37–1 The Circulatory System

Your heartbeat is a sign of life itself. Even when you drift off to sleep, your heart continues to beat at a steady rhythm. Why is this process so important that it must keep going even when you sleep?

Each breath you take brings air into your respiratory system. The oxygen in that air is needed by the trillions of cells in your body. Your heart is essential in delivering that oxygen. Its beating produces the force to move oxygen-rich blood through the circulatory system. Interrelationships between the circulatory and respiratory systems supply cells throughout the body with the nutrients and oxygen they need to stay alive.

Functions of the Circulatory System

Organisms composed of a small number of cells do not need a circulatory system. Most cells in such organisms are in direct contact with the environment. Oxygen, nutrients, and waste products can easily diffuse back and forth across cell membranes.

Larger organisms, however, cannot rely on diffusion. Most of their cells are not in direct contact with the environment, and substances made in one part of the organism may be needed in another part. In a way, this same problem is faced by the millions of people living in a large city. Cities have transportation systems that move people, goods, and waste material from one place to another. The transportation system of a city is its streets, highways, and rail lines. The transportation system of a living organism is its circulatory system.

Humans and other vertebrates have closed circulatory systems. This means that a circulating fluid called blood is contained within a system of vessels. **The human circulatory system consists of the heart, a series of blood vessels, and the blood that flows through them.**

Guide for Reading

Key Concepts

- What are the structures of the circulatory system?
- What are the three types of blood vessels in the circulatory system?

Vocabulary

myocardium
atrium
ventricle
pulmonary circulation
systemic circulation
valve
pacemaker
aorta
artery
capillary
vein
atherosclerosis

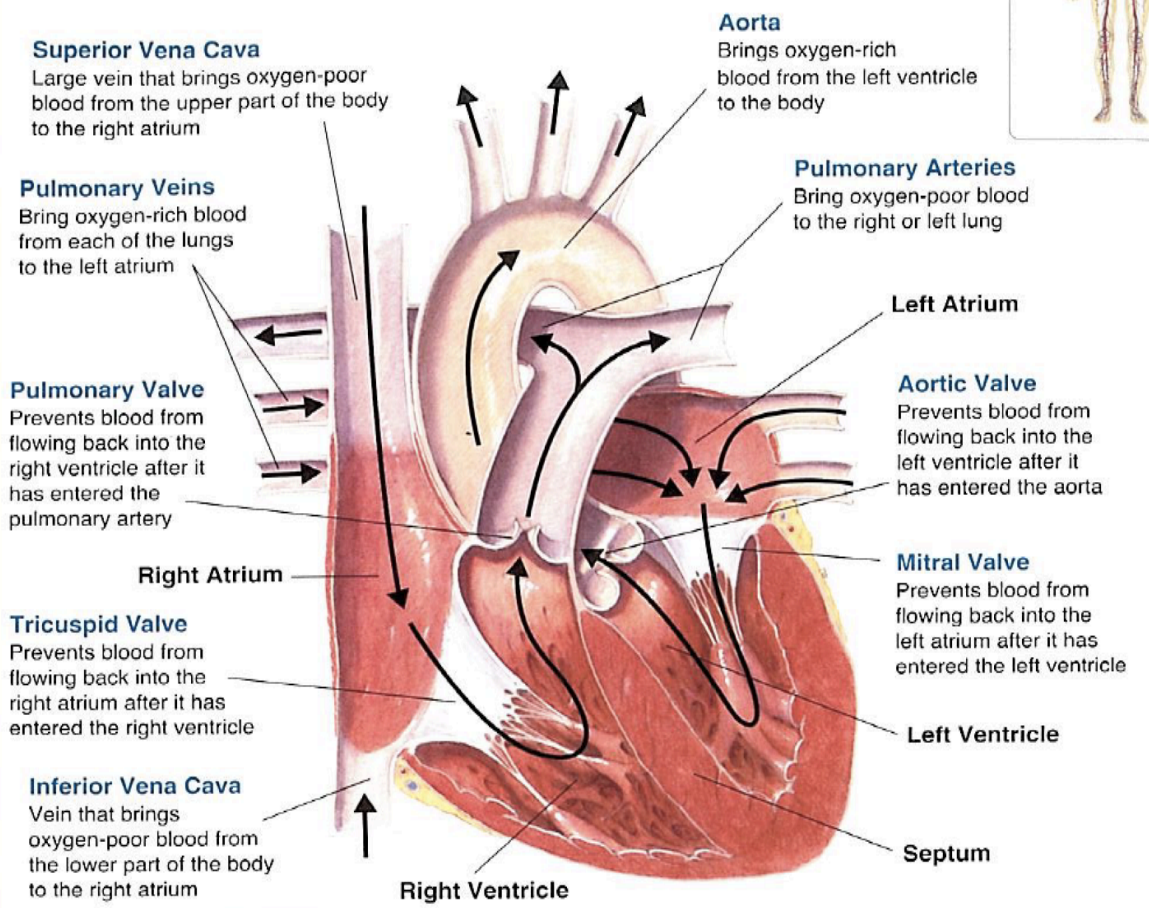
Reading Strategy: Using Visuals

Before you read, preview **Figure 37–3.** Make a list of questions about the illustration. As you read, write down the answers to the questions.

