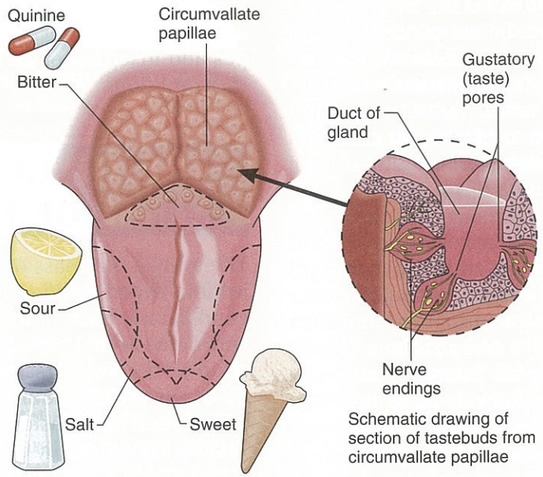

FIGURE 7-38 Locations of taste buds.

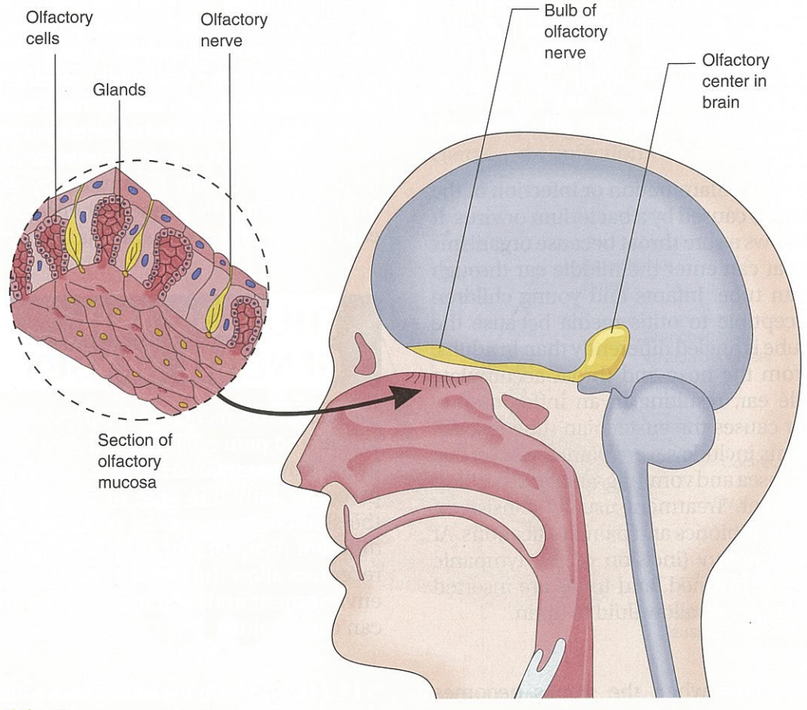

FIGURE 7-39 The sense of smell.

7:8 Circulatory System

Objectives

After completing this section, you should be able to:

- Label the layers, chambers, valves, and major blood vessels on a diagram of the heart
- Differentiate between systole and diastole by explaining what happens in the heart during each phase
- List the three major types of blood vessels and the action of each type
- Compare the three main types of blood cells by describing the function of each
- Describe at least five diseases of the circulatory system
- Define, pronounce, and spell all key terms

KEY TERMS

aortic valve *(ay-or'-tick)*
arrhythmias
arteries
blood
capillaries *(cap'-ih-lair-eez)*
circulatory system
diastole *(dy-az'-tah-lee")*
endocardium *(en-doe-car'-dee-um)*
erythrocytes *(eh-rith'-row-sitez)*
hemoglobin *(hee'-mow-glow"-bin)*
left atrium *(ay'-tree-um)*
left ventricle *(ven'tri"-kul)*
leukocytes *(lew'-coh-sitez")*
mitral valve *(my'-tral)*
myocardium
pericardium
plasma *(plaz'-ma)*
pulmonary valve
right atrium
right ventricle
septum
systole *(sis'-tah-lee")*
thrombocytes *(throm'-bow-sitez)*
tricuspid valve
veins

RELATED HEALTH CAREERS

- Cardiac Surgeon
- Cardiologist
- Cardiovascular Technologist
- Echocardiographer
- Electrocardiographic Technician
- Hematologist
- Internist
- Medical Laboratory Technologist/Technician
- Perfusionist
- Phlebotomist
- Radiology Technologist
- Thoracic Surgeon

7:8 INFORMATION

The **circulatory system,** also known as the cardiovascular system, is often referred to as the "transportation" system of the body. It consists of the heart, blood vessels, and blood. It transports oxygen and nutrients to the body cells, and carbon dioxide and metabolic materials away from the body cells.

