

Anatomy of the Blood Vessels

Key Terms

aorta (p. 343)**arteries** (p. 341)**arterioles** (p. 341)**capacitance vessels** (p. 343)**capillaries** (p. 341)**conductance vessels** (p. 342)**exchange vessels** (p. 343)**pulmonary circulation** (p. 340)**resistance vessels** (p. 342)**splanchnic circulation** (p. 350)**systemic circulation** (p. 340)**veins** (p. 341)**venae cavae** (p. 346)**venules** (p. 341)

Objective

1. Describe the pulmonary and systemic circulations.
2. Describe the structure and function of arteries, capillaries, and veins, including:
 - List the three layers of tissue found in arteries and veins.
 - Explain the functions of conductance, resistance, exchange, and capacitance vessels.
3. List the major arteries of the systemic circulation that are branches of the ascending aorta, aortic arch, and descending aorta.
4. List the major veins of the systemic circulation.
5. Describe the following special circulations: blood supply to the head and brain, hepatic circulation, and fetal circulation.
6. Explain pulse and its use as an assessment tool.

The circulatory system consists of the heart and blood vessels. The historical description of the heart and blood vessels is intriguing. The ancients knew that the heart played an important role in pumping blood through the body, but no one described the intricate role of the blood vessels. The ancient Greeks thought that blood moved throughout the body like an ocean tide. Blood was seen as washing out from the heart through a series of blood vessels and then ebbing back to it through those same blood vessels, with impurities removed from the blood as it washed through the lungs. Not until the seventeenth century did the English physician William Harvey, described as a crackpot by his fellow scientists, identify the system of blood vessels and thus provide the first accurate description of the circulation.

CIRCLES, CIRCUITS, AND CIRCULATIONS

The blood vessels are a series of connected hollow tubes that begin and end in the heart. The blood vessels form a path through the body, much like the system of highways and roads that enables us to travel from place to place. Note the path of the delivery truck in Figure 18-1. Leaving the bakery, the truck travels on a

major highway and exits onto a smaller road. The truck then arrives at a grocery store, where it makes a delivery. The empty truck returns to the bakery through a number of connecting roads. Note the circle, or circuit, from bakery to grocery store to bakery.

The heart and blood vessels also form a circuit. The heart pumps blood into the large artery. The blood flows through a series of blood vessels back to the heart. Moving from heart to blood vessels to heart, the blood forms a circuit, or circulation. This arrangement ensures a continuous one-way movement of blood. As Chapter 16 explained, the two main circulations are the pulmonary circulation and the systemic circulation.

The **pulmonary circulation** carries blood from the right ventricle of the heart to the lungs and back to the left atrium of the heart (see Figure 16-3). The pulmonary circulation transports unoxygenated blood to the lungs, where oxygen is loaded and carbon dioxide is unloaded. Oxygenated blood then returns to the left side of the heart to be pumped into the systemic circulation.

The **systemic circulation** is the larger circulation; it provides the blood supply to the rest of the body. The systemic circulation carries oxygen and other nutrients to the cells and picks up carbon dioxide and other waste.

3. According to Figure 17-2, the postganglionic parasympathetic fiber
 - a. secretes NE.
 - b. secretes a transmitter that binds to a β_1 -adrenergic receptor.
 - c. is cholinergic.
 - d. is adrenergic.
4. According to Figure 17-2
 - a. Sympathetic firing affects force of myocardial contraction.
 - b. The AV node can be stimulated only by ACh.
 - c. The SA node contains receptors that respond only to ACh.
 - d. The fibers that are color-coded red are cholinergic.
5. According to Figures 17-3 and 17-4
 - a. An increase in venous return stretches the ventricular myocardium.
 - b. A decrease in venous return increases preload.
 - c. Chronic hypertension is expressed as a decrease in afterload.
 - d. All of the above are true.
6. According to Figure 17-4
 - a. Increased venous return increases preload.
 - b. Increased venous return decreases EDV.
 - c. Increased EDV increases afterload.
 - d. Dilation of the aorta and peripheral blood vessels increases afterload.
7. According to Figures 17-5 and 17-6
 - a. Right ventricular failure causes orthopnea.
 - b. Left ventricular failure causes jugular vein distention and ankle edema.
 - c. Left-sided heart failure causes pulmonary edema.
 - d. Jugular vein distention, liver congestion, and ankle edema cause right-sided failure.

