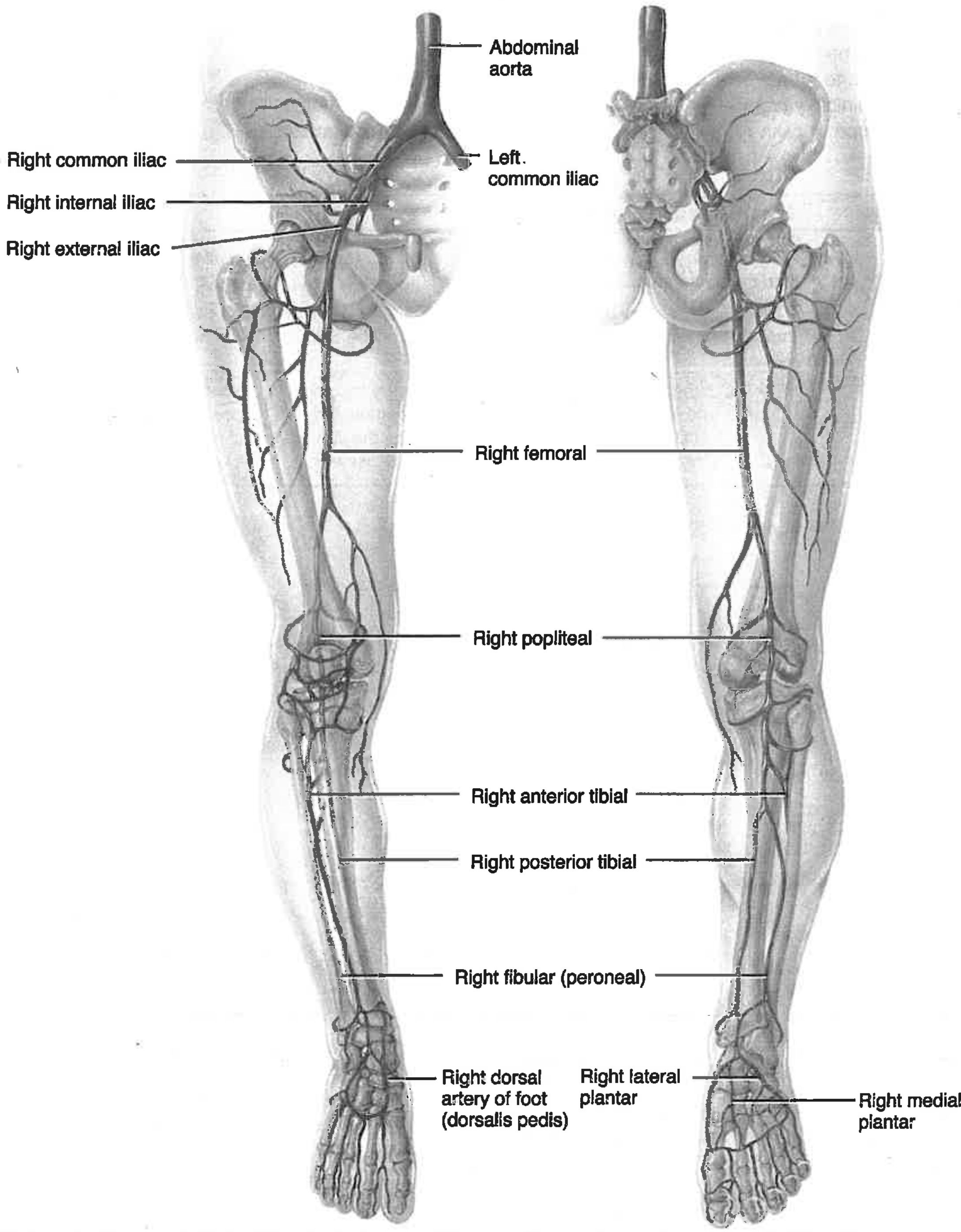
Figure 16.11 Arteries of the pelvis and right lower limb.

The internal iliac arteries carry most of the blood supply to the pelvis, buttocks, external genitals, and thigh.



? At what point does the abdominal aorta divide into the common iliac arteries?

Exhibit 16.4 Veins of the Systemic Circulation *(Figure 16.12)*

OBJECTIVE • **Identify the three systemic veins that return deoxygenated blood to the heart.**

• Arteries distribute blood to various parts of the body, and veins drain blood away from them. For the most part, arteries are deep. Veins may be ***superficial*** (located just beneath the skin) or ***deep***. Deep veins generally travel alongside arteries and usually bear the same name. Because there are no large superficial arteries, the names of superficial veins do not correspond to those of arteries. Superficial veins are clinically important as sites for withdrawing blood or giving injections. Arteries usually follow definite pathways. Veins are more difficult to follow because they connect in irregular networks in which many smaller veins merge to form a larger vein. Although only one systemic artery, the aorta, takes oxygenated blood away from the heart (left ventricle), three systemic veins, the ***coronary sinus***, ***superior vena cava***, and ***inferior vena cava***, deliver deoxygenated blood to the right atrium of the heart. The coronary sinus receives blood from the cardiac veins; the superior vena cava receives blood from other veins superior to the diaphragm, except the air sacs (alveoli) of the lungs; the inferior vena cava receives blood from veins inferior to the diaphragm.

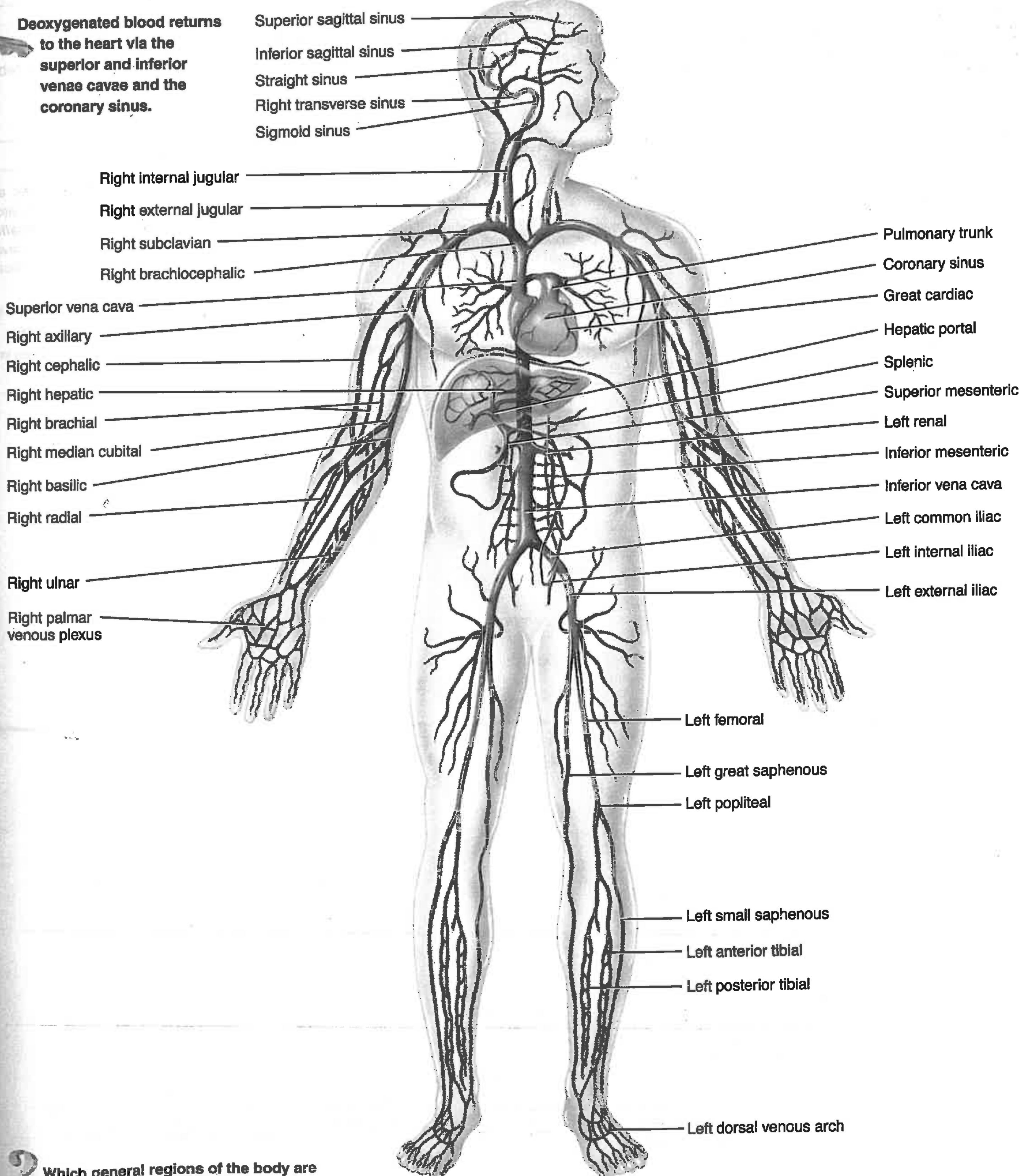
■ **CHECKPOINT**

What are the basic differences between systemic arteries and veins?