◀ **Figure 37–1** These roads form a transportation system. **Using Analogies** *How is the human circulatory system like the streets and highways of a large city?*

Structures of the Heart

Figure 37–2 The circulatory system consists of the heart, a series of blood vessels, and the blood. Notice the valves between the atria and ventricles and those between the ventricles and the blood vessels leaving the heart. The valves prevent blood from flowing backward.



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The Heart

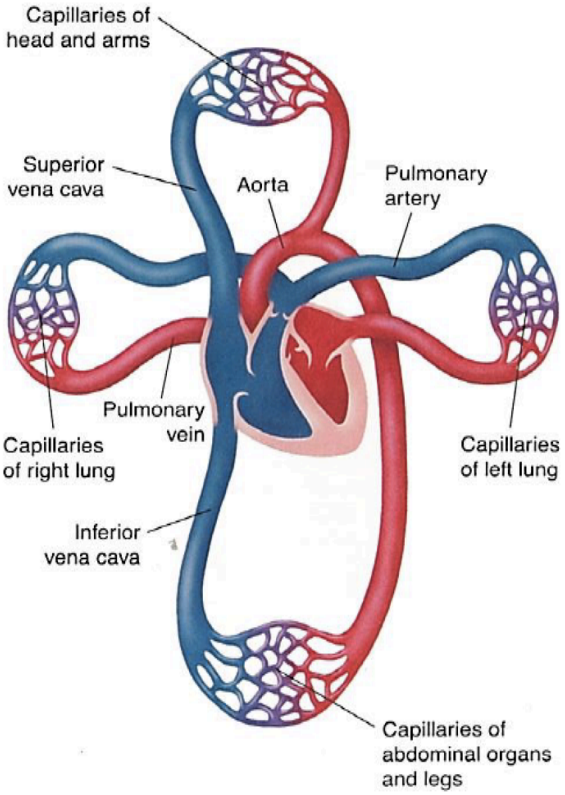
As you can feel with your hand, your heart is located near the center of your chest. The heart, shown in **Figure 37–2,** which is composed almost entirely of muscle, is a hollow organ that is about the size of your clenched fist. The heart is enclosed in a protective sac of tissue called the pericardium (pehr-ih-KAHR-dee-um). In the walls of the heart, there are two thin layers of epithelial and connective tissue that form a sandwich around a thick layer of muscle called the **myocardium.** The powerful contractions of the myocardium pump blood through the circulatory system.

The heart muscle contracts on average 72 times a minute, pumping about 70 milliliters of blood with each contraction. This means that during one year, an average person's heart pumps more than enough blood to fill an Olympic-sized swimming pool. (An Olympic-sized swimming pool is about 2,000,000 liters: 0.07 liters × 4320 beats per hour × 24 hours × 365 days = 2,649,024 liters.)

Dividing the right side of the heart from the left side of the heart is the septum. The septum prevents the mixing of oxygen-poor and oxygen-rich blood. On each side of the septum are two chambers. The upper chamber, which receives the blood, is the **atrium** (plural: atria). The lower chamber, which pumps blood out of the heart, is the **ventricle.** The heart has four chambers in total—two atria and two ventricles.

Circulation Through the Body The heart functions as two separate pumps. **Figure 37–3** shows the circulation of blood through the body. The right side of the heart pumps blood from the heart to the lungs. This pathway is known as **pulmonary circulation.** In the lungs, carbon dioxide leaves the blood and oxygen is absorbed. The oxygen-rich blood then flows into the left side of the heart and is pumped to the rest of the body. This pathway is called **systemic circulation.** Blood that returns to the right side of the heart is oxygen-poor because cells have absorbed much of the oxygen and loaded the blood with carbon dioxide. At this point, it is ready for another trip to the lungs.