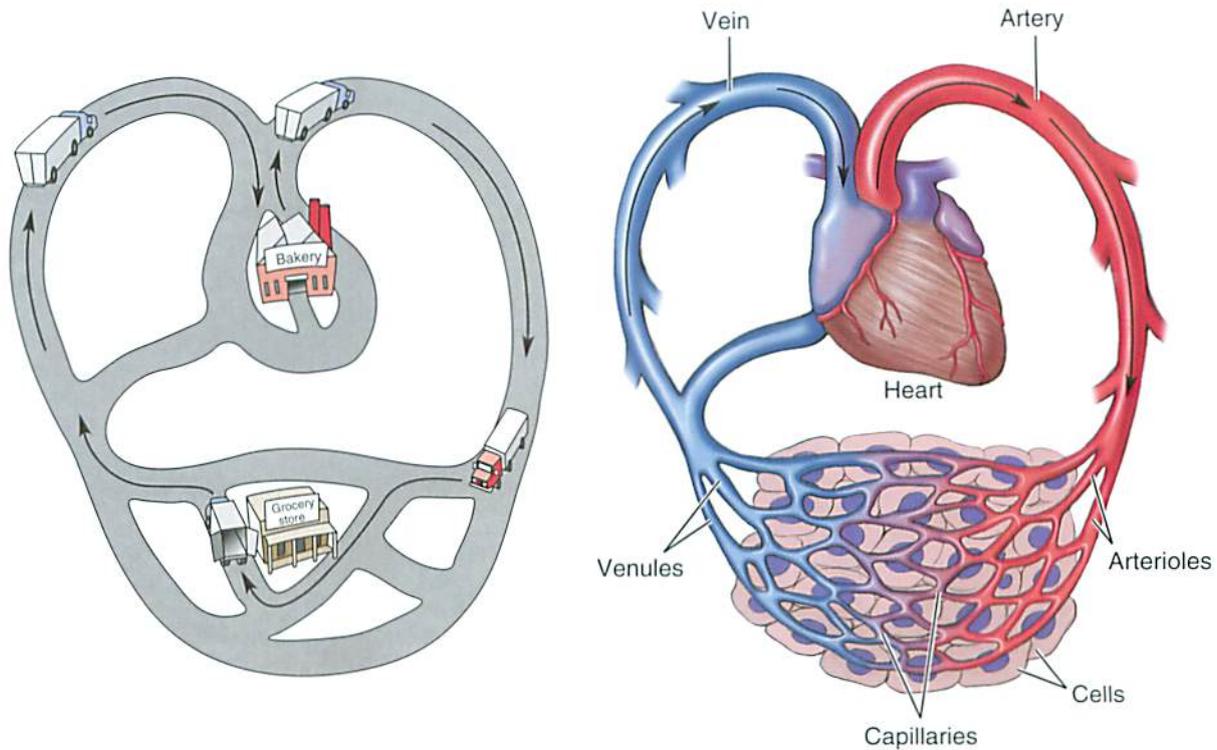


FIGURE 18-1 A circuit or route: the circulatory system.

BLOOD VESSELS

NAMING THE BLOOD VESSELS

Note the different types of blood vessels (Figure 18-2), their relationship to the heart, and the color coding. The blood vessels are the body's highways and byways; they are anatomically classified as arteries, capillaries, and veins (Table 18-1).

ARTERIES

Arteries are blood vessels that carry blood away from the heart. The large arteries repeatedly branch into smaller and smaller arteries as they are distributed throughout the entire body. As they branch, the arteries become much more numerous but smaller in diameter. The smallest arteries are called **arterioles** (ar-TEER-ee-ohls). The arteries are red in Figure 18-2 because they carry oxygenated blood.

CAPILLARIES

Blood flows from the arterioles into the capillaries. The **capillaries** (KAP-i-lair-ees) are the smallest and most numerous of all the blood vessels. They connect the arterioles with the venules. Because the body has so many of them, a capillary is close to every cell in the body. This arrangement provides every cell with a continuous supply of oxygen and other nutrients. The capillaries are colored from red to purple to blue. Why? At the capillary level, the blood gives up its oxygen to the tissues; the unoxygenated blood leaving the tissues is therefore bluish.

VEINS

Blood flows from the capillaries into the veins. **Veins** are blood vessels that carry blood back to the heart. The smallest veins are called **venules** (VEN-yools). The small venules converge to form fewer but larger veins. The largest veins empty the blood into the right atrium of the heart. The veins are colored blue because they transport unoxygenated blood.

BLOOD VESSEL WALLS: THE LAYERED LOOK

With the exception of the capillaries, the blood vessels are composed of three layers (or tunics) of tissue (see Figure 18-2): tunica intima, tunica media, and tunica adventitia.

1. **Tunica intima.** The tunica (TOO-nik-kah) intima is the innermost layer, an endothelium. The endothelial lining forms a slick shiny surface continuous with the endocardium, the inner lining of the heart. Blood flows easily and smoothly along this surface.
2. **Tunica media.** The tunica media is the middle layer. It is the thickest layer and is composed primarily of elastic tissue and smooth muscle; the thickness and composition vary according to the function of the blood vessel. The large arteries, for example, contain considerable elastic tissue so that they can stretch in response to the pumping of blood by the heart. The smallest of the arteries, the arterioles, are composed primarily of smooth muscle. The muscle allows the arterioles to contract and relax, thereby changing the diameter of the arteriole.