Vein	Description and Region Drained
Coronary sinus (KOR-ō-nar-ē; *corona* = crown)	The ***coronary sinus*** is the main vein of the heart; it receives almost all venous blood from the myocardium. It opens into the right atrium between the opening of the inferior vena cava and the tricuspid valve.
Superior vena cava (SVC) (VĒ-na CĀ-va; *vena* = vein; *cava* = cavelike	The ***SVC*** empties its blood into the superior part of the right atrium. It begins by the union of the right and left brachiocephalic veins and enters the right atrium. The SVC drains the head, neck, chest, and upper limbs.
Inferior vena cava (IVC)	The ***IVC*** is the largest vein in the body. It begins by the union of the common iliac veins, passes through the diaphragm, and enters the inferior part of the right atrium. The IVC drains the abdomen, pelvis, and lower limbs. The inferior vena cava is commonly compressed during the later stages of pregnancy by the enlarging uterus, producing edema of the ankles and feet and temporary varicose veins.

Figure 16.12 Principal veins.

Deoxygenated blood returns to the heart via the superior and inferior venae cavae and the coronary sinus.



Overall anterior view of the principal veins

Which general regions of the body are drained by the superior vena cava and the inferior vena cava?

Exhibit 16.5 Veins of the Head and Neck *(Figure 16.13)*

OBJECTIVE • **Identify the three major veins that drain blood from the head.**

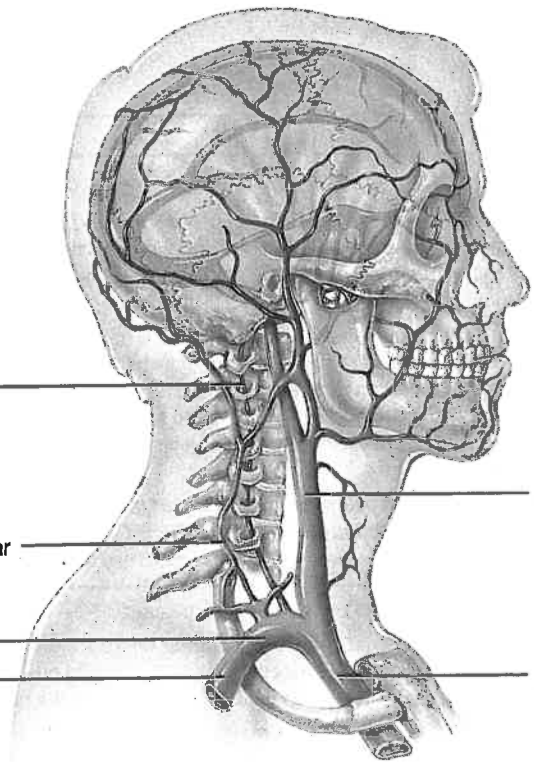
• Most blood draining from the head passes into three pairs of veins: the ***internal jugular veins***, ***external jugular veins***, and ***vertebral veins***. Within the brain, all veins drain into dural venous sinuses and then into the internal jugular veins. ***Dural venous sinuses*** are endothelium-lined venous channels between layers of the cranial dura mater.

CHECKPOINT
Which general areas are drained by the internal jugular, external jugular, and vertebral veins?

Vein	Description and Region Drained
Internal jugular veins (JUG-ū-lar; *jugular* = throat)	The dural venous sinuses (the light blue vessels in Figure 16.13) drain blood from the cranial bones, meninges, and brain. The right and left ***internal jugular veins*** pass inferiorly on either side of the neck lateral to the internal carotid and common carotid arteries. They then unite with the subclavian veins to form the right and left ***brachiocephalic veins*** (brā′-kē-ō-se-FAL-ik; *brachio-* = arm; *-cephalic* = head). From here blood flows into the superior vena cava. The general structures drained by the internal jugular veins are the brain (through the dural venous sinuses), face, and neck.
External jugular veins	The right and left ***external jugular veins*** empty into the subclavian veins. The general structures drained by the external jugular veins are external to the cranium, such as the scalp and superficial and deep regions of the face.
Vertebral veins (VER-te-bral; *vertebra* = vertebrae)	The right and left ***vertebral veins*** empty into the brachiocephalic veins in the neck. They drain deep structures in the neck such as the cervical vertebrae, cervical spinal cord, and some neck muscles.

Figure 16.13 Principal veins of the head and neck.

Blood draining from the head passes into the internal jugular, external jugular, and vertebral veins.



Right lateral view

Into which veins in the neck does all venous blood from the brain drain?

Exhibit 16.6 Veins of the Upper Limbs *(Figure 16.14)*

OBJECTIVE • **Identify the principal veins that drain the upper limbs.**

• Blood from the upper limbs is returned to the heart by both *superficial* and *deep veins.* Both sets of veins have valves, which are more numerous in the deep veins.

• Superficial veins are larger than deep veins and return most of the blood from the upper limbs.

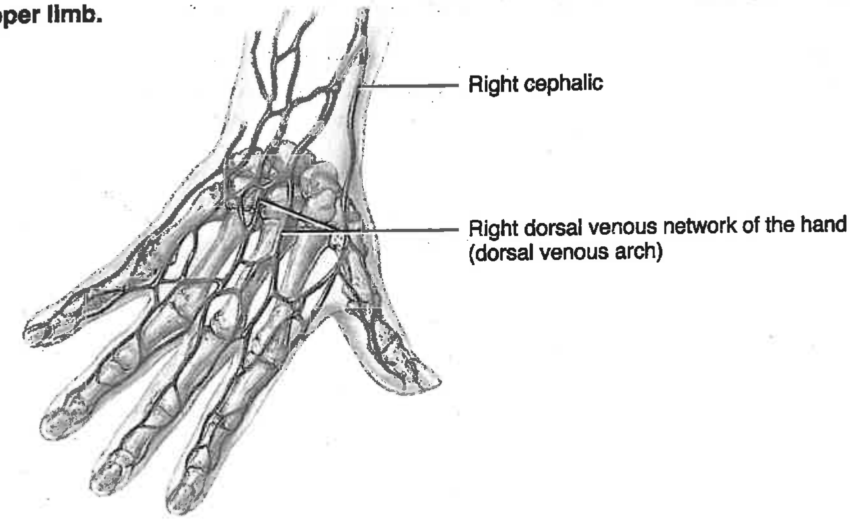
■ **CHECKPOINT**

Where do the cephalic, basilic, median antebrachial, radial, and ulnar veins originate?