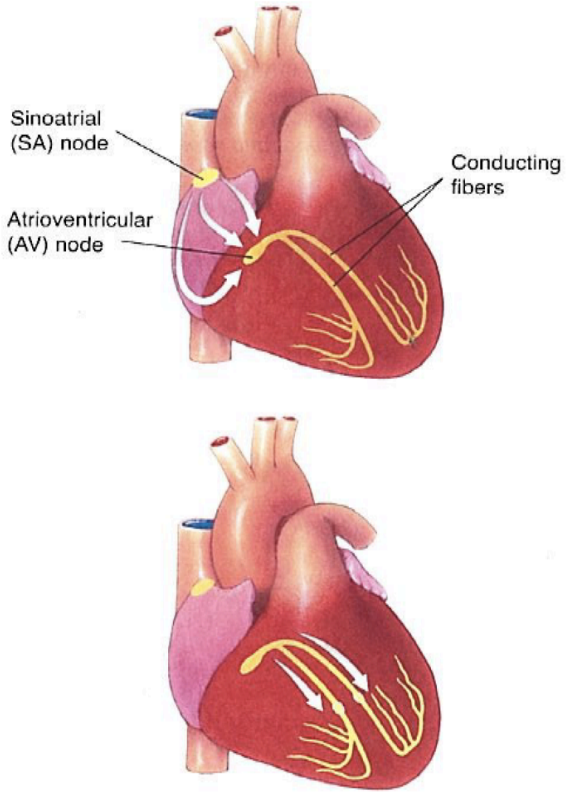
▼ **Figure 37–3** The circulatory system is divided into two pathways. Pulmonary circulation carries blood between the heart and the lungs. Systemic circulation carries blood between the heart and the rest of the body. **Observing** *What kind of blood—oxygen-rich or oxygen-poor—leaves the lungs and returns to the heart?*



Circulation Through the Heart Blood enters the heart through the right and left atria. As the heart contracts, blood flows into the ventricles and then out from the ventricles to either the body or the lungs. There are flaps of connective tissue called **valves** between the atria and the ventricles. Blood moving from the atria holds the valves open. When the ventricles contract, the valves close, which prevents blood from flowing back into the atria.

At the exits from the right and left ventricles, there are valves that prevent blood that flows out of the heart from flowing back in. This system of valves keeps blood moving through the heart in one direction, like traffic on a one-way street. The one-way flow increases the pumping efficiency of the heart. The valves are so important to heart function that surgeons often attempt to repair or replace a valve that has been damaged due to disease.

CHECKPOINT *What is the function of the heart valves?*



▲ **Figure 37–4** The signal to contract spreads from the sinoatrial node to the cardiac muscle cells of the atria, causing the atria to contract. The impulse is picked up by the atrioventricular node, which transmits the impulse to muscle fibers in the ventricles, causing the ventricles to contract.
Predicting *In times of stress, does the heart beat faster or slower?*

Heartbeat There are two networks of muscle fibers in the heart, one in the atria and one in the ventricles. When a single fiber in either network is stimulated, all the fibers are stimulated and the network contracts as a unit. Each contraction begins in a small group of cardiac muscle cells—the sinoatrial node—located in the right atrium. Because these cells "set the pace" for the heart as a whole by starting the wave of muscle contraction through the heart, they are also called the **pacemaker.**

As shown in **Figure 37–4,** the impulse spreads from the pacemaker (SA node) to the network of fibers in the atria. It is picked up by a bundle of fibers called the atrioventricular node and carried to the network of fibers in the ventricles. When the network in the atria contracts, blood in the atria flows into the ventricles. When the muscles in the ventricles contract, blood flows out of the heart. This two-step pattern of contraction makes the heart a more efficient pump.