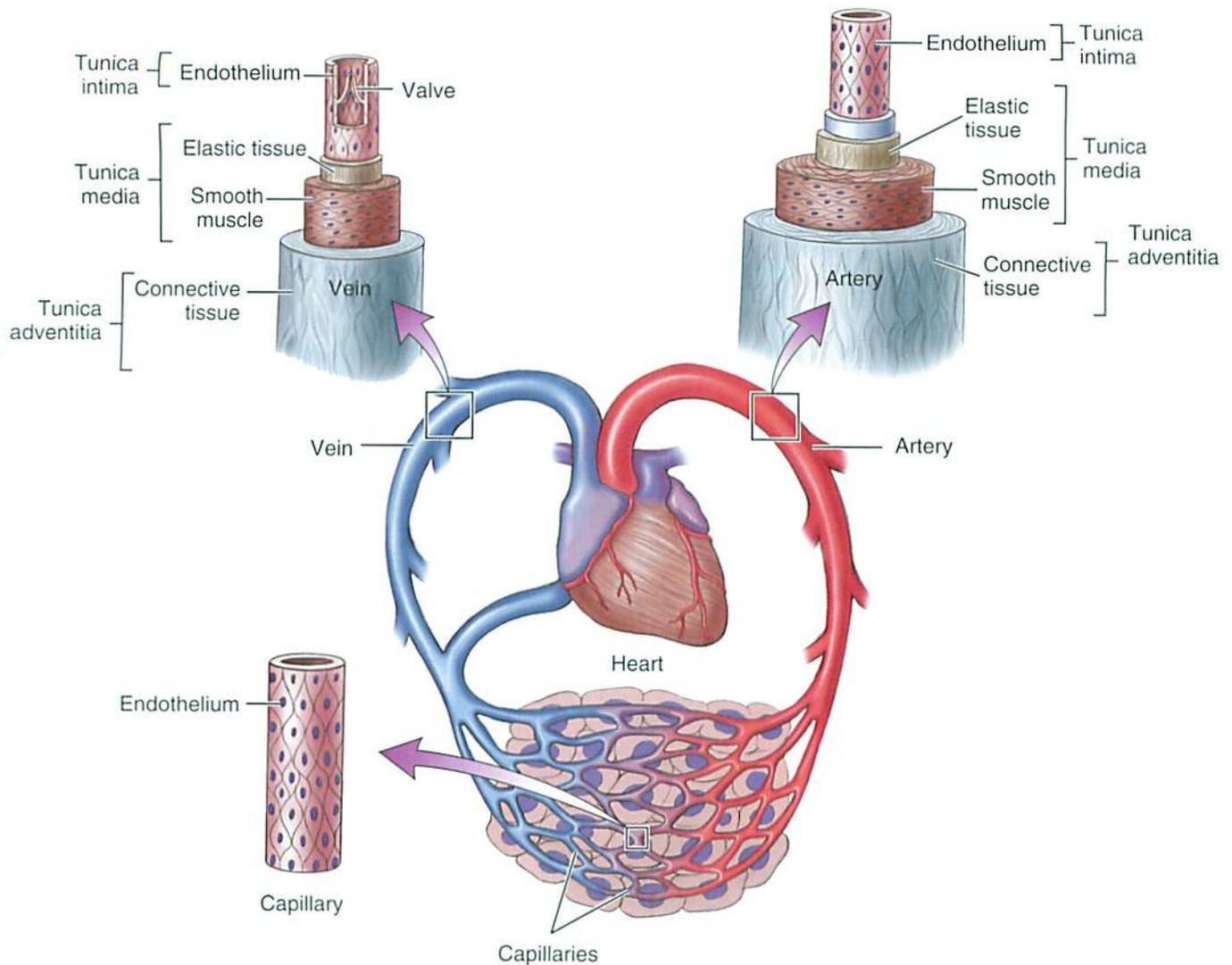


FIGURE 18-2 Blood vessel wall layers: the tunica intima, tunica media, and tunica adventitia.

3. *Tunica adventitia*. The outer layer is called the tunica adventitia (ad-ven-TEESH-ah). Composed of tough connective tissue, its main function is to support and protect blood vessels.

BLOOD VESSELS: WHAT THEY DO

Note how the structure of the blood vessels changes from artery to capillary to vein (see Figure 18-2 and Table 18-1). As always, the structure is related to its function. The following is a functional classification of blood vessels.

ARTERIES

The walls of the large arteries are thick, tough, and elastic because they must withstand the high pressure of the blood pumped from the ventricles. Because the primary function of the large arteries is to conduct blood from the heart to the arterioles, the large arteries are called **conductance vessels**.