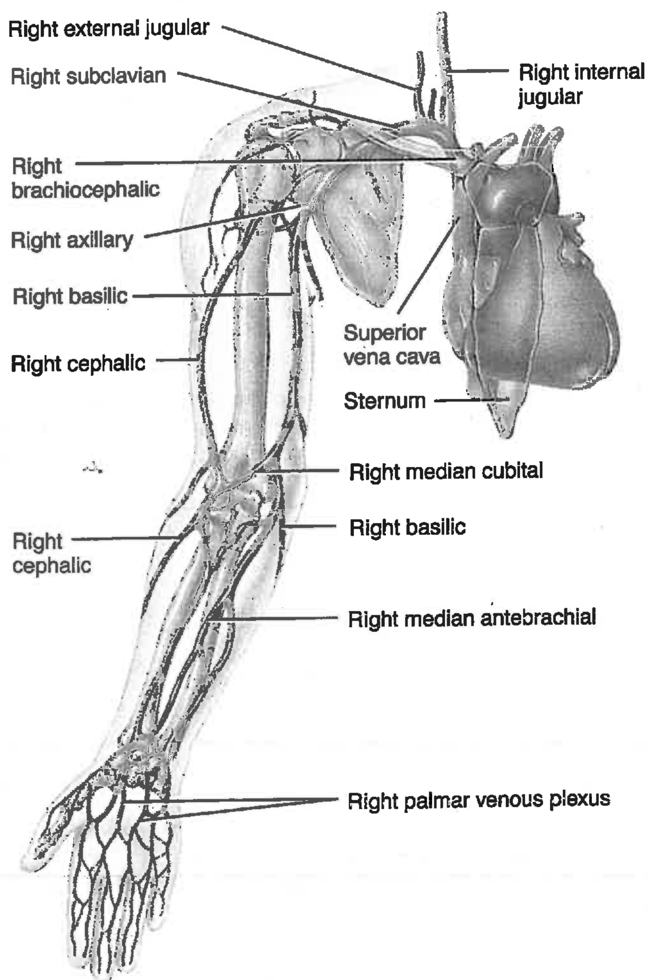
Vein	Description and Region Drained
Superficial Veins	
Cephalic veins (se-FAL-ik = head)	The principal superficial veins that drain the upper limbs originate in the hand and convey blood from the smaller superficial veins into the axillary veins. The ***cephalic veins*** begin on the lateral aspect of the ***dorsal venous networks of the hands (dorsal venous arches),*** networks of veins on the dorsum of the hands (Figure 16.14a) that drain the fingers. The cephalic veins drain blood from the lateral aspect of the upper limbs.
Basilic veins (ba-SIL-ik = royal)	The ***basilic veins*** begin on the medial aspects of the dorsal venous networks of the hands (Figure 16.14b) and drain blood from the medial aspects of the upper limbs. Anterior to the elbow, the basilic veins are connected to the cephalic veins by the ***median cubital veins*** (*cubitus* = elbow), which drain the forearm. If a vein must be punctured for an injection, transfusion, or removal of a blood sample, the median cubital vein is preferred. The basilic veins continue ascending until they join the brachial veins. As the basilic and brachial veins merge in the axillary area, they form the axillary veins.
Median antebrachial veins (an′-tē-BRĀ-kē-al; *ante-* = before, in front of; *brachi-* = arm)	The ***median antebrachial veins (median veins of the forearm)*** begin in the ***palmar venous plexuses,*** networks of veins on the palms. The plexuses drain the fingers. The median antebrachial veins ascend in the forearms to join the basilic or median cubital veins, sometimes both. They drain the palms and forearms.
Deep Veins	
Radial veins (RĀ-dē-al = pertaining to the radius)	The paired ***radial veins*** begin at the ***deep palmar venous arches*** (Figure 16.14c). These arches drain the palms. The radial veins drain the lateral aspects of the forearms and pass alongside each radial artery. Just below the elbow joint, the radial veins unite with the ulnar veins to form the brachial veins.
Ulnar veins (UL-nar = pertaining to the ulna)	The paired ***ulnar veins*** begin at the ***superficial palmar venous arches,*** which drain the palms and the fingers. The ulnar veins drain the medial aspect of the forearms, pass alongside each ulnar artery, and join with the radial veins to form the brachial veins.
Brachial veins (BRĀ-kē-al)	The paired ***brachial veins*** accompany the brachial arteries. They drain the forearms, elbow joints, and arms. They join with the basilic veins to form the axillary veins.
Axillary veins (AK-si-ler′-ē; *axilla* = armpit)	The ***axillary veins*** ascend to become the subclavian veins. They drain the arms, axillae, and upper part of the chest wall.
Subclavian veins (sub-KLĀ-vē-an; *sub-* = under; *-clavian* = pertaining to the clavicle)	The ***subclavian veins*** are continuations of the axillary veins that unite with the internal jugular veins to form the brachiocephalic veins. The brachiocephalic veins unite to form the superior vena cava. The subclavian veins drain the arms, neck, and thoracic wall.

Figure 16.14 Principal veins of the right upper limb.

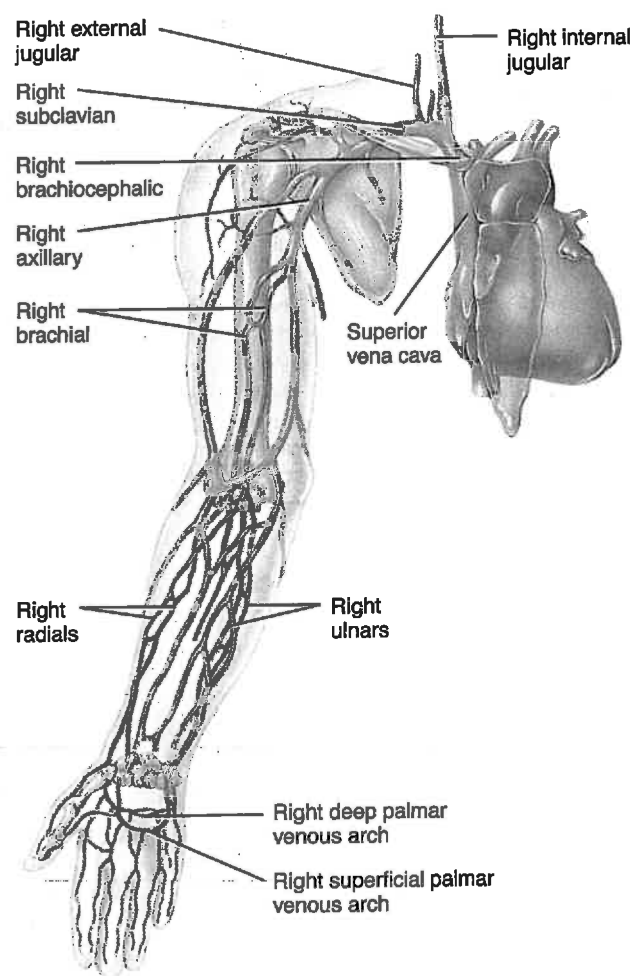
Deep veins usually accompany arteries that have similar names.



(a) Posterior view of superficial veins of the hand



(b) Anterior view of superficial veins



(c) Anterior view of deep veins

From which vein in the upper limb is a blood sample often taken?

Exhibit 16.7 Veins of the Lower Limbs *(Figure 16.15)*

OBJECTIVE • Identify the principal veins that drain the lower limbs.

• As with the upper limbs, blood from the lower limbs is drained by both *superficial* and *deep veins*. The superficial veins often branch with each other and with deep veins along their length. All veins of the lower limbs have valves, which are more numerous than in veins of the upper limbs.

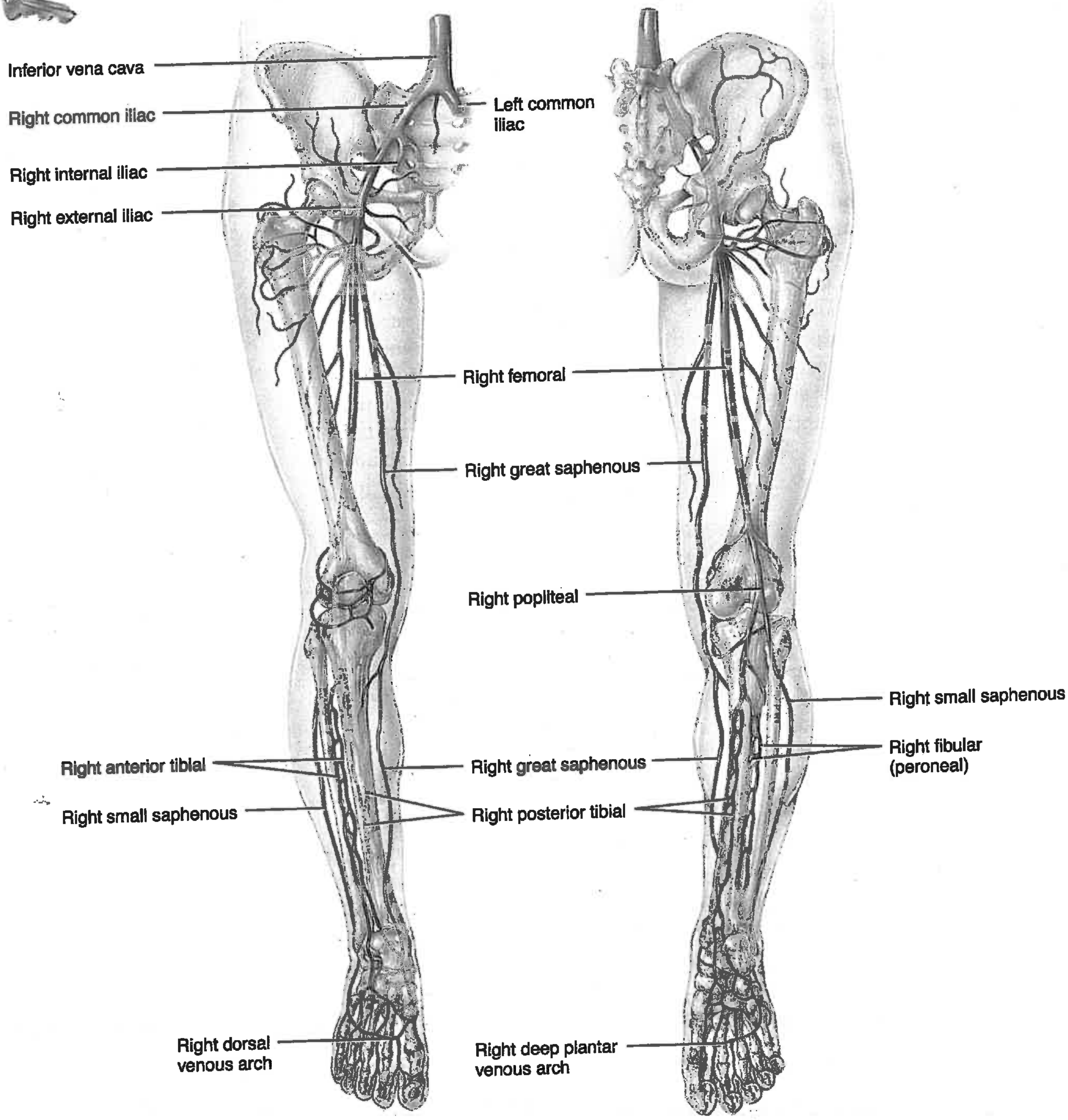
CHECKPOINT

Why are the great saphenous veins clinically important?

