33.1 The Circulatory System

Key Questions

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

Vocabulary

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

Taking Notes

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

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

Functions of the Circulatory System

What are the functions of the circulatory system?

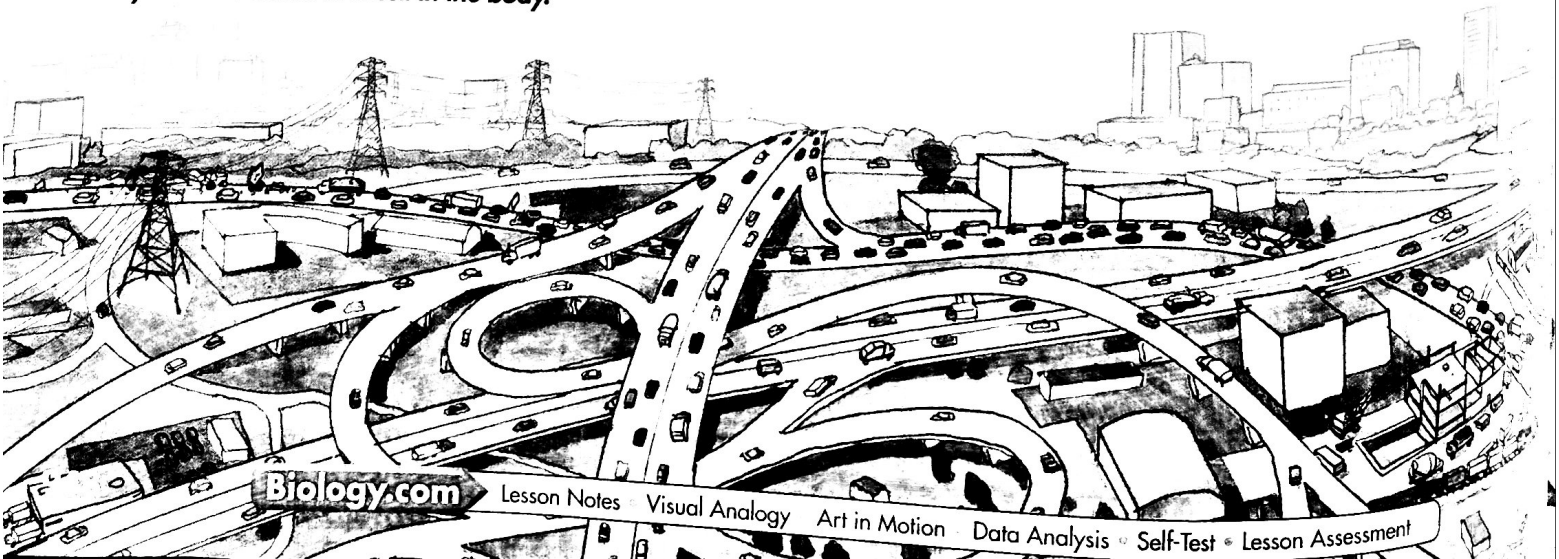
Some animals have so few cells that all of their cells are in direct contact with the environment. Diffusion and active transport across cell membranes supply the cells with oxygen and nutrients and remove waste products. The human body, however, contains millions of cells that are not in direct contact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

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

VISUAL ANALOGY

A CITY'S TRANSPORTATION SYSTEM

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



The Heart

How does the heart pump blood through the body?