ARTERIOLES

The arterioles are the smallest of the arteries. They are composed primarily of smooth muscle and spend most of their time contracting and relaxing. By changing their diameter, the arterioles affect resistance to the flow of blood. A narrow (constricted) vessel offers an increased resistance to blood flow; a wider (dilated) vessel offers less resistance. Because of their effect on resistance, the arterioles are called **resistance vessels**.

CAPILLARIES

The capillaries have the thinnest walls of any of the blood vessels. The capillary wall is made up of a single layer of endothelium lying on a delicate basement membrane. The thin capillary wall enables water and dissolved substances, including oxygen, to diffuse from the blood into the tissue spaces, where they become available for use by the cells. The capillary also allows waste from the metabolizing cell to diffuse from the tissue spaces into the capillaries for transport by

Table 18-1 Structure and Function of Blood Vessels

VESSEL	STRUCTURE	FUNCTION
Artery	Thick wall with three layers: tunica intima (endothelial lining), tunica media (elastic tissue and smooth muscle), and tunica adventitia (connective tissue)	Called <i>conductance vessels</i> because they carry blood from the heart to the arterioles
Arteriole	Small artery but with three layers, mostly smooth muscle	Called <i>resistance vessels</i> because the contraction and relaxation of the muscle changes vessel diameter, which alters resistance to blood flow
Capillary	Layer of endothelium on a basement membrane	Called <i>exchange vessels</i> because nutrients, gases, and wastes exchange between the blood and interstitial fluid
Venule	Thin wall with less smooth muscle and elastic tissue than an artery or arteriole	Venules and veins collect and return blood from the tissues to the heart. They are called <i>capacitance vessels</i> because they hold or store blood.
Vein	Three layers (intima, media, and adventitia), but thinner and less elastic than an artery; contain valves	

the blood to the organs of excretion. The capillaries are called **exchange vessels** because they allow for an exchange of nutrients and waste.

? Re-Think

1. Why are the layers of the arteries thicker than those of the capillaries?
2. Explain the color coding of arteries, capillaries, and veins.

VEINS AND VENULES

As the capillaries begin to converge to form venules, the structure of the wall changes again. The venule wall is slightly thicker than the capillary wall. As the venules converge to form larger veins, the walls become even thicker. The tunica media of the vein, however, is much thinner than the tunica media of the artery. This difference is appropriate, because pressure in the veins is much less than the pressure in the arterial blood vessels.

In addition to thinner walls, the veins differ in another way; most veins contain one-way valves. These valves direct the flow of blood toward the heart. The valves are most numerous in the veins of the lower extremities, where they prevent backflow, helping move blood up and away from the ankles.

In addition to carrying blood back to the heart, the veins play another role. The veins store blood. In fact, about 70% of the total blood volume is found on the venous side of the circulation. Because the veins store blood, they are called **capacitance vessels**. (*Capacitance* refers to storage.) When this stored blood is needed, the veins constrict (venoconstriction) and move blood to the heart for circulation.

? Re-Think

1. Why are the arterioles called *resistance vessels*?
2. Why are the capillaries called *exchange vessels*?
3. Why are the large arteries and veins not suitable for exchange?
4. Why do the veins, but not the arteries, contain valves?

2+2 Sum It Up!

The blood vessels are a series of connected hollow tubes that form a circuit. There are two circulations: the pulmonary circulation and the systemic circulation. The three types of blood vessels are arteries (conductance), capillaries (exchange), and veins (capacitance). The arterioles are tiny arteries called *resistance vessels*.

MAJOR ARTERIES OF THE SYSTEMIC CIRCULATION

The major arteries of the systemic circulation include the aorta and the arteries arising from the aorta.

AORTA

The **aorta** (ay-OR-tah) is the mother of all arteries; its average diameter is that of a garden hose. The aorta originates in the heart's left ventricle (Figure 18-3), extends upward from the left ventricle, curves in an archlike fashion, and then descends through the thorax (chest) and abdomen. The aorta ends in the pelvic cavity, where it splits into two common iliac arteries.

The aorta is divided into segments, each named according to two systems. One system is the path that the aorta follows as it courses through the body. In this