THE HEART

The heart is a muscular, hollow organ often called the "pump" of the body (figure 7-40). Even though

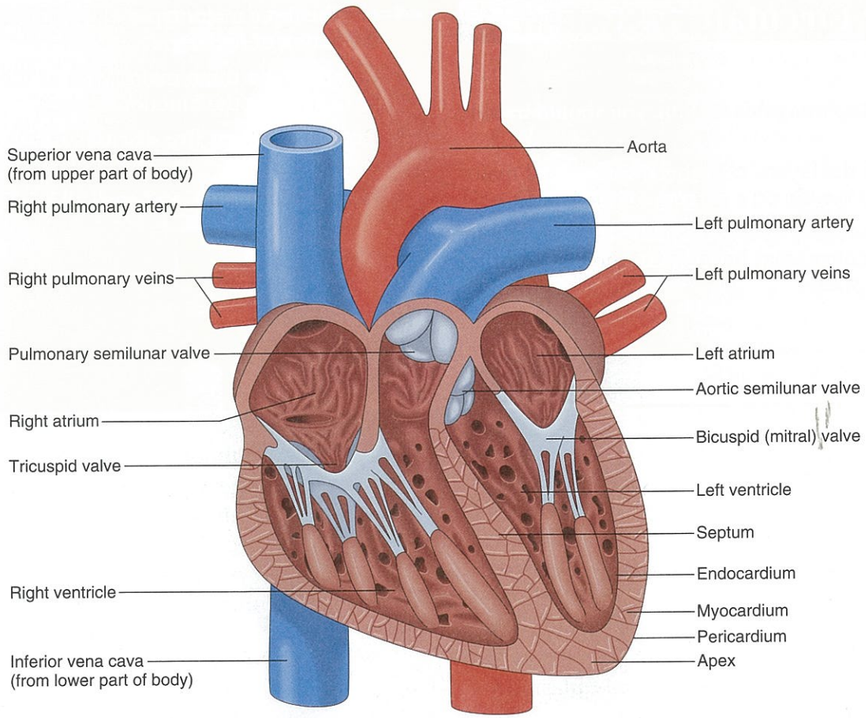

FIGURE 7-40 Basic structure of the heart.

it weighs less than one pound and is approximately the size of a closed fist, it contracts about 100,000 times each day to pump the equivalent of 2,000 gallons of blood through the body. The heart is located in the mediastinal cavity, between the lungs, behind the sternum, and above the diaphragm. Three layers of tissue form the heart. The **endocardium** is a smooth layer of cells that lines the inside of the heart and is continuous with the inside of blood vessels. It allows for the smooth flow of blood. The thickest layer is the **myocardium,** the muscular middle layer. The **pericardium** is a double-layered membrane, or sac, that covers the outside of the heart. A lubricating fluid, pericardial fluid, fills the space between the two layers to prevent friction and damage to the membranes as the heart beats or contracts.

The **septum** is a muscular wall that separates the heart into a right side and a left side. It prevents blood from moving between the right and left sides of the heart. The upper part of the septum is called the *interatrial septum,* and the lower part is called the *interventricular septum.*

The heart is divided into four parts, or chambers. The two upper chambers are called *atria,* and the two lower chambers are called *ventricles.* The **right atrium** receives blood as it returns from the body cells. The **right ventricle** receives blood from the right atrium and pumps the blood into the pulmonary artery, which carries the blood to the lungs for oxygen. The **left atrium** receives oxygenated blood from the lungs. The **left ventricle** receives blood from the left atrium and pumps the blood into the aorta for transport to the body cells.

One-way valves in the chambers of the heart keep the blood flowing in the right direction. The **tricuspid valve** is located between the right atrium and the right ventricle. It closes when the right ventricle contracts, allowing blood to flow to the lungs and preventing blood from flowing back into the right atrium. The **pulmonary valve** is located between the right ventricle and the pulmonary artery, a blood vessel that carries blood to the lungs. It closes when the right ventricle has finished contracting, preventing blood from flowing back into the right ventricle. The **mitral valve** is located between the left atrium and left ventricle. It closes when the left ventricle is contracting, allowing blood to flow into the aorta (for transport to the body) and preventing blood from flowing back into the left atrium. The **aortic valve** is located between the left ventricle and the aorta, the largest artery in the body. It closes when the left ventricle is finished contracting, allowing blood to flow into the aorta and preventing blood from flowing back into the left ventricle.

Cardiac (Heartbeat) Cycle

Although they are separated by the septum, the right and left sides of the heart work together in a cyclic manner. The cycle consists of a brief period of rest, called **diastole,** followed by a period of ventricular contraction, called **systole** (figure 7-41). At the start of the cycle, the atria contract and push blood into the ventricles. The atria then relax, and blood returning from the body enters the right atrium, while blood returning from the lungs enters the left atrium. As the atria are filling, systole begins, and the ventricles contract. The right ventricle pushes blood into the pulmonary artery, sending the blood to the lungs for oxygen. The left ventricle pushes blood into the aorta, sending the blood to all other parts of the body. The blood in the right side of the heart is low in oxygen and high in carbon dioxide. When this blood arrives in the lungs, the carbon dioxide is released into the lungs, and oxygen is taken into the blood. This oxygenated blood is then carried to the left side of the heart by the pulmonary veins. This blood in the left side of the heart, high in oxygen and low in carbon dioxide, is ready for transport to the body cells.