Vein	Description and Region Drained
Superficial Veins	
Great saphenous veins (sa-FĒ-nus = clearly visible)	The ***great saphenous veins***, the longest veins in the body, begin at the medial side of the ***dorsal venous arches*** (VĒ-nus) of the foot, networks of veins on the top of the foot that collect blood from the toes. The great saphenous veins empty into the femoral veins, and they mainly drain the leg and thigh, the groin, external genitals, and abdominal wall. Along their length, the great saphenous veins have from 10 to 20 valves, with more located in the leg than the thigh. The great saphenous veins are often used for prolonged administration of intravenous fluids. This is particularly important in very young children and in patients of any age who are in shock and whose veins are collapsed. The great saphenous veins are also often used as a source of vascular grafts, especially for coronary bypass surgery. In the procedure, the vein is removed and then reversed so that the valves do not obstruct the flow of blood.
Small saphenous veins	The ***small saphenous veins*** begin at the lateral side of the dorsal venous arches of the foot. They empty into the popliteal veins behind the knee. Along their length, the small saphenous veins have from 9 to 12 valves. The small saphenous veins drain the foot and leg.
Deep Veins	
Posterior tibial veins (TIB-ē-al)	The ***deep plantar venous arches*** on the soles drain the toes and ultimately give rise to the paired ***posterior tibial veins***. They accompany the posterior tibial arteries through the leg and drain the foot and posterior leg muscles. About two-thirds the way up the leg, the posterior tibial veins drain blood from the ***fibular (peroneal) veins***, which serve the lateral and posterior leg muscles.
Anterior tibial veins	The paired ***anterior tibial veins*** arise in the dorsal venous arch and accompany each anterior tibial artery. They unite with the posterior tibial veins to form the popliteal vein. The anterior tibial veins drain the ankle joint, knee joint, tibiofibular joint, and anterior portion of the leg.
Popliteal veins (pop′-li-TĒ-al; *popliteus* = hollow behind knee)	The ***popliteal veins*** are formed by the union of the anterior and posterior tibial veins. They drain the skin, muscles, and bones of the knee joint.
Femoral veins (FEM-o-ral)	The ***femoral veins*** accompany each femoral artery and are the continuations of the popliteal veins. They drain the muscles of the thighs, femurs, external genitals, and superficial lymph nodes. The femoral veins enter the pelvic cavity, where they are known as the ***external iliac veins***. The external and internal iliac veins unite to form the common iliac veins, which unite to form the inferior vena cava.

Figure 16.15 Principal veins of the pelvis and lower limbs.

All veins of the lower limbs have valves.



(a) Anterior view

(b) Posterior view

Which veins of the lower limb are superficial?

Focus on Wellness

Arterial Health—Undoing the Damage of Atherosclerosis

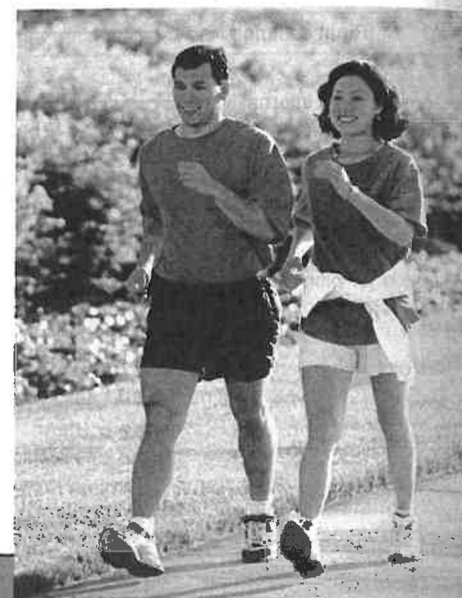
Not so long ago scientists believed that once plaque formed in an artery, it never went away. Medical researchers thought that lifestyle changes and drugs could slow the process of atherosclerosis, but they could not undo damage already done. In recent years, however, researchers have discovered that the body's own healing processes can reverse arterial plaque buildup. Lifestyle changes and drug treatments appear to stabilize the most dangerous atherosclerotic plaques and may even eliminate the need for surgical interventions, such as bypass surgery, in some people.

Stabilizing Dangerous Plaque

The health risk imposed by plaque that accumulates within the artery lining depends upon several factors. Some plaque is fairly stable: It has a low lipid content, is not growing much in size, and has a strong fibrous cap that keeps it from rupturing when blood pressure rises. Unstable plaque is characterized by a large accumulation of lipid in its core and only a thin fibrous cap. In addition, unstable plaques contain a large number of macrophages. In a misguided attempt to heal endothelial damage, macrophages ingest plaque lipids; the net result is increased arterial injury and lipid accumulation. An unstable plaque is apt to rupture, triggering formation of a life-threatening blood clot at the plaque site.

Aggressive Prevention

The first step in preventing, slowing, and possibly reversing artery disease is to control the risk factors associated with its progression. Recommendations for a heart-healthy and artery-healthy lifestyle include no smoking, regular exercise (at least 30 minutes of moderate-intensity exercise per day), stress management, and a heart-healthy diet. Diet recommendations include limiting fat intake and dramatically increasing consumption of plant foods, such as grains, fruits, and vegetables. These recommendations help prevent arterial disease by reducing obesity, blood lipids, platelet stickiness, and blood pressure, and by improving blood glucose control in people at risk for type 2 diabetes.



▶ **Think It Over . . .**

▶ *Studies have found that only diets extremely low in fat (10% or fewer calories from fat) lead to plaque regression. Why do you think public health officials generally recommend a diet that supplies up to 30% of its calories from fat? Do you think this recommendation should be lower? Remember, this guideline is supposed to apply to all North Americans, not just those at risk for artery disease.*

Pulmonary Circulation

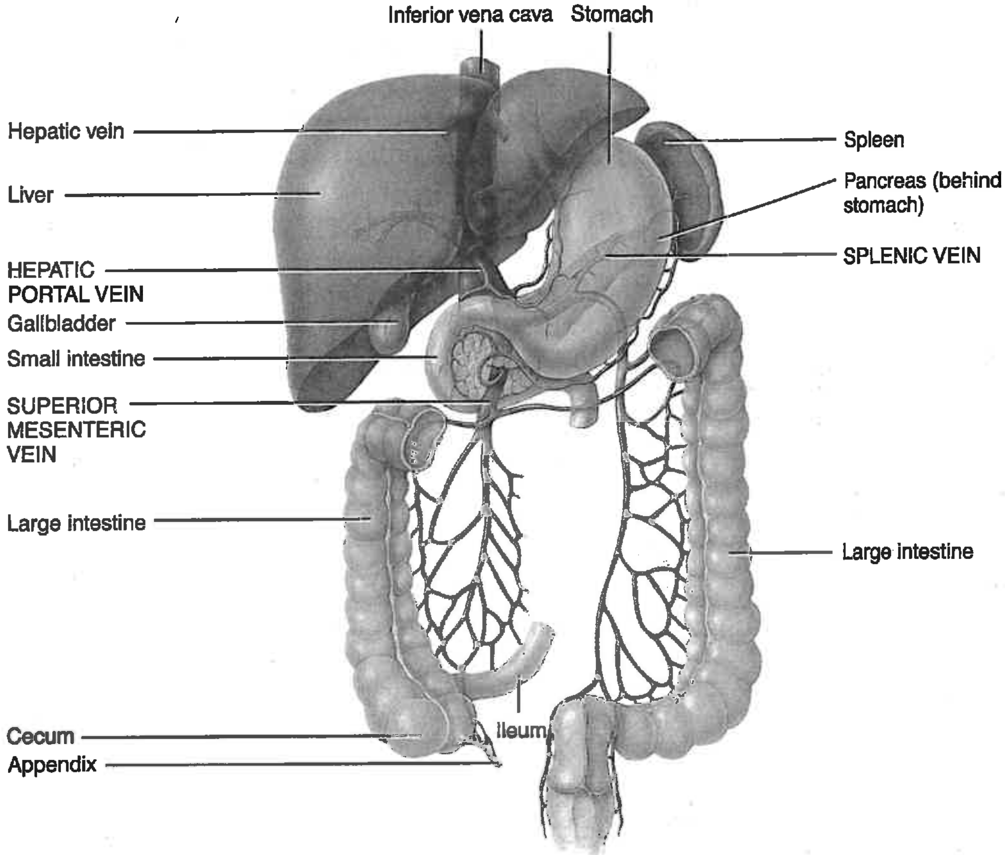
When deoxygenated blood returns to the heart from the systemic route, it is pumped out of the right ventricle into the lungs. In the lungs, it loses carbon dioxide and picks up oxygen. Now bright red again, the blood returns to the left atrium of the heart and is pumped again into the systemic circulation. The flow of deoxygenated blood from the right ventricle to the air sacs of the lungs and the return of oxygenated blood from the air sacs to the left atrium is called the ***pulmonary circulation*** (see Figure 16.8). The ***pulmonary trunk*** emerges from the right ventricle and then divides into two branches. The ***right pulmonary artery*** runs to the right lung; the ***left pulmonary artery*** goes to the left lung. After birth, the pulmonary arteries are the only arteries that carry deoxygenated blood. On entering the lungs, the branches divide and subdivide until ultimately they form capillaries around the air sacs in the lungs. Carbon dioxide passes from the blood into the air sacs and is exhaled, while inhaled oxygen passes from the air sacs into the blood. The capillaries unite, venules and veins are formed, and, eventually, two ***pulmonary veins*** from each lung transport the oxygenated blood to the left atrium. (After birth, the pulmonary veins are the only veins that carry oxygenated blood.) Contractions of the left ventricle then send the blood into the systemic circulation.