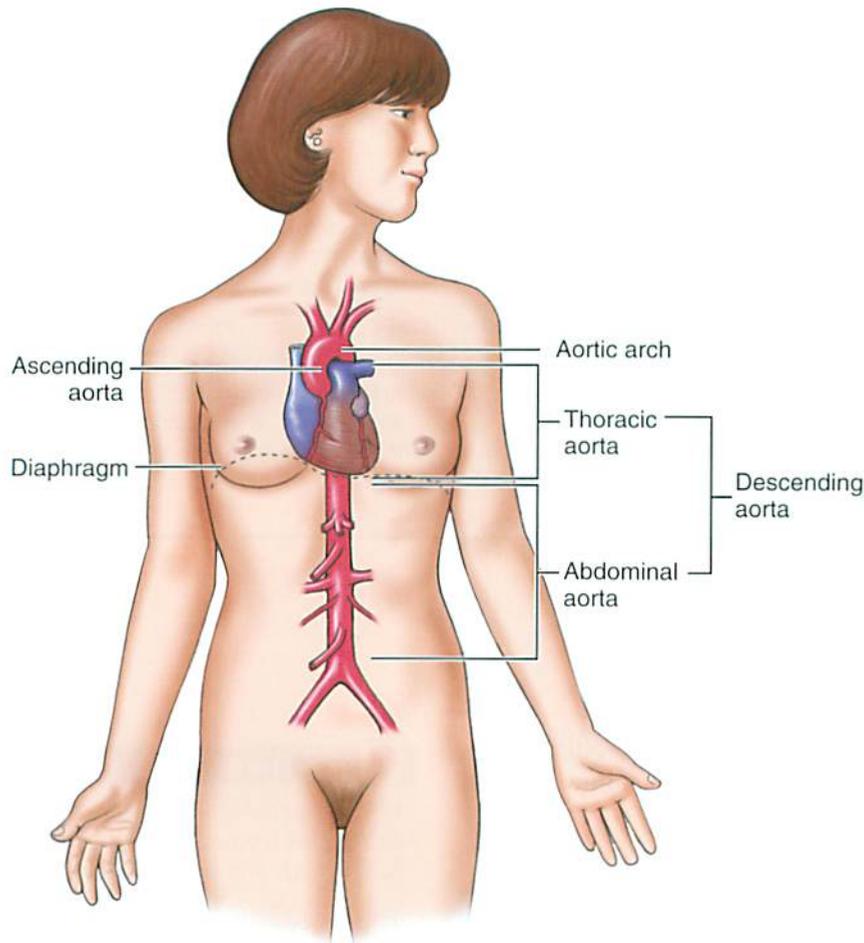


FIGURE 18-3 Naming the parts of the aorta.

system, the aorta is divided into the ascending aorta, the arch of the aorta, and the descending aorta. In the second naming system, the aorta is named according to its location within the body cavities. Thus, we have the thoracic aorta and the abdominal aorta. This text, like most texts, uses both naming systems.

? Re-Think

List five words that describe parts of the aorta.

BRANCHES OF THE AORTA

All systemic arteries are direct or indirect branches of the aorta. In other words, the arteries arise directly from the aorta or they arise from vessels that are themselves branches of the aorta. For example, the coronary arteries arise directly from the ascending aorta. The brachial artery in the right arm, however, arises from the axillary artery. The axillary artery has its origin in the subclavian artery, an extension of the brachiocephalic artery, which arises from the arch of the aorta. The brachial artery therefore arises indirectly from the aorta.

The systemic arteries are described in the order in which they arise from the aorta. Refer to Figure 18-4 as you read the text to identify the arteries and the structures that they supply.

BRANCHES OF THE ASCENDING AORTA

The ascending aorta arises from the left ventricle of the heart. It begins at the aortic semilunar valve and extends to the aortic arch. The right and left coronary arteries branch from the ascending aorta. The coronary arteries are distributed throughout the heart and supply oxygenated blood to the myocardium.

BRANCHES OF THE AORTIC ARCH

The aortic arch extends from the ascending aorta to the beginning of the descending aorta. The following three large arteries arise from the aortic arch:

- The brachiocephalic artery is a large artery on the right side of the body. It supplies blood to the right side of the head and neck, right shoulder, and right upper extremity. Refer to Figure 18-4 for the names of the arteries that extend from, or branch off, the brachiocephalic artery. These arteries supply the right side of the head and neck and the arm and