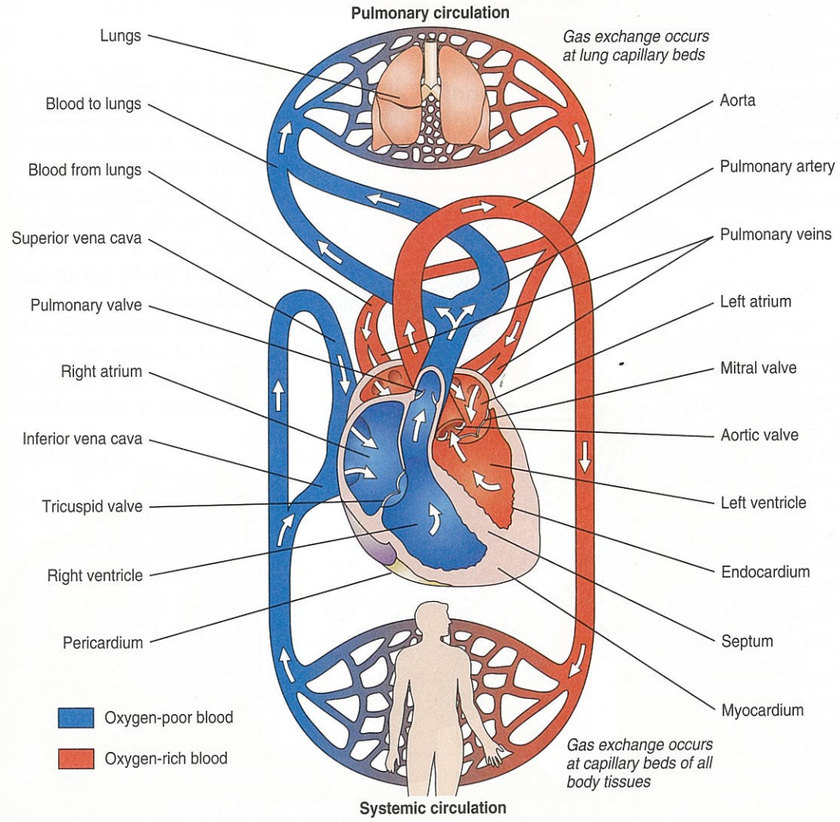

FIGURE 7-41 The pattern of circulation in the cardiovascular system.

Conductive Pathway

Electrical impulses originating in the heart cause the cyclic contraction of the muscles (figure 7-42). A group of nerve cells located in the right atrium and called the *sinoatrial (SA) node,* or the "pacemaker," sends out an electrical impulse that spreads out over the muscles in the atria. The atrial muscles then contract and push blood into the ventricles. After the electrical impulse passes through the atria, it reaches the *atrioventricular (AV) node,* a group of nerve cells located between the atria and ventricles. The AV node sends the electrical impulse through the *bundle of His,* nerve fibers in the septum. The bundle of His divides into a *right bundle branch* and a *left bundle branch,* which carry the impulse down through the ventricles. The bundle branches further subdivide into the *Purkinje fibers,* a network of nerve fibers throughout the ventricles. In this way, the electrical impulse reaches all the muscle tissue in the ventricles, and the ventricles contract. This electrical conduction pattern occurs approximately every 0.8 seconds. The movement of the electrical impulse can be recorded on an electrocardiogram (ECG) and used to detect abnormal activity or disease.

If something interferes with the normal electrical conduction pattern of the heart, arrhythmias occur. **Arrhythmias** are abnormal heart rhythms and can be mild to life-threatening. For example, an early contraction of the atria, or premature atrial contraction (PAC), can occur in anyone and usually goes unnoticed. Ventricle fibrillation, in which the ventricles contract at random without coordination, decreases or eliminates blood output and causes death if not treated. Cardiac monitors and electrocardiograms are used to diagnose arrhythmias. Treatment depends on the type and severity of the arrhythmia. Life-threatening fibrillations are treated with a *defibrillator,* a device that shocks the heart with an electrical current to stop the uncoordinated contraction and allow the SA node to regain control.

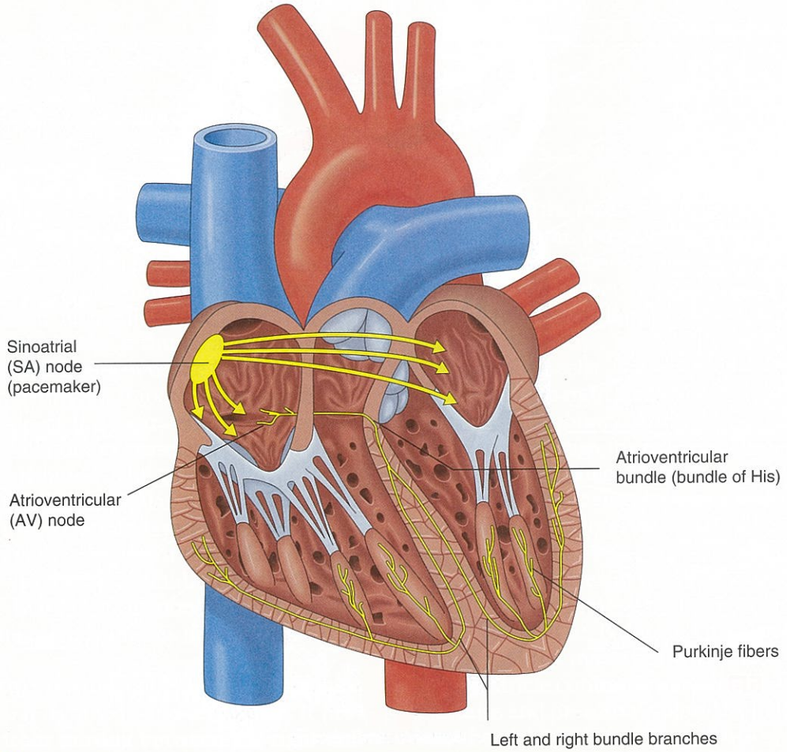

FIGURE 7-42 Electrical conduction pathways in the heart.