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

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

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

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

BUILD Vocabulary

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

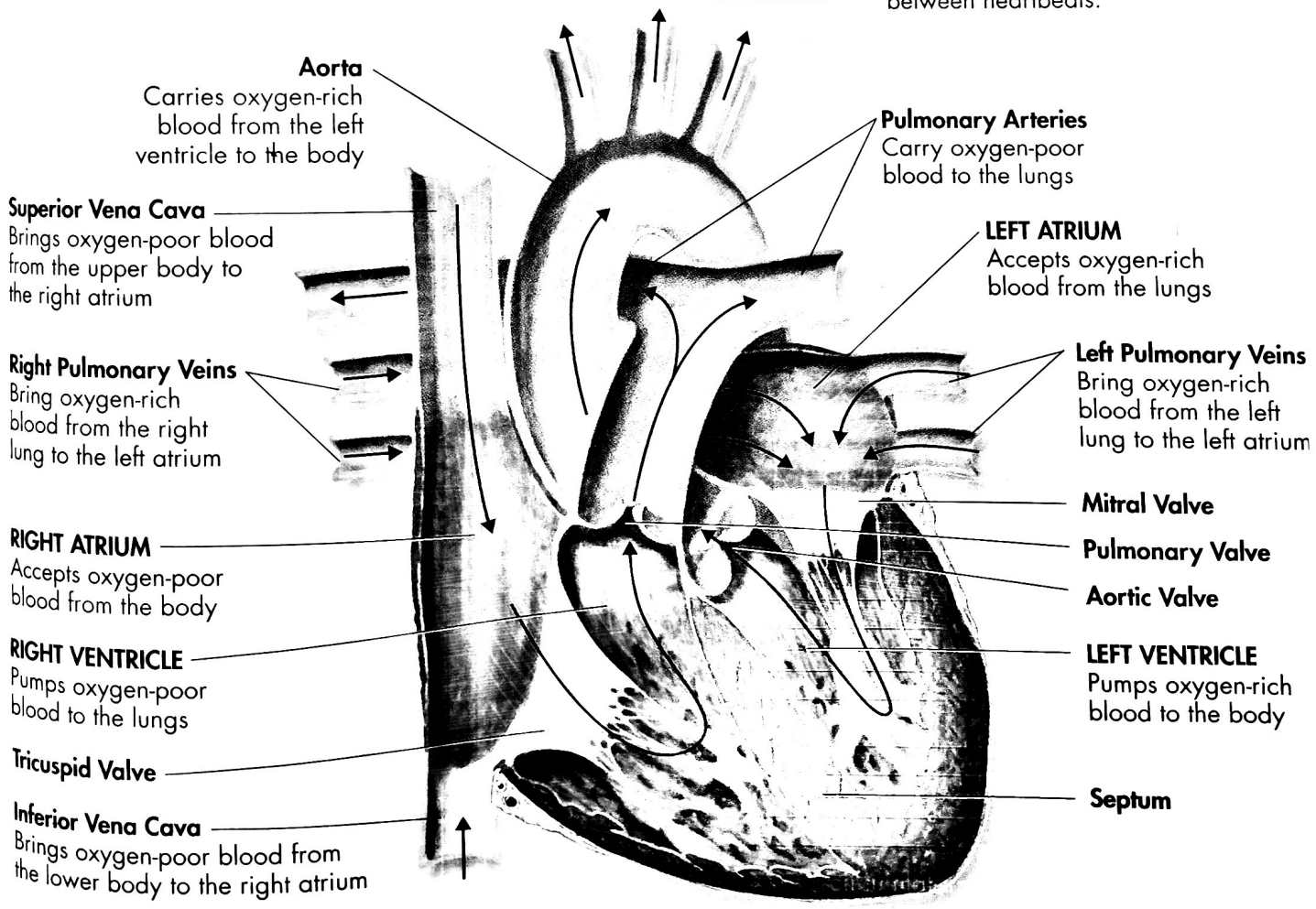
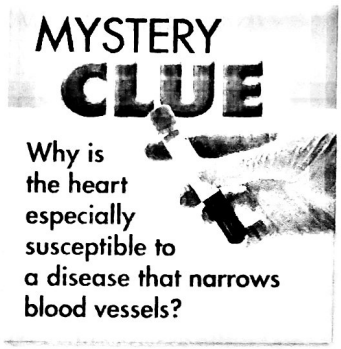


FIGURE 33–2 The Heart
The human heart has four chambers: the right atrium, the right ventricle, the left atrium, and the left ventricle. Valves located between the atria and ventricles and between the ventricles and vessels leaving the heart prevent blood from flowing backward between heartbeats.