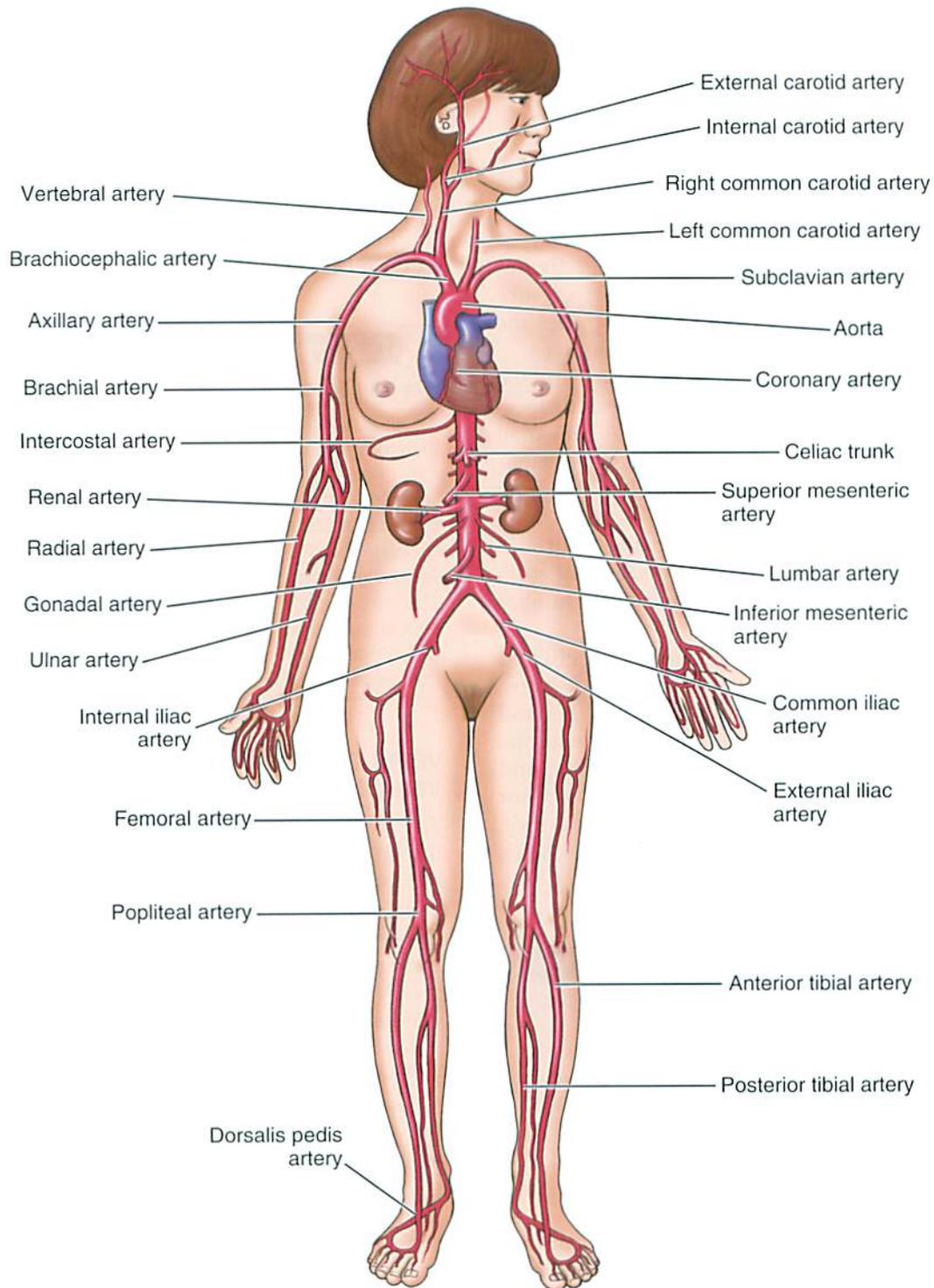


FIGURE 18-4 Major arteries.

hand regions. (There is no left brachiocephalic artery.)

- The left common carotid artery extends upward from the highest part of the aortic arch and supplies the left side of the head and neck. Note that the left common carotid artery arises directly from the aorta, whereas the right common carotid arises from the brachiocephalic artery.

- The left and right subclavian arteries supply blood to the shoulders and upper arms.

BRANCHES OF THE DESCENDING AORTA (THORACIC AORTA)

The thoracic aorta is the upper portion of the descending aorta. It extends from the aortic arch to the diaphragm. Intercostal arteries arise from the aorta and

supply the intercostal muscles between the ribs. Other small arteries supply the organs in the thorax.

BRANCHES OF THE DESCENDING AORTA (ABDOMINAL AORTA)

The abdominal aorta extends from the thoracic aorta to the lower abdomen. Branches of the abdominal aorta include the following:

- The celiac trunk is a short artery that further divides into three smaller arteries: the gastric artery supplies the stomach, the splenic artery supplies the spleen, and the hepatic artery supplies the liver.
- Two mesenteric (MEZ-en-tair-ik) arteries are the superior and inferior segments. The superior mesenteric artery supplies blood to most of the small intestine and part of the large intestine. The other part of the large intestine receives its blood supply from the inferior mesenteric artery.
- Two renal arteries supply blood to the right and left kidneys. Other branches of the abdominal aorta include the gonadal arteries and the lumbar arteries.

The distal abdominal aorta splits into the right and left common iliac arteries that supply the pelvic organs, thigh, and lower extremities. Refer to Figure 18-4 and identify the major arteries of the thigh and leg: external iliac arteries and the femoral, popliteal, anterior, and posterior tibial arteries. The anterior and posterior tibial arteries give rise to arteries that supply the foot. The anterior tibial artery becomes the dorsalis pedis artery in the foot.

Re-Think

1. Identify the origin of the right and left common carotid arteries.
2. List five arteries that emerge *directly* from the aorta.
3. Trace a drop of blood from the left ventricle to the left foot.