At times it is necessary to use external or internal artificial pacemakers to regulate the heart's rhythm, (figure 7-43). The *pacemaker* is a small, battery-powered device with electrodes. The electrodes are threaded through a vein and positioned in the right atrium and in the apex of the right ventricle. The pacemaker monitors the heart's activity and delivers an electrical impulse through the electrodes to stimulate contraction. Fixed pacemakers deliver electrical impulses at a predetermined rate. Demand pacemakers, the most common type, deliver electrical impulses only when the heart's own conduction system is not responding correctly. Even though modern pacemakers are protected from electromagnetic forces, such as microwave ovens, most manufacturers still recommend that people with pacemakers avoid close contact with digital cellular telephones. For example, the cellular telephone should not be stored in a shirt pocket close to the pacemaker.

BLOOD VESSELS

When the blood leaves the heart, it is carried throughout the body in blood vessels. The heart and blood vessels form a closed system for the flow of blood. There are three main types of blood vessels: arteries, capillaries, and veins.

Arteries (figure 7-44) carry blood away from the heart. The aorta is the largest artery in the body; it receives the blood from the left ventricle of the heart. The aorta branches into all of the other arteries that supply blood to the body. The first branch of the aorta is the coronary artery, which divides into a right and left coronary artery to carry blood to the myocardium of the heart.

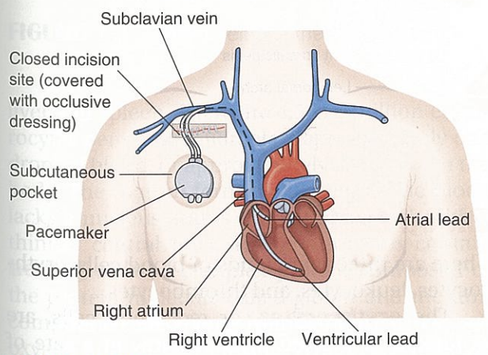

FIGURE 7-43 Artificial pacemakers can help regulate the heart's rhythm.

Additional branches of the aorta carry blood to the head, neck, arms, chest, back, abdomen, and legs. The smallest branches of arteries are called *arterioles.* They join with capillaries. Arteries are more muscular and elastic than are the other blood vessels because they receive the blood as it is pumped from the heart.

Capillaries connect arterioles with *venules,* the smallest veins. Capillaries are located in close proximity to almost every cell in the body. They have thin walls that contain only one layer of cells. These thin walls allow oxygen and nutrients to pass through to the cells and allow carbon dioxide and metabolic products from the cells to enter the capillaries.

Veins (figure 7-45) are blood vessels that carry blood back to the heart. *Venules,* the smallest branches of veins, connect with the capillaries. The venules join together and, becoming larger, form veins. The veins continue to join together until they form the two largest veins: the superior vena cava and the inferior vena cava. The superior vena cava brings the blood from the upper part of the body, and the inferior vena cava brings the blood from the lower part of the body. Both vena cavae drain into the right atrium of the heart. Veins are thinner and have less muscle tissue than do arteries. Most veins contain valves, which keep the blood from flowing in a backward direction (figure 7-46).

BLOOD COMPOSITION

The **blood** that flows through the circulatory system is often called a *tissue* because it contains many kinds of cells. There are approximately 4–6 quarts of blood in the average adult. This blood circulates continuously throughout the body. It transports oxygen from the lungs to the body cells, carbon dioxide from the body cells to the lungs, nutrients from the digestive tract to the body cells, metabolic and waste products from the body cells to the organs of excretion, heat produced by various body parts, and hormones produced by endocrine glands to the body organs.

Plasma

Blood is made of the fluid called *plasma* and formed or solid elements called *blood cells* (figure 7-47). **Plasma** is approximately 90 percent water,