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

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

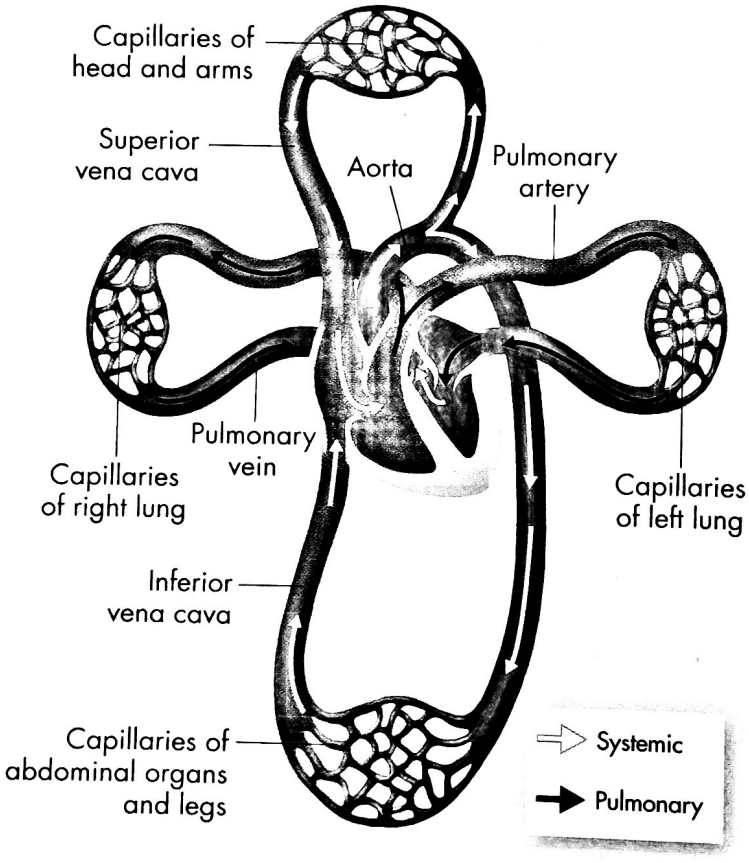


FIGURE 33–3 Circulation Pathways The circulatory system is divided into two pathways. Pulmonary circulation carries blood between the heart and the lungs. Systemic circulation carries blood between the heart and the rest of the body. **Observe** ***What kind of blood—oxygen-rich or oxygen-poor—leaves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

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

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

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

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

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

❶ 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.

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

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

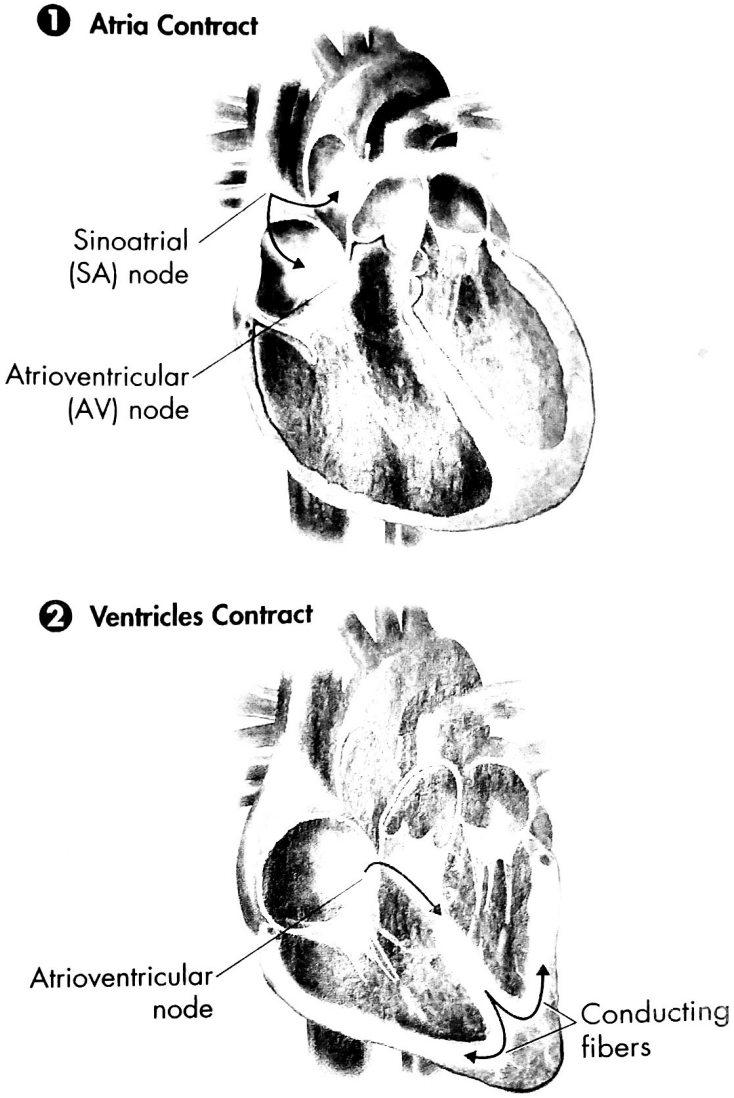


FIGURE 33–4 Heartbeat The SA node generates an impulse that spreads through the atria, causing the muscle fibers to contract and pump blood to the ventricles. The AV node picks up the signal and, after a slight delay, sends an impulse through the ventricles, causing them to contract.

Quick Lab GUIDED INQUIRY

What Factors Affect Heart Rate?