MAJOR VEINS OF THE SYSTEMIC CIRCULATION

If you look at the back of your hand, you can see several veins but no arteries. Why? The arteries are usually located in deep and well-protected areas. Many of the veins, however, are located more superficially and can be seen. These are called *superficial veins*. Deep veins are located more deeply and usually run parallel to the arteries. With few exceptions, the names of the deep veins are the same as the names of the companion arteries. For example, the femoral artery is accompanied by the femoral vein. In Figures 18-4 and 18-5, note the similarity in the names of many of the arteries and veins. Good news! If you learn the names of the arteries, you'll also know most of the names of the veins.

VENAE CAVAE

The veins carry blood from all parts of the body to the venae cavae for delivery to the heart. The **venae cavae** are the main veins. They are divided into the superior vena cava (SVC) and the inferior vena cava (IVC). Veins draining blood from the head, shoulders, and upper extremities empty into the SVC. Veins draining the lower part of the body empty into the IVC. The SVC and IVC empty into the right atrium.



Do You Know...

Why Your Veins May Hum?

About 20% of the cardiac output flows to the brain and must therefore be returned to the right side of the heart. The large flow of blood through the jugular veins causes the walls of the veins to vibrate; the vibration can be heard as a venous hum in the upper chest near the clavicle (collarbone). The condition is benign but may be confused with a heart murmur. How do we differentiate between a heart murmur and venous hum? The venous hum disappears when the patient is placed in a supine position or if the clinician presses on the jugular vein. A true heart murmur is not affected by a change of position or compression of the jugular vein.

VEINS THAT EMPTY INTO THE SUPERIOR VENA CAVA

The SVC receives blood from the head, shoulder, and upper extremities. Veins may drain directly or indirectly into the SVC. For example, the brachiocephalic veins empty directly into the SVC. The axillary vein, however, drains into the subclavian vein, which drains into the brachiocephalic vein, which in turn drains into the SVC. Refer to Figure 18-5 to help trace the flow of venous blood from a distal site to the vena cava, as follows:

- The cephalic vein is a superficial vein that drains the lateral arm region and carries blood to the axillary vein toward the SVC.
- The basilic vein is a superficial vein that drains the medial arm region. The cephalic and basilic veins are joined by the median cubital vein (anterior aspect of the elbow). Blood samples are often drawn from the median cubital vein.
- The subclavian veins receive blood from the axillary veins and from the jugular veins. Blood is carried by these veins to the brachiocephalic veins, which empty into the superior vena cava.
- The jugular veins drain blood from the head and drain into the subclavian veins. The external jugular veins drain blood from the face, scalp, and neck. The internal jugular veins drain blood from the brain. The internal jugular vein, in fact, is the main vein that drains the brain. Because the jugular veins are so close to the heart (right atrium), the pressure in the jugular veins reflects the pressure of blood in the