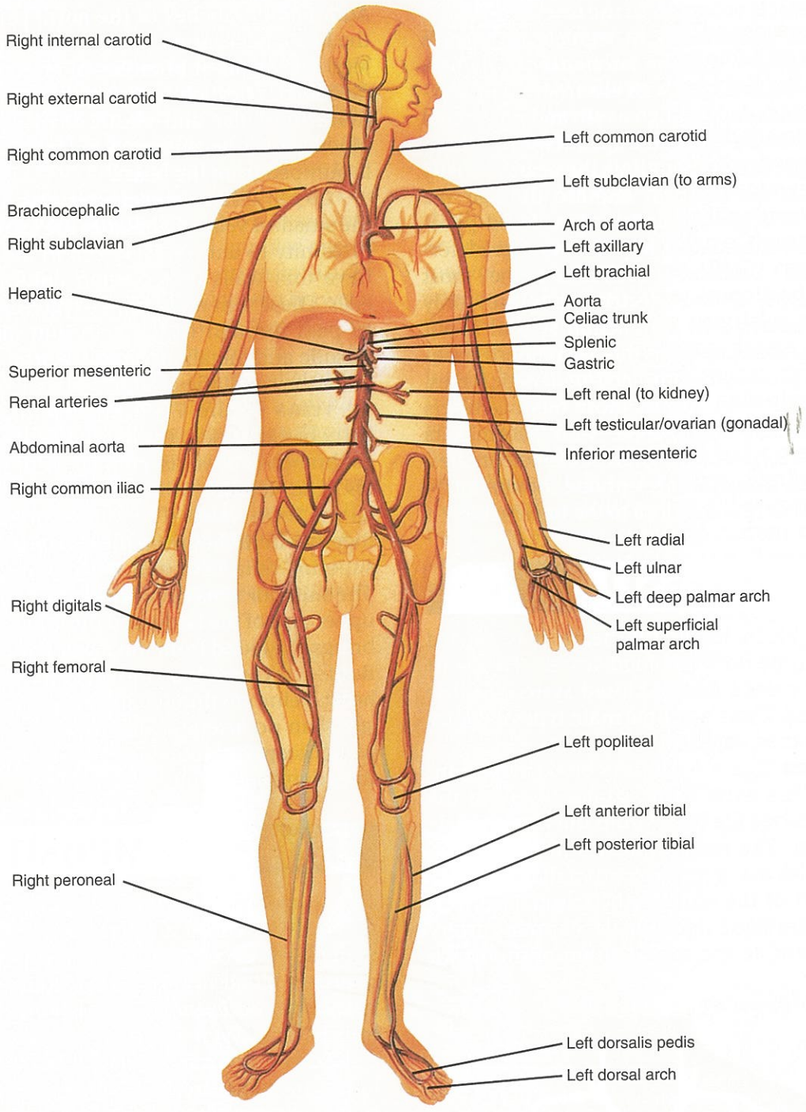

FIGURE 7-44 Major arteries of the body.

with many dissolved, or suspended, substances. Among these substances are blood proteins such as fibrinogen and prothrombin (both necessary for clotting); nutrients such as vitamins, carbohydrates, and proteins; mineral salts or electrolytes such as potassium, calcium, and sodium; gases such as carbon dioxide and oxygen; metabolic and waste products; hormones; and enzymes.

Blood Cells

There are three main kinds of blood cells: erythrocytes, leukocytes, and thrombocytes.

The **erythrocytes,** or red blood cells, are produced in the red bone marrow at a rate of about one million per minute. They live approximately 120 days before being broken down by the

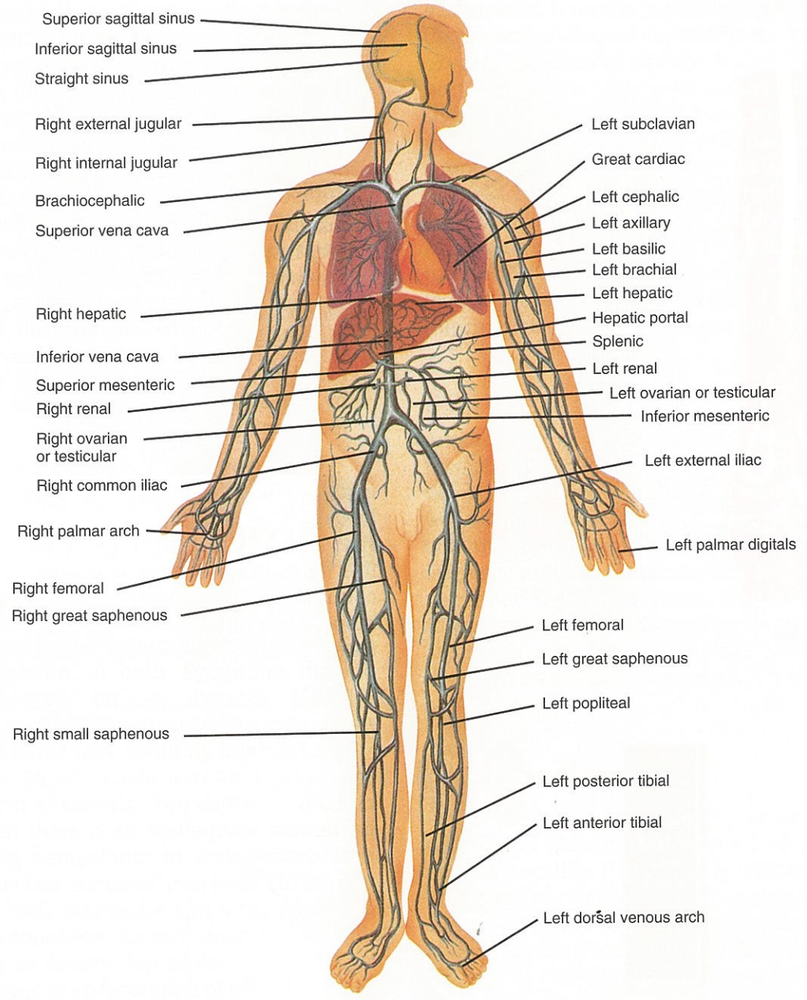

FIGURE 7-45 Major veins of the body.

liver and spleen. There are 4.5–5.5 million erythrocytes per cubic millimeter (approximately one drop) of blood, or approximately 25 trillion in the body. The mature form circulating in the blood lacks a nucleus and is shaped like a disk with a thinner central area. The erythrocytes contain **hemoglobin,** a complex protein composed of the protein molecule called *globin* and the iron compound called *heme.* Hemoglobin carries both oxygen and carbon dioxide. When carrying oxygen, hemoglobin gives blood its characteristic red color. When blood contains a lot of oxygen, it is bright red; when blood contains less oxygen and more carbon dioxide, it is a much darker red with a bluish cast.