Hepatic Portal Circulation

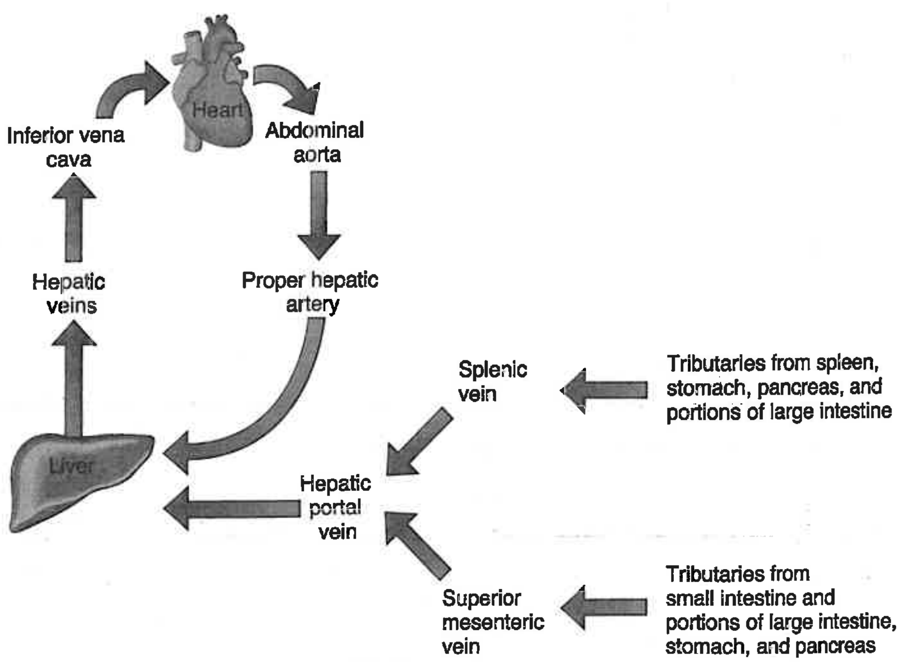
A vein that carries blood from one capillary network to another is called a ***portal vein***. The hepatic portal vein, formed by the union of the splenic and superior mesenteric veins (Figure 16.16), receives blood from capillaries of digestive organs and delivers it to capillary-like structures in the liver called sinusoids. In the ***hepatic portal circulation*** (*hepat-* = liver), venous blood from the gastrointestinal organs and spleen, rich with substances absorbed from the gastrointestinal tract, is delivered to the hepatic

Figure 16.16 Hepatic portal circulation.

The hepatic portal circulation delivers venous blood from the gastrointestinal organs and spleen to the liver.



(a) Anterior view of veins draining into the hepatic portal vein



(b) Scheme of principal blood vessels of hepatic portal circulation and arterial supply and venous drainage of liver

Which veins carry blood away from the liver?

portal vein and enters the liver. The liver processes these substances before they pass into the general circulation. At the same time, the liver receives oxygenated blood from the systemic circulation via the hepatic artery. The oxygenated blood mixes with the deoxygenated blood in sinusoids. Ultimately, all blood leaves the sinusoids of the liver through the hepatic veins, which drain into the inferior vena cava.

Fetal Circulation

The circulatory system of a fetus, called ***fetal circulation***, exists only in the fetus and contains special structures that allow the developing fetus to exchange materials with its mother (Figure 16.17). It differs from the postnatal (after birth) circulation because the lungs, kidneys, and gastrointestinal organs do not begin to function until birth. The fetus obtains O_2 and nutrients from and eliminates CO_2 and other wastes into the maternal blood.

The exchange of materials between fetal and maternal circulations occurs through the ***placenta*** (pla-SEN-ta), which forms inside the mother's uterus and attaches to the umbilicus (navel) of the fetus by the ***umbilical cord*** (um-BIL-i-kal). Blood passes from the fetus to the placenta via two ***umbilical arteries*** (Figure 16.17a). These branches of the internal iliac arteries are within the umbilical cord. At the placenta, fetal blood picks up O_2 and nutrients and eliminates CO_2 and wastes. The oxygenated blood returns from the placenta via a single ***umbilical vein***. This vein ascends to the liver of the fetus, where it divides into two branches. Some blood flows through the branch that joins the hepatic portal vein and enters the liver, but most of the blood flows into the second branch, the ***ductus venosus*** (DUK-tus ve-NŌ-sus), which drains into the inferior vena cava.

Deoxygenated blood returning from lower body regions of the fetus mingles with oxygenated blood from the ductus venosus in the inferior vena cava. This mixed blood then enters the right atrium. Deoxygenated blood returning from upper body regions of the fetus enters the superior vena cava and passes into the right atrium.

Most of the fetal blood does not pass from the right ventricle to the lungs, as it does in postnatal circulation, because an opening called the ***foramen ovale*** (fō-RĀ-men ō-VAL-ē) exists in the septum between the right and left atria. About one-third of the blood that enters the right atrium passes through the foramen ovale into the left atrium and joins the systemic circulation. The blood that does pass into the right ventricle is pumped into the pulmonary trunk, but little of this blood reaches the nonfunctioning fetal lungs. Instead, most is sent through the ***ductus arteriosus*** (ar-tē-rē-Ō-sus), a vessel that connects the pulmonary trunk with the aorta, so that most blood bypasses the fetal lungs. The blood in the aorta is carried to all fetal tissues through the systemic circulation. When the common iliac arteries branch into the external and internal iliacs, part of the blood flows into the internal iliacs, into the umbilical arteries, and back to the placenta for another exchange of materials.

After birth, when pulmonary (lung), renal, and digestive functions begin, the following vascular changes occur (Figure 16.17b):

1. When the umbilical cord is tied off, blood no longer flows through the umbilical arteries, they fill with connective tissue, and the distal portions of the umbilical arteries become fibrous cords called ***medial umbilical ligaments***.
2. The umbilical vein collapses but remains as the ***ligamentum teres (round ligament)***, a structure that attaches the umbilicus to the liver.
3. The ductus venosus collapses but remains as the ***ligamentum venosum***, a fibrous cord on the inferior surface of the liver.
4. The placenta is expelled as the "***afterbirth***."
5. The foramen ovale normally closes shortly after birth to become the ***fossa ovalis***, a depression in the interatrial septum. When an infant takes its first breath, the lungs expand and blood flow to the lungs increases. Blood returning from the lungs to the heart increases pressure in the left atrium. This closes the foramen ovale by pushing the valve that guards it against the interatrial septum. Permanent closure occurs in about a year.
6. The ductus arteriosus closes by vasoconstriction almost immediately after birth and becomes the ***ligamentum arteriosum***.

■ **CHECKPOINT**

10. What are the main functions of the systemic, pulmonary, hepatic portal, and fetal circulations?

AGING AND THE CARDIOVASCULAR SYSTEM

OBJECTIVE • **Describe the effects of aging on the cardiovascular system.**

General changes in the cardiovascular system associated with aging include increased stiffness of the aorta, reduction in cardiac muscle fiber size, progressive loss of cardiac muscular strength, reduced cardiac output, a decline in maximum heart rate, and an increase in systolic blood pressure. Coronary artery disease (CAD) is the major cause of heart disease and death in older Americans. Congestive heart failure (CHF), a set of symptoms associated with impaired pumping of the heart, is also prevalent in older individuals. Changes in blood vessels that serve brain tissue—for example, atherosclerosis—reduce nourishment to the brain and result in the malfunction or death of brain cells. By age 80, blood flow to the brain is 20% less, and blood flow to the kidneys is 50% less, than it was in the same person at age 30.