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

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

Analyze and Conclude

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

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

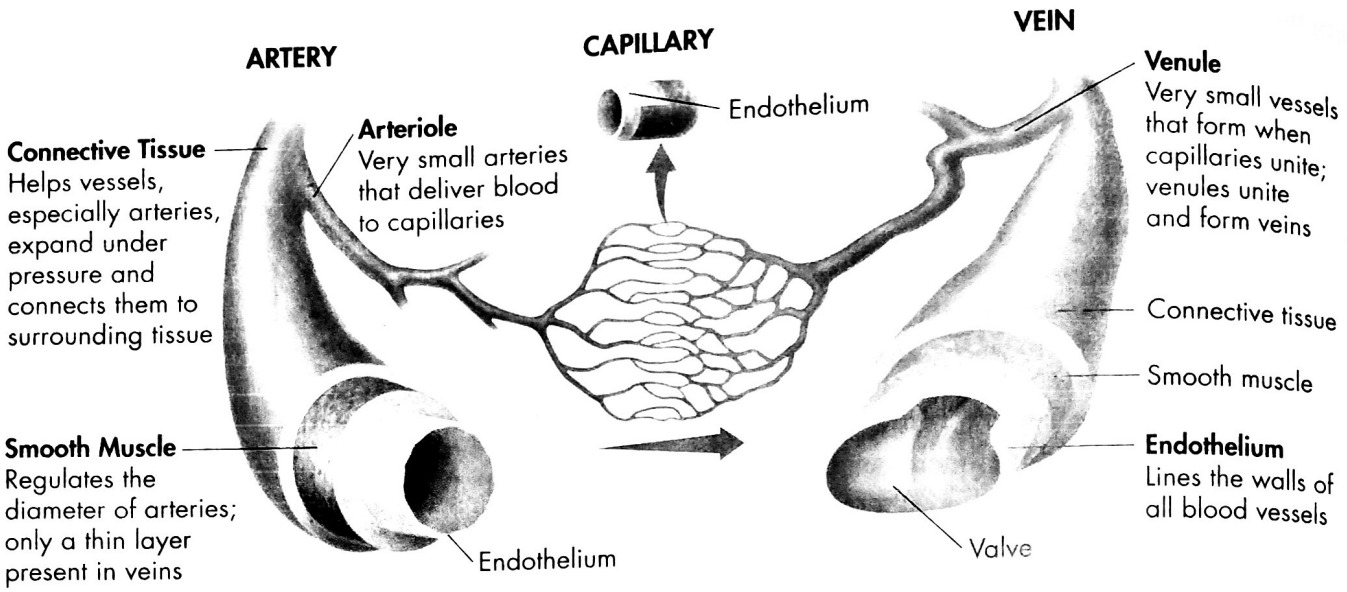


FIGURE 33–5 Structure of Blood Vessels The structure of blood vessel walls contributes to the vessels' functions.

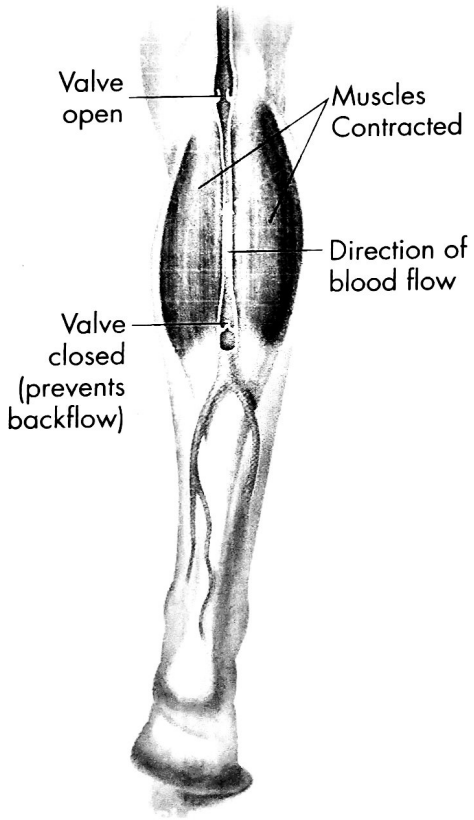


FIGURE 33–6 Blood Flow in Veins The contraction of skeletal muscles helps move blood in veins toward the heart.
Draw Conclusions ***What role do valves play in large veins?***

Blood Vessels

What are three types of blood vessels?

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

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

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

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

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

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

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

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

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

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

33.1 Assessment

Review Key Concepts

1. **a. Review** List the structures of the circulatory system and explain their roles.
   b. Apply Concepts Why do humans need a circulatory system?
2. **a. Review** Describe the two paths of blood circulation through the body.
   b. Relate Cause and Effect How would damage to the sinoatrial node affect the heart's function?
3. **a. Review** Describe the functions of three types of blood vessels in the circulatory system.
   b. Infer If you were standing, would you expect the blood pressure to be higher in your arm or in your leg? Explain your answer. (*Hint:* Think about which area of the body is closer to the source of pressure.)

VISUAL THINKING

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