Leukocytes, or white blood cells, are not as numerous as are erythrocytes. They are formed in the bone marrow and lymph tissue and usually live about 3–9 days. A normal count is 5,000–9,000 leukocytes per cubic millimeter of blood. Leukocytes can pass through capillary walls and enter body tissue. Their main function is to fight infection. Some do this by engulfing, ingesting, and destroying pathogens, or germs, by a process

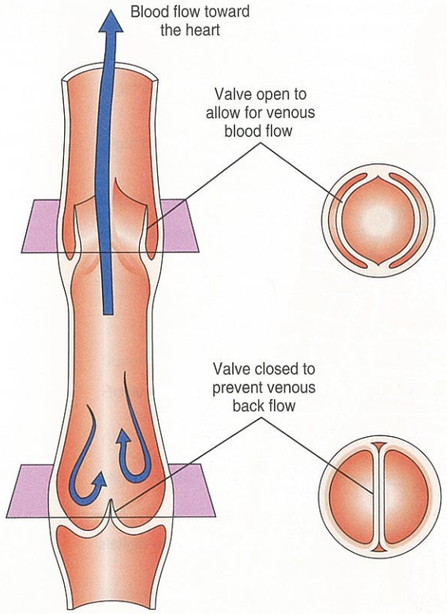

FIGURE 7-46 Most veins contain valves to prevent the backflow of blood.

called *phagocytosis*. The five types of leukocytes and their functions include:

- *Neutrophils*: phagocytize bacteria by secreting an enzyme called *lysozyme*
- *Eosinophils*: remove toxins and defend the body from allergic reactions by producing antihistamines
- *Basophils*: participate in the body's inflammatory response; produce histamine, a vasodilator, and heparin, an anticoagulant
- *Monocytes*: phagocytize bacteria and foreign materials
- *Lymphocytes*: provide immunity for the body by developing antibodies; protect against the formation of cancer cells

Thrombocytes, also called *platelets,* are usually described as fragments or pieces of cells because they lack nuclei and vary in shape and size. They are formed in the bone marrow and live for about 5–9 days. A normal thrombocyte count is 250,000–400,000 per cubic millimeter of blood. Thrombocytes are important for the clotting process, which stops bleeding. When a blood

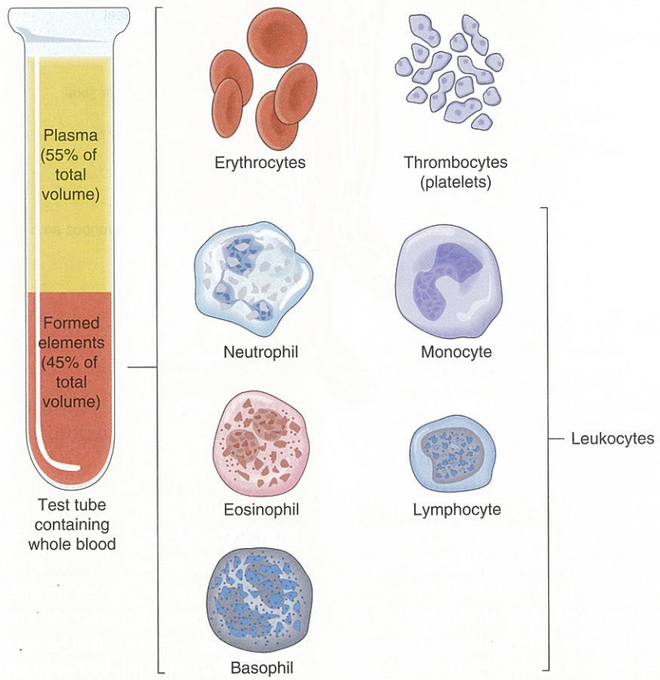

FIGURE 7-47 The major components of blood.

vessel is cut, the thrombocytes collect at the site to form a sticky plug. They secrete a chemical, serotonin, which causes the blood vessel to spasm and narrow, decreasing the flow of blood. At the same time, the thrombocytes release an enzyme, thromboplastin, which acts with calcium and other substances in the plasma to form thrombin. Thrombin acts on the blood protein fibrinogen to form fibrin, a gel-like net of fine fibers that traps erythrocytes, platelets, and plasma to form a clot. This is an effective method for controlling bleeding in smaller blood vessels. If a large blood vessel is cut, the rapid flow of blood can interfere with the formation of fibrin. In these instances, a doctor may have to insert sutures (stitches) to close the opening and control the bleeding.