■ **CHECKPOINT**

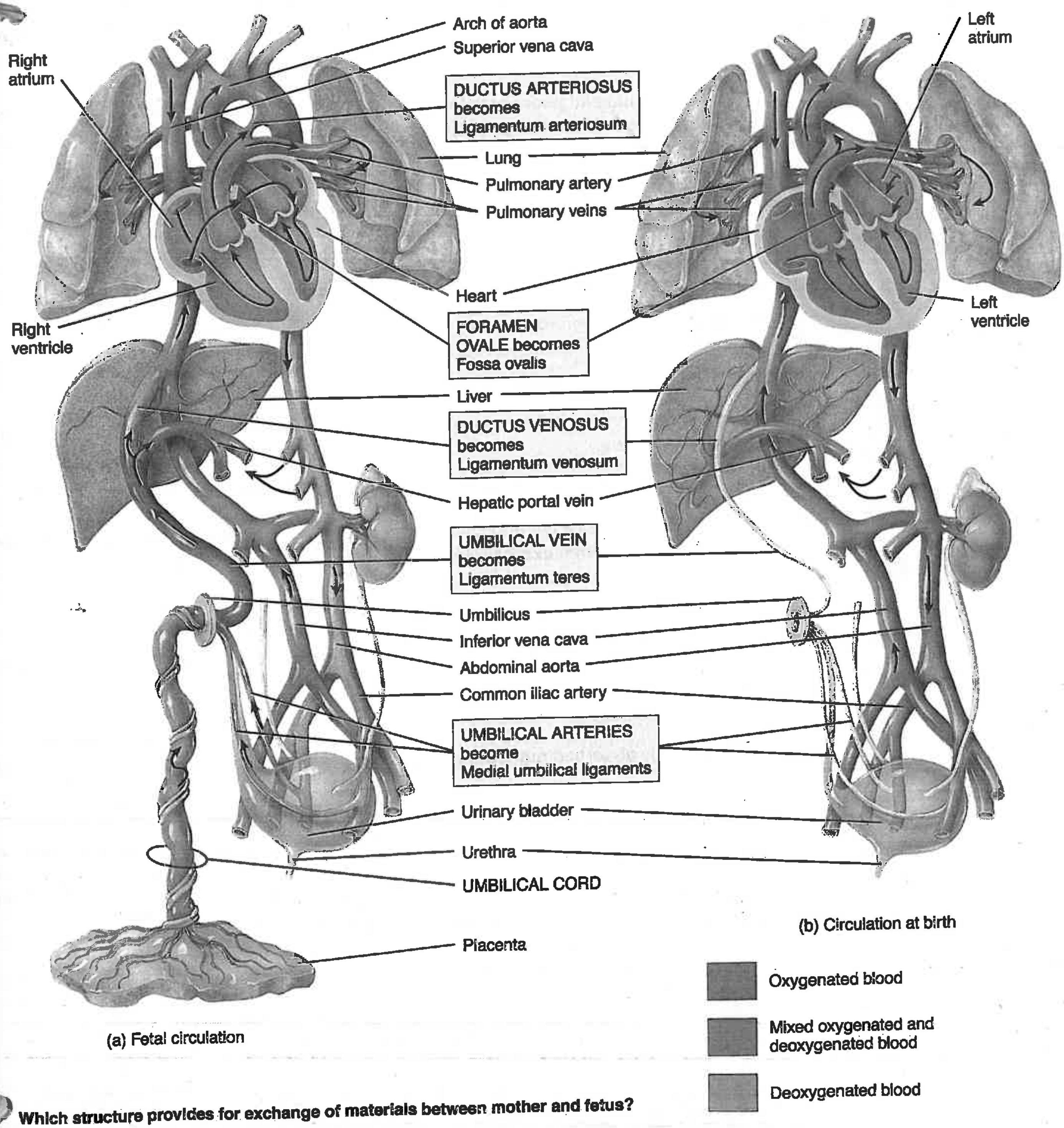
11. What are some of the signs that the cardiovascular system is aging?

• • •

To appreciate the many ways the cardiovascular system contributes to homeostasis of other body systems, examine Focus on Homeostasis: The Cardiovascular System on page 414. Next, in Chapter 17, we will examine the structure and function of the lymphatic system, seeing how it returns excess fluid filtered from capillaries to the cardiovascular system. We will also take a more detailed look at how some white blood cells function as defenders of the body by carrying out immune responses.

Figure 16.17 Fetal circulation and changes at birth. The boxes between parts (a) and (b) describe the fate of certain fetal structures once postnatal circulation is established.

The lungs and gastrointestinal organs do not begin to function until birth.

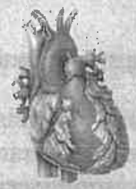


(a) Fetal circulation

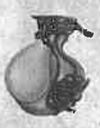
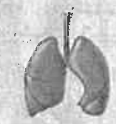
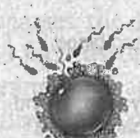
(b) Circulation at birth

Which structure provides for exchange of materials between mother and fetus?

FOCUS ON HOMEOSTASIS



THE CARDIOVASCULAR SYSTEM

BODY SYSTEM		CONTRIBUTION OF THE CARDIOVASCULAR SYSTEM
For all body systems		The heart pumps blood through blood vessels to body tissues, delivering oxygen and nutrients and removing wastes by means of capillary exchange. Circulating blood keeps body tissues at a proper temperature.
Integumentary system		Blood delivers clotting factors and white blood cells that aid in hemostasis when skin is damaged and contribute to repair of injured skin. Changes in skin blood flow contribute to body temperature regulation by adjusting the amount of heat loss via the skin. Blood flowing in skin may give skin a pink hue.
Skeletal system		Blood delivers calcium and phosphate ions that are needed for building bone extracellular matrix, hormones that govern building and breakdown of bone extracellular matrix, and erythropoietin that stimulates production of red blood cells by red bone marrow.
Muscular system		Blood circulating through exercising muscles remove heat and lactic acid.
Nervous system		Endothelial cells lining choroid plexuses in brain ventricles help produce cerebrospinal fluid (CSF) and contribute to the blood–brain barrier.
Endocrine system		Circulating blood delivers most hormones to their target tissues. Atrial cells of the heart secrete atrial natriuretic peptide.
Lymphatic system and immunity		Circulating blood distributes lymphocytes, antibodies, and macrophages that carry out immune functions. Lymph forms from excess interstitial fluid, which filters from blood plasma due to blood pressure generated by the heart.
Respiratory system		Circulating blood transports oxygen from the lungs to body tissues and carbon dioxide to the lungs for exhalation.
Digestive system		Blood carries newly absorbed nutrients and water to the liver. Blood distributes hormones that aid digestion.
Urinary system		The heart and blood vessels deliver 20% of the resting cardiac output to the kidneys, where blood is filtered, needed substances are reabsorbed, and unneeded substances are eliminated as part of urine, which is excreted.
Reproductive systems		Vasodilation of arterioles in the penis and clitoris causes erection during sexual intercourse. Blood distributes hormones that regulate reproductive functions.

COMMON DISORDERS

Hypertension

About 50 million Americans have ***hypertension***, or persistently high blood pressure. It is the most common disorder affecting the heart and blood vessels and is the major cause of heart failure, kidney disease, and stroke. In May 2003, the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure published new guidelines for hypertension because clinical studies have linked what were once considered fairly low pressure readings to an increased risk of cardiovascular disease. The new guidelines are as follows:

Category	Systolic (mm Hg)	Diastolic (mm Hg)
Normal	Less than 120 *and*	Less than 80
Prehypertension	120–139 *or*	80–89
Stage 1 hypertension	140–159 *or*	90–99
Stage 2 hypertension	Greater than 160 *or*	Greater than 100

Using the new guidelines, the normal classification was previously considered optimal; prehypertension now includes many more individuals previously classified as normal or high-normal; stage 1 hypertension is the same as in previous guidelines; and stage 2 hypertension now combines the previous stage 2 and stage 3 categories since treatment options are the same for the former stages 2 and 3.