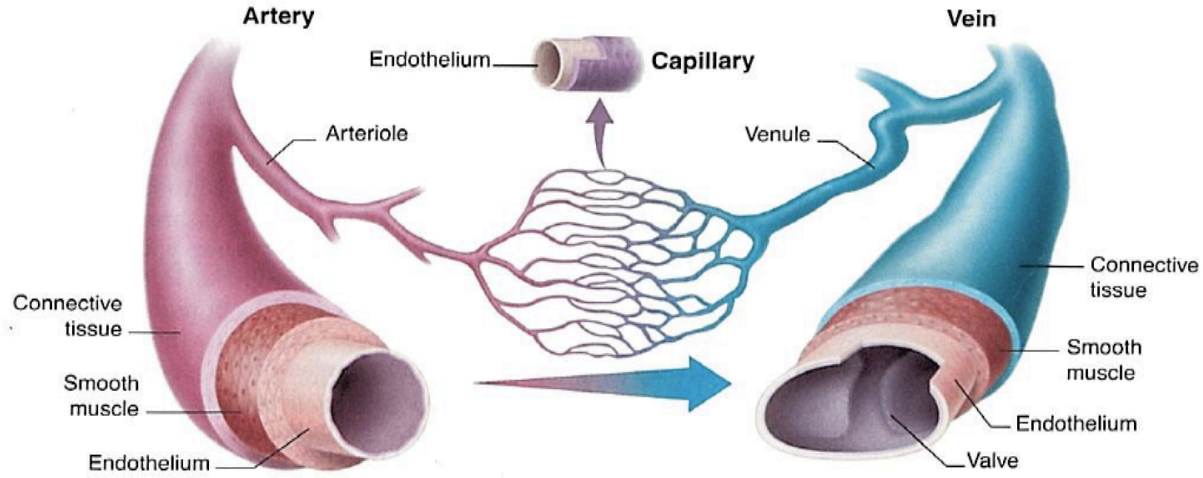
Your heart can beat faster or more slowly, depending on your body's need for oxygen-rich blood. During vigorous exercise, your heart rate may increase to about 200 beats per minute. Although the heartbeat is not directly controlled by the nervous system, the autonomic nervous system does influence heart rate. Neurotransmitters released by the sympathetic nervous system increase heart rate. Those released by the parasympathetic nervous system decrease heart rate.

Blood Vessels

Blood leaving the left side of the heart is loaded with oxygen from the lungs. When it leaves the left ventricle, the blood passes into a large blood vessel known as the **aorta.** The aorta is the first of a series of blood vessels that carry the blood on its round trip through the body 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 Large vessels that carry blood from the heart to the tissues of the body are called **arteries.** Arteries are the superhighways of the circulatory system. Except for the pulmonary arteries, all arteries carry oxygen-rich blood. Arteries have thick walls that help them withstand the powerful pressure produced when the heart contracts and pushes blood into the arteries.



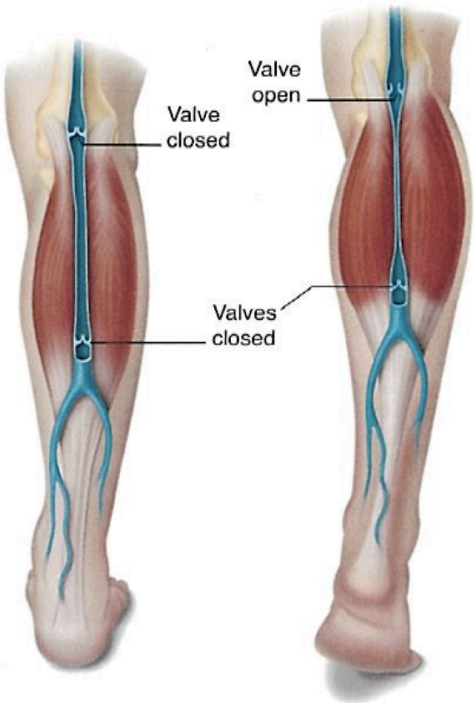
▲ **Figure 37–5** In the circulatory system, there are three types of blood vessels—arteries, capillaries, and veins. The walls of these vessels contain connective tissue, smooth muscle, and endothelium.

Figure 37–5 shows that the walls contain connective tissue, smooth muscle, and endothelium. The elastic connective tissue allows an artery to expand under pressure. Contractions of the smooth muscle regulate the diameter of an artery.

Capillaries The smallest of the blood vessels are the **capillaries.** Capillaries are the side streets and alleys of the circulatory system. The walls of capillaries are only one cell thick, and most are so narrow that blood cells must pass through them in single file. The real work of the circulatory system—bringing nutrients and oxygen to the tissues and absorbing carbon dioxide and other waste products from them—is done in the capillaries.

Veins Once blood has passed through the capillary system, it must be returned to the heart. This is the job of the **veins.** As with arteries, the walls of veins contain connective tissue and smooth muscle. Large veins, such as those shown in the leg in **Figure 37–6,** contain valves that keep blood moving toward the heart. Many veins are located near and between skeletal muscles. When you exercise, contracting these muscles helps force blood through the veins. Blood flow through the veins of the arms and legs often occurs against the force of gravity. Exercise helps to keep blood from accumulating in the limbs and stretching the veins out of shape. If the walls around the veins weaken from lack of activity, the valves can weaken. This causes blood to pool in the veins, producing a condition known as varicose veins.

CHECKPOINT *What happens in the capillaries?*



▶ **Figure 37–6** Contraction of skeletal muscles helps move blood in veins toward the heart. **Drawing Conclusions** *What role do valves play in large veins?*