DISEASES AND ABNORMAL CONDITIONS

Anemia

Anemia is an inadequate number of red blood cells, hemoglobin, or both. Symptoms include pallor (paleness), fatigue, dyspnea (difficult breathing), and rapid heart rate. Hemorrhage can cause rapid blood loss, resulting in acute-blood-loss anemia. Blood transfusions are used to correct this form of anemia. *Iron deficiency anemia* results when there is an inadequate amount of iron to form hemoglobin in erythrocytes. Iron supplements and increased iron intake in the diet from green leafy vegetables and other foods can correct this condition. *Aplastic anemia* is a result of injury to or destruction of the bone marrow, leading to poor or no formation of red blood cells. Common causes include chemotherapy, radiation, toxic chemicals, and viruses. Treatment includes eliminating the cause, blood transfusions, and in severe cases, a bone marrow transplant. Unless the damage can be reversed, it is frequently fatal. *Pernicious anemia* results in the formation of erythrocytes that are abnormally large in size, but inadequate in number. The cause is a lack of intrinsic factor (a substance normally present in the stomach), which results in inadequate absorption of vitamin B_{12}. Vitamin B_{12} and folic acid are required for the development of mature erythrocytes. Administering vitamin B_{12} injections can control and correct this condition. *Sickle cell anemia* is a chronic, inherited anemia. It results in the production of abnormal, crescent-shaped erythrocytes that carry less oxygen, break easily, and block blood vessels (figure 7-48). Sickle cell anemia occurs almost exclusively among African Americans. Treatment methods include transfusions of packed cells and supportive therapy during crisis. Research directed toward bone marrow transplants, stem cell transplants from placental blood, and gene cell therapy may offer a cure for sickle cell anemia in the near future. Genetic counseling can lead to prevention of the disease if carriers make informed decisions not to have children.

Aneurysm

An aneurysm is a ballooning out of, or saclike formation on, an artery wall. Disease, congenital defects, and injuries leading to weakened arterial wall structure can cause this defect. Although some aneurysms cause pain and pressure, others generate no symptoms. Common sites are the cerebral, aortal, and abdominal arteries. If an aneurysm ruptures, hemorrhage, which can cause death, occurs. Treatment usually involves surgically removing the damaged area of blood vessel and replacing it with a plastic graft or another blood vessel.

Arteriosclerosis

Arteriosclerosis is a hardening or thickening of the arterial walls, resulting in a loss of elasticity and contractility. It commonly occurs as a result of aging. Arteriosclerosis causes high blood pressure, or hypertension, and can lead to an aneurysm or cerebral hemorrhage. The main focus of treatment is lowering blood pressure through the use of diet, medications, or both.

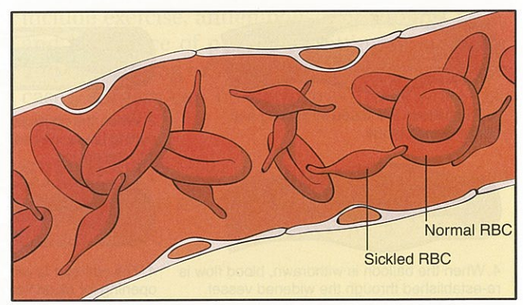

FIGURE 7-48 Sickle cell anemia is characterized by abnormal, crescent-shaped erythrocytes.

Atherosclerosis

Atherosclerosis occurs when fatty plaques (frequently cholesterol) are deposited on the walls of the arteries. This narrows the arterial opening, which reduces or eliminates blood flow. If plaques break loose, they can circulate through the bloodstream as *emboli.* A low-cholesterol diet, medications to lower cholesterol blood levels, abstaining from smoking, reduction of stress, and exercise are used to prevent atherosclerosis. Angioplasty (figure 7-49) may be used to remove or compress the deposits, or to insert a stent to allow blood flow. Bypass surgery is used when the arteries are completely blocked.

Congestive Heart Failure

Congestive heart failure (CHF) is a condition that occurs when the heart muscles do not beat adequately to supply the blood needs of the body. It may involve either the right side or the left side of the heart. Symptoms include edema (swelling); dypsnea; pallor or cyanosis; distention of the neck veins; a weak, rapid pulse; and a cough accompanied by pink, frothy sputum. Cardiotonic drugs (to slow and strengthen the heartbeat), diuretics (to remove retained body fluids), elastic support hose, oxygen therapy, bedrest, and/or a low-sodium diet are used as treatment methods.

Embolus

An embolus is a foreign substance circulating in the bloodstream. It can be air, a blood clot, bacterial clumps, a fat globule, or other similar substances. When an embolus enters an artery or capillary too small for passage, blockage of the blood vessel occurs.

