pick up oxygen. During exercise, much more blood flows through the skeletal muscles to fuel the production of energy needed for muscle contraction.

After students have read through the Chapter Mystery solution, discuss the cause and symptoms of familial hypercholesterolemia.

Ask How does familial hypercholesterolemia affect homeostasis in the body? (Familial hypercholesterolemia affects the body’s ability to control cholesterol levels, which disrupts homeostasis and can result in atherosclerosis and lead to heart attacks.)

Ask Why has Lila shown symptoms at such a young age? (She is homozygous for the allele that causes familial hypercholesterolemia.)

Ask Can Lila’s liver cells take in cholesterol from her blood? Why or why not? (No, her liver cells lack receptors for LDL.)

CHAPTER MYSTERY ANSWERS

1. The allele for familial hypercholesterolemia is recessive.

2. Homozygous patients have no LDL receptors, so medications to keep their liver cells from producing cholesterol do not help the body control the cholesterol that is consumed in food.

3. A healthy diet and exercise are two steps an individual with a family history of familial hypercholesterolemia can take to keep healthy. Medication may also help some individuals.

To learn how some animals survive and thrive in cold climates, watch Chillin’ in the Cold.
31. Sample answer: When I cough, the sound changes from a muffled roar to a loud, sharp rushing sound.

Connecting Concepts

USE SCIENCE GRAPHICS

32. Student A: minute 6; Student B: minute 7
33. Student A is most likely in better physical condition than Student B because his or her heart beats fewer times per minute to maintain the same level of effort as Student B. Also, Student A’s heart returns to its normal rate much faster than Student B’s, which also indicates a more efficient circulatory system.

34. During exercise, you would expect blood pressure to rise because blood is moving more quickly through the circulatory system. Also, breathing rate increases to keep pace with the increase in the amount of gas exchange taking place in the muscles of the body.

WRITE ABOUT SCIENCE

35. Answers will vary. Students’ responses might list an unhealthy diet or not exercising regularly as things they do that are harmful to their circulatory and respiratory systems. They might explain how they will eat more healthfully or join a sports team to get more exercise.

36. Students’ responses should mention that the respiratory system picks up oxygen from the air we inhale and releases carbon dioxide into the air we exhale. They should also mention that the circulatory system delivers the oxygen to the cells of the body and picks up the waste carbon dioxide from the cells. Proper functioning of these systems is necessary for the survival of the cells, tissues, and organs that make up the entire body.

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.

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.

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?

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

ANSWERS

37. 55–64
38. a
Answers

1. C
2. D
3. B
4. B
5. D
6. C
7. A
8. C
9. C
10. C

11. Heart disease and strokes can both be caused by narrowing of the arteries—a result of the plaque buildup within the arteries. Therefore, both illnesses have similar risk factors.