Although several categories of drugs can reduce elevated blood pressure, the following lifestyle changes are also effective in managing hypertension:

- *Lose weight*. This is the best treatment for high blood pressure short of using drugs. Loss of even a few pounds helps reduce blood pressure in overweight hypertensive individuals.
- *Limit alcohol intake*. Drinking in moderation may lower the risk of coronary heart disease, mainly among males over 45 and females over 55. Moderation is defined as no more than one 12-oz beer per day for females and no more than two 12-oz beers per day for males.
- *Exercise*. Becoming more physically fit by engaging in moderate activity (such as brisk walking) several times a week for 30 to 45 minutes can lower systolic blood pressure by about 10 mm Hg.
- *Reduce intake of sodium (salt)*. Roughly half the people with hypertension are "salt sensitive." For them, a high-salt diet appears to promote hypertension, and a low-salt diet can lower their blood pressure.
- *Maintain recommended dietary intake of potassium, calcium, and magnesium*. Higher levels of potassium, calcium, and magnesium in the diet are associated with a lower risk of hypertension.
- *Don't smoke*. Smoking has devastating effects on the heart and can augment the damaging effects of high blood pressure by promoting vasoconstriction.
- *Manage stress*. Various meditation and biofeedback techniques help some people reduce high blood pressure. These methods may work by decreasing the daily release of epinephrine and norepinephrine by the adrenal medulla.

Shock

Shock is a failure of the cardiovascular system to deliver enough O_2 and nutrients to meet cellular metabolic needs. The causes of shock are many and varied, but all are characterized by inadequate blood flow to body tissues. Common causes of shock include loss of body fluids, as occurs in hemorrhage, dehydration, burns, excessive vomiting, diarrhea, or sweating. If shock persists, cells and organs become damaged, and cells may die unless proper treatment begins quickly.

Although the symptoms of shock vary with the severity of the condition, the following are commonly observed: systolic blood pressure lower than 90 mm Hg; rapid resting heart rate due to sympathetic stimulation and increased blood levels of epinephrine and norepinephrine; weak, rapid pulse due to reduced cardiac output and fast heart rate; cool, pale skin due to vasoconstriction of skin blood vessels; sweating due to sympathetic stimulation; reduced urine formation and output due to increased levels of aldosterone and antidiuretic hormone (ADH); altered mental state due to reduced oxygen supply to the brain; thirst due to loss of extracellular fluid; and nausea due to impaired circulation to digestive organs.

Aneurysm

An ***aneurysm*** (AN-ū-rizm) is a thin, weakened section of the wall of an artery or a vein that bulges outward, forming a balloonlike sac. Common causes are atherosclerosis, syphilis, congenital blood vessel defects, and trauma. If untreated, the aneurysm enlarges and the blood vessel wall becomes so thin that it bursts. The result is massive hemorrhage along with shock, severe pain, stroke, or death.

MEDICAL TERMINOLOGY AND CONDITIONS

Angiogenesis (an′-jē-ō-JEN-e-sis) Formation of new blood vessels.

Aortography (a′-or-TOG-ra-fē) X-ray examination of the aorta and its main branches after injection of a dye.

Circulation time The time required for a drop of blood to pass from the right atrium, through the pulmonary circulation, back to the left atrium, through the systemic circulation, down to the foot, and back again to the right atrium; normally about 1 minute in a resting person.

Claudication (klaw′-di-KĀ-shun) Pain and lameness or limping caused by defective circulation of the blood in the vessels of the limbs.

Deep vein thrombosis (DVT) The presence of a thrombus (blood clot) in a deep vein of the lower limbs.

Hypotension (hī-pō-TEN-shun) Low blood pressure; most commonly used to describe an acute drop in blood pressure, as occurs during excessive blood loss.

Occlusion (ō-KLOO-zhun) The closure or obstruction of the lumen of a structure such as a blood vessel. An example is an atherosclerotic plaque in an artery.

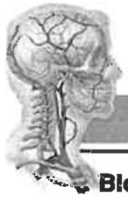
Orthostatic hypotension (or′-thō-STAT-ik; *ortho-* = straight; *-static* = causing to stand) An excessive lowering of systemic blood pressure when a person stands up; usually a sign of disease. May be caused by excessive fluid loss, certain drugs, and cardiovascular or neurogenic factors. Also called ***postural hypotension.***

Phlebitis (fle-BĪ-tis; *phleb-* = vein) Inflammation of a vein, often in a leg. The condition is often accompanied by pain and redness of the skin over the inflamed vein. It is frequently caused by trauma or bacterial infection.

Syncope (SIN-kō-pē) A temporary cessation of consciousness; a faint. One cause is insufficient blood supply to the brain.

Thrombophlebitis (throm′-bō-fle-BĪ-tis) Inflammation of a vein involving clot formation. Superficial thrombophlebitis occurs in veins under the skin, especially in the calf.

White coat (office) hypertension A stress-induced syndrome found in patients who have elevated blood pressure when being examined by health-care personnel, but otherwise have normal blood pressure.



STUDY OUTLINE

Blood Vessel Structure and Function (p. 386)

1. Arteries carry blood away from the heart. Their walls consist of three layers.
2. The structure of the middle layer gives arteries their two major properties, elasticity and contractility.
3. Arterioles are small arteries that deliver blood to capillaries.
4. Through constriction and dilation, arterioles play a key role in regulating blood flow from arteries into capillaries.
5. Capillaries are microscopic blood vessels through which materials are exchanged between blood and interstitial fluid.
6. Precapillary sphincters regulate blood flow through capillaries.
7. Capillary blood pressure "pushes" fluid out of capillaries into interstitial fluid (filtration).
8. Blood colloid osmotic pressure "pulls" fluid into capillaries from interstitial fluid (reabsorption).
9. Autoregulation refers to local adjustments of blood flow in response to physical and chemical changes in a tissue.
10. Venules are small vessels that emerge from capillaries and merge to form veins. They drain blood from capillaries into veins.
11. Veins consist of the same three layers as arteries but have less elastic tissue and smooth muscle. They contain valves that prevent backflow of blood.
12. Weak venous valves can lead to varicose veins.
13. Venous return, the volume of blood flowing back to the heart through systemic veins, occurs due to the pumping action of the heart, aided by skeletal muscle contractions (the skeletal muscle pump), and breathing (the respiratory pump).

Blood Flow Through Blood Vessels (p. 390)

1. Blood flow is determined by blood pressure and vascular resistance.
2. Blood flows from regions of higher pressure to regions of lower pressure.
3. Blood pressure is highest in the aorta and large systemic arteries; it drops progressively as distance from the left ventricle increases. Blood pressure in the right atrium is close to 0 mm Hg.
4. An increase in blood volume increases blood pressure, and a decrease in blood volume decreases it.
5. Vascular resistance is the opposition to blood flow mainly as a result of friction between blood and the walls of blood vessels.
6. Vascular resistance depends on size of the blood vessel lumen, blood viscosity, and total blood vessel length.
7. Blood pressure and blood flow are regulated by neural and hormonal negative feedback systems and by autoregulation.
8. The cardiovascular center in the medulla oblongata helps regulate heart rate, stroke volume, and size of blood vessel lumen.
9. Vasomotor nerves (sympathetic) control vasoconstriction and vasodilation.
10. Baroreceptors (pressure-sensitive receptors) send impulses to the cardiovascular center to regulate blood pressure.
11. Chemoreceptors (receptors sensitive to concentrations of oxygen, carbon dioxide, and hydrogen ions) also send impulses to the cardiovascular center to regulate blood pressure.
12. Hormones such as angiotensin II, aldosterone, epinephrine, norepinephrine, and antidiuretic hormone raise blood pressure; atrial natriuretic peptide lowers it.

Checking Circulation (p. 394)

1. Pulse is the alternate expansion and elastic recoil of an artery with each heartbeat. It may be felt in any artery that lies near the surface or over a hard tissue.
2. A normal pulse rate is about 70–80 beats per minute.
3. Blood pressure is the pressure exerted by blood on the wall of an artery when the left ventricle undergoes systole and then diastole. It is measured by a sphygmomanometer.
4. Systolic blood pressure (SBP) is the force of blood recorded during ventricular contraction. Diastolic blood pressure (DBP) is the force of blood recorded during ventricular relaxation. The normal blood pressure of a young adult male is less than 120/80 mm Hg.

Circulatory Routes (p. 394)

1. The two major circulatory routes are the systemic circulation and the pulmonary circulation.
2. The systemic circulation takes oxygenated blood from the left ventricle through the aorta to all parts of the body and returns deoxygenated blood to the right atrium.
3. The parts of the aorta include the ascending aorta, the arch of the aorta, the thoracic aorta, and the abdominal aorta. Each part gives off arteries that branch to supply the whole body.
4. Deoxygenated blood is returned to the heart through the systemic veins. All the veins of systemic circulation flow into either the superior or inferior vena cava or the coronary sinus, which empty into the right atrium.
5. The pulmonary circulation takes deoxygenated blood from the right ventricle to the air sacs of the lungs and returns oxygenated blood from the air sacs to the left atrium. It allows blood to be oxygenated for systemic circulation.
6. The hepatic portal circulation collects deoxygenated blood from the veins of the gastrointestinal tract and spleen and directs it into the hepatic portal vein of the liver. This routing allows the liver to extract and modify nutrients and detoxify harmful substances in the blood. The liver also receives oxygenated blood from the hepatic artery.
7. Fetal circulation exists only in the fetus. It involves the exchange of materials between fetus and mother via the placenta. The fetus derives O_2 and nutrients from and eliminates CO_2 and wastes into maternal blood. At birth, when pulmonary (lung), digestive, and liver functions begin, the special structures of fetal circulation are no longer needed.