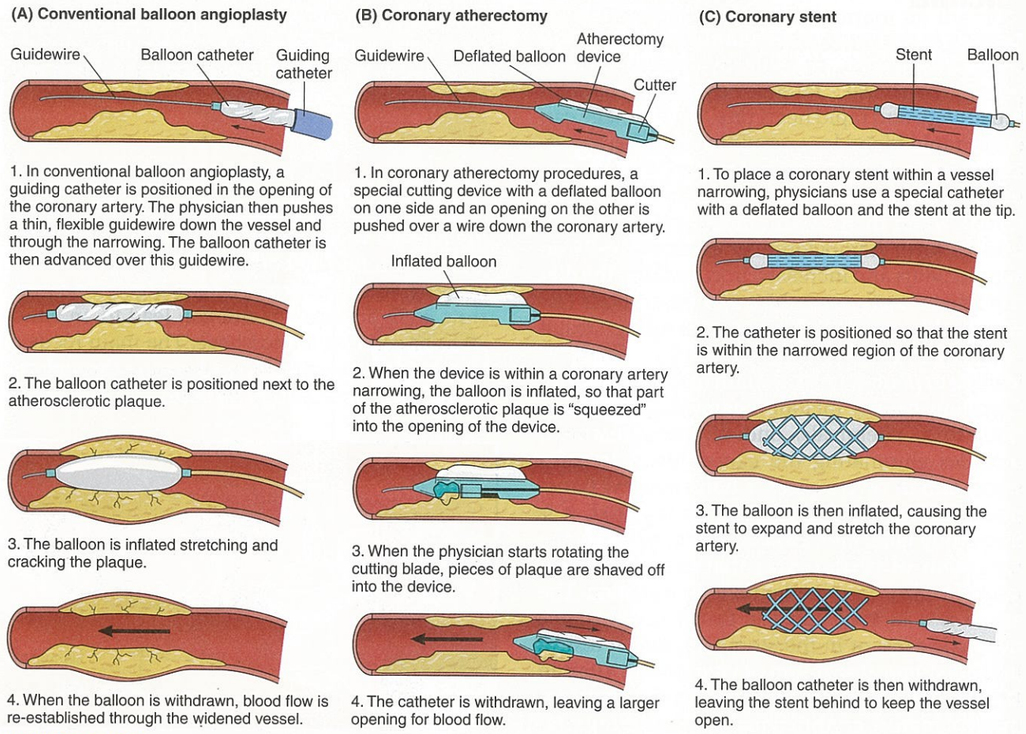

FIGURE 7-49 Ways to open clogged arteries: (A) balloon angioplasty, (B) coronary atherectomy, and (C) coronary stent.

Hemophilia

Hemophilia is an inherited disease that occurs almost exclusively in male individuals but can be carried by female individuals. Because of the lack of a plasma protein required for the clotting process, the blood is unable to clot. A minor cut can lead to prolonged bleeding, and a minor bump can cause internal bleeding. Treatment involves transfusing whole blood, or plasma, and administering the missing protein factor.

Hypertension

Hypertension is high blood pressure. A systolic pressure above 140 and a diastolic pressure above 90 millimeters of mercury (mmHg) is usually regarded as hypertension. Risk factors that increase the incidence of hypertension include family history, race (higher in African Americans), obesity, stress, smoking, aging (higher in postmenopausal women), and a diet high in saturated fat. Although there is no cure, hypertension can usually be controlled with antihypertensive drugs, diuretics (to remove retained body fluids), limited stress, avoidance of tobacco, and/or a low-sodium or low-fat diet. If hypertension is not treated, it can cause permanent damage to the heart, blood vessels, and kidneys.

Leukemia

Leukemia is a malignant disease of the bone marrow or lymph tissue. It results in a high number of immature white blood cells. There are different types of leukemia, some acute and some chronic. Symptoms include fever, pallor, swelling of lymphoid tissues, fatigue, anemia, bleeding gums, excessive bruising, and joint pain. Treatment methods vary with the type of leukemia but can include chemotherapy, radiation, and/or bone marrow transplant.

Myocardial Infarction

A myocardial infarction, or heart attack, occurs when a blockage in the coronary arteries cuts off the supply of blood to the heart. The affected heart tissue dies and is known as an *infarct.* Death can occur immediately. Symptoms include severe crushing pain (angina pectoris) that radiates to the arm, neck, and jaw; pressure in the chest; perspiration and cold, clammy skin; dypsnea; and a change in blood pressure. If the heart stops, cardiopulmonary resuscitation should be started immediately. Immediate treatment with a thrombolytic or "clot-busting" drug such as streptokinase or TPA, tissue plasminogen activator, may open the blood vessel and restore blood flow to the heart. However, the clot-busting drug must be used within the first several hours, and its use is prohibited if bleeding is present. Additional treatment methods include complete bed rest, pain medications, vasodilators, cardiotonic drugs (to slow and strengthen the heartbeat), oxygen therapy, anticoagulants (to prevent additional clots), and control of arrhythmias (abnormal heart rhythms). Long-term care includes control of blood pressure, a diet low in cholesterol and saturated fat, avoidance of tobacco and stress, regular exercise, and weight control.

Phlebitis

Phlebitis is an inflammation of a vein, frequently in the leg. If a thrombus, or clot, forms, the condition is termed *thrombophlebitis.* Symptoms include pain, edema, redness, and discoloration at the site. Treatment methods include anticoagulants; pain medication; elevation of the affected area; antiembolism or support hose; and if necessary, surgery to remove the clot.

Varicose Veins

Varicose veins are dilated, swollen veins that have lost elasticity and cause stasis, or decreased blood flow. They frequently occur in the legs and result from pregnancy, prolonged sitting or standing, and hereditary factors. Treatment methods include exercise, antiembolism or support hose, and avoidance of prolonged sitting or standing and tight-fitting or restrictive clothing. In severe cases, surgery can be performed to remove the vein.

STUDENT: *Go to the workbook and complete the assignment sheet for 7:8, Circulatory System.*