Aging and the Cardiovascular System (p. 412)

1. General changes associated with aging include reduced elasticity of blood vessels, reduction in cardiac muscle size, reduced cardiac output, and increased systolic blood pressure.
2. The incidence of coronary artery disease (CAD), congestive heart failure (CHF), and atherosclerosis increases with age.

SELF-QUIZ

1. Sensory receptors that monitor changes in the blood pressure to the brain are
   - a. chemoreceptors in the aorta
   - b. baroreceptors in the carotid arteries
   - c. the aortic bodies
   - d. precapillary sphincters in the arterioles
   - e. proprioceptors in the muscles
2. The blood vessels that allow the exchange of nutrients, wastes, oxygen, and carbon dioxide between the blood and tissues are the
   - a. capillaries b. arteries c. venules d. arterioles e. veins
3. Substances undergo capillary exchange by means of
   - a. simple diffusion and bulk flow
   - b. endocytosis, exocytosis, and active transport
   - c. simple diffusion and facilitated diffusion
   - d. simple diffusion and active transport
   - e. filtration, reabsorption, and secretion
4. Blood flows through the blood vessels because of the
   - a. establishment of a concentration gradient
   - b. elastic recoil of the veins
   - c. establishment of a pressure gradient
   - d. viscosity (stickiness) of the blood
   - e. thinness of the walls of capillaries
5. Which of the following represents pulmonary circulation as the blood flows from the right ventricle?
   - a. pulmonary trunk → pulmonary veins → pulmonary capillaries → pulmonary arteries
   - b. pulmonary arteries → pulmonary capillaries → pulmonary trunk → pulmonary veins
   - c. pulmonary capillaries → pulmonary trunk → pulmonary arteries → pulmonary veins
   - d. pulmonary trunk → pulmonary arteries → pulmonary capillaries → pulmonary veins
   - e. pulmonary veins → pulmonary capillaries → pulmonary arteries → pulmonary trunk
6. The tissue that allows arteries to stretch is
   - a. endothelium b. collagen c. basement membrane d. cardiac muscle e. elastic lamina
7. Match the following descriptions to the appropriate blood vessel:

____ a. composed of a single layer of endothelial cells and a basement membrane	A. arteries
____ b. formed by reuniting capillaries	B. arterioles
____ c. carry blood away from heart	C. veins
____ d. regulate blood flow to capillaries	D. venules
____ e. may contain valves	E. capillaries

8. Filtration of substances out of capillaries occurs when the capillary blood pressure
   - a. is less than the blood colloid osmotic pressure
   - b. and the blood colloid osmotic pressure are equal
   - c. is high and the blood colloid osmotic pressure is high
   - d. is higher than the blood colloid osmotic pressure
   - e. is low and the blood colloid osmotic pressure is low
9. Weakened leg muscles would slow the
   - a. blood flow out of the heart
   - b. respiratory pump
   - c. venous return
   - d. ability of arteries to vasodilate
   - e. pulse

10. Which of the following statements about blood vessels is true?
   a. Capillaries contain valves.
   b. Walls of arteries are generally thicker and contain more elastic tissue than walls of veins.
   c. Veins carry blood away from the heart.
   d. Blood flows most rapidly through veins.
   e. Blood pressure in arteries is always lower than in veins.

11. Why is it important that blood flows slowly through the capillaries?
   a. It allows time for the materials in the blood to pass through the thick capillary walls.
   b. It prevents damage to the capillaries.
   c. It permits the efficient exchange of nutrients and wastes between the blood and body cells.
   d. It allows the heart time to rest.
   e. It allows the blood pressure in capillaries to rise above the blood pressure in the veins.

12. Match the following:

____ a. source of all systemic arteries	A. hepatic portal vein
____ b. supplies a lower limb	B. pulmonary trunk
____ c. heart's blood system	C. pulmonary vein
____ d. returns blood to heart from lower limbs	D. common iliac artery
____ e. carries blood to liver	E. coronary circulation
____ f. leads to lungs	F. inferior vena cava
____ g. returns blood from lungs to heart	G. superior vena cava
____ h. supplies blood to brain	H. aorta
____ i. returns blood to heart from head and upper body	I. cerebral arterial circle

13. For each of the following factors, indicate if it increases (A) or decreases (B) blood pressure:
   ____ a. an increase in cardiac output
   ____ b. hemorrhage
   ____ c. vasodilation
   ____ d. vasoconstriction
   ____ e. stimulation of the heart by the sympathetic nervous system
   ____ f. hypoxia
   ____ g. epinephrine
   ____ h. increase in blood volume
   ____ i. bradycardia

14. Aldosterone affects blood pressure by
   a. increasing heart rate
   b. increasing vasoconstriction of arterioles
   c. reducing blood volume
   d. stimulating release of atrial natriuretic peptide by the heart
   e. increasing reabsorption of sodium ions and water by the kidneys

15. In a blood pressure reading of 110/70,
   a. 110 represents the diastolic pressure
   b. 70 represents the pressure of the blood against the arteries during ventricular relaxation
   c. 110 represents the blood pressure and 70 represents the heart rate
   d. 70 is the reading taken when the first sound is heard
   e. the patient has a severe problem with hypertension

16. Which of the following statements is NOT true?
   a. Regulation of blood vessel diameter originates from the vasomotor region of the cerebral cortex.
   b. The cerebral cortex may provide input to the CV center.
   c. Baroreceptors may stimulate the cardiovascular center.
   d. Activation of proprioceptors increases heart rate at the beginning of exercise.
   e. Vasomotor tone is due to a moderate level of vasoconstriction.

17. Venous return to the heart is enhanced by all of the following EXCEPT
   a. skeletal muscle "milking"
   b. valves in veins
   c. the pressure difference from venules to the right ventricle
   d. vasodilation
   e. inhalation during breathing

CRITICAL THINKING APPLICATIONS

1. The local anesthetic injected by a dentist often contains a small amount of epinephrine. What effect would epinephrine have on the blood vessels in the vicinity of the dental work? Why might this effect be desired?

2. In this chapter, you've read about varicose veins. Why didn't you read about varicose arteries?

3. Julie was all flustered when she ran in late to her anatomy and physiology lab. She had spilled a cup of coffee on herself while she was weaving in and out of traffic while trying to get around a traffic jam. Then she missed her exit while she was changing the station on the radio, couldn't find a place to park, and missed the lab quiz. The lab today is learning to take blood pressures, and Julie's is high! (It's normally 110 over 70.) What is the physiological explanation for Julie's elevated BP?

4. Peter spent 10 minutes sharpening his favorite knife before carving the roast. Unfortunately, he sliced his finger along with the roast. His wife slapped a towel over the spurting cut and drove him to the emergency room. What type of vessel did Peter cut, and how do you know?

ANSWERS TO FIGURE QUESTIONS

16.1 The femoral artery has the thicker wall; the femoral vein has the wider lumen.

16.2 Metabolically active tissues have more capillaries because they use oxygen and produce wastes more rapidly than inactive tissues.

16.3 Excess filtered fluid and proteins that escape from plasma drain into lymphatic capillaries and are returned by the lymphatic system to the cardiovascular system.

16.4 The skeletal muscle pump and the respiratory pump help boost venous return.

16.5 As blood pressure increases, blood flow increases.

16.6 Vasoconstriction increases vascular resistance, which decreases blood flow through the vasoconstricted blood vessels.

16.7 It happens when you stand up because gravity causes pooling of blood in leg veins as you stand upright, decreasing the blood pressure in your upper body.

16.8 The principal circulatory routes are the systemic and the pulmonary circulations.

16.9 The four parts of the aorta are the ascending aorta, arch of the aorta, thoracic aorta, and abdominal aorta.

16.10 Branches of the arch of the aorta are the brachiocephalic trunk, left common carotid artery, and left subclavian artery.

16.11 The abdominal aorta divides into the common iliac arteries at about the level of the fourth lumbar vertebra.

16.12 The superior vena cava drains regions above the diaphragm (except the cardiac veins and the alveoli of the lungs), and the inferior vena cava drains regions below the diaphragm.

16.13 All venous blood in the brain drains into the internal jugular veins.

16.14 The median cubital vein is often used for withdrawing blood.

16.15 Superficial veins of the lower limbs include the dorsal venous arch and the great saphenous and small saphenous veins.

16.16 The hepatic veins carry blood away from the liver.

16.17 The exchange of materials between mother and fetus occurs across the placenta.