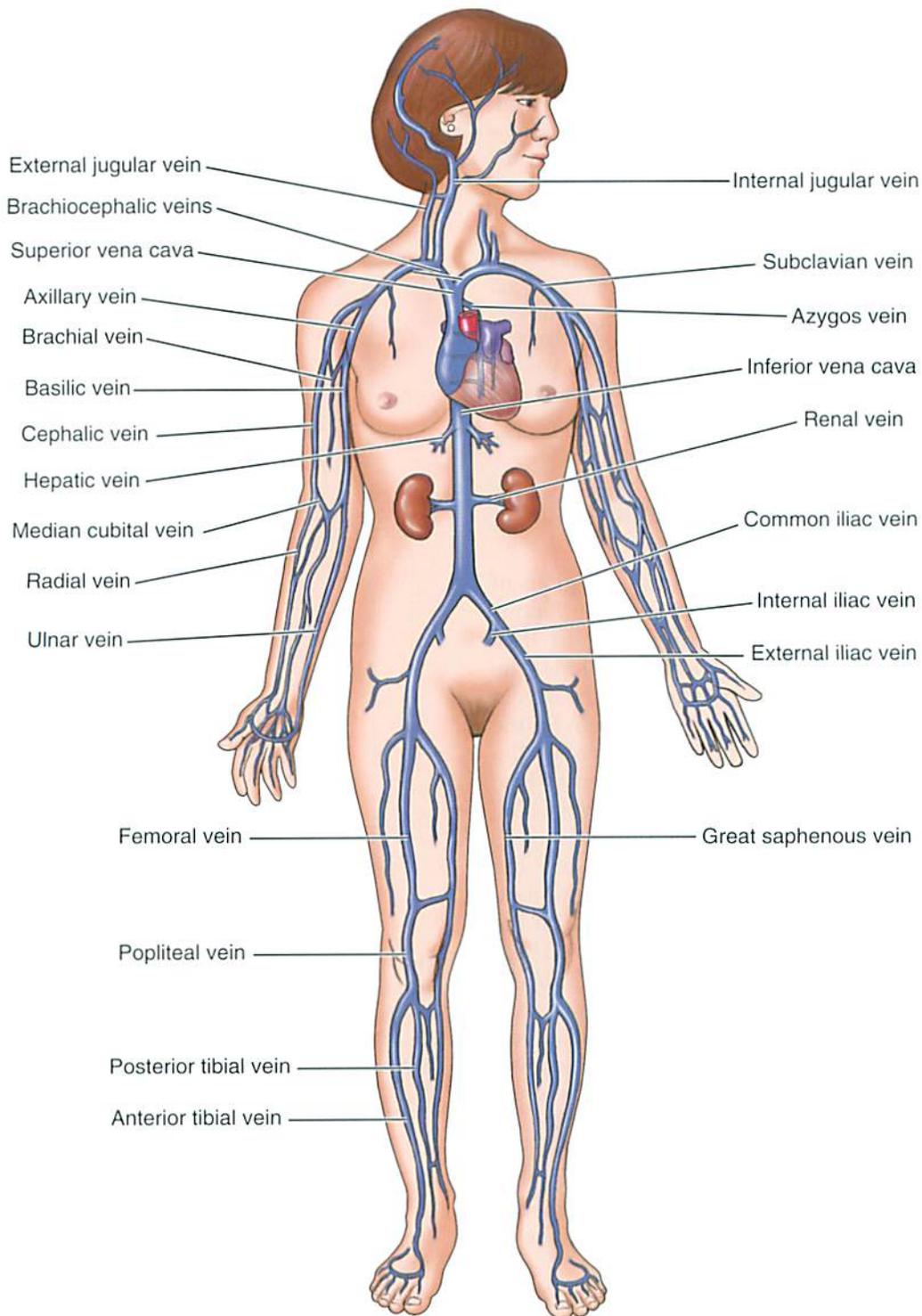


FIGURE 18-5 Major veins.

right side of the heart. A person in right-sided heart failure has a higher-than-normal pressure in the right heart. This is observed clinically as pulsating jugular veins and is referred to as *jugular vein distention* (JVD). As a clinician, you will be observing, measuring, and recording JVD.

- The brachiocephalic veins are large veins formed by the union of the subclavian and internal jugular veins. The right and left brachiocephalic veins drain into the SVC.
- The azygos vein is a single vein that drains the thorax and empties directly into the SVC.

Do You Know...

What the Subclavian Steal?

"Thou shalt not steal." Good advice! It even applies to blood, with a condition called *subclavian steal syndrome*. This is how the heist goes down. A person develops an occlusion in the subclavian artery proximal to the origin of the vertebral artery. (Remember, the vertebral artery supplies blood to the posterior brain and the subclavian artery supplies blood to the shoulder and arm.) When the affected arm is exercised, the subclavian artery is unable to supply enough blood. Blood pressure in the exercising shoulder and arm decreases, causing a retrograde (backward) flow of blood from the vertebral artery to the subclavian artery. The subclavian artery robs the posterior brain of blood, causing neurological symptoms such as impaired vision, dizziness, and syncope (fainting).

VEINS THAT EMPTY INTO THE INFERIOR VENA CAVA

The IVC returns blood to the heart from all regions of the body below the diaphragm. Follow the venous drainage from the leg to the right atrium in Figure 18-5.

- The tibial veins drain the calf and foot regions. The posterior tibial vein drains into the popliteal vein (behind the knee) and then the femoral vein (in the thigh). The femoral vein enters the pelvis as the external iliac vein; it joins with the internal iliac vein and continues as the common iliac vein. The common iliac vein continues as the IVC.
- The great saphenous (SAF-en-us) veins are the longest veins in the body. They begin in the foot, ascend along the medial side, and merge with the femoral vein to become the external iliac vein. These veins receive drainage from the superficial veins of the leg and thigh region. The great saphenous veins also connect with the deep veins of the leg and thigh. Thus, blood can return from the lower extremities to the heart by several routes. The great saphenous veins are sometimes "borrowed" by cardiac surgeons. Portions of a vein are surgically removed and transplanted into the heart to bypass clogged coronary arteries.
- The renal veins drain the right and left kidneys, emptying blood directly into the IVC.
- The hepatic veins drain the liver, emptying blood directly into the upper IVC. Because the hepatic veins are so close to the heart, congestion of the right heart often causes congestion in the hepatic veins and liver.

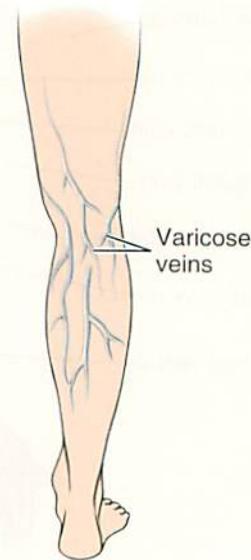
? Re-Think

1. Why aren't all veins colored blue?
2. List five veins that empty directly into the venae cavae.
3. Trace a drop of blood from the left hand to the right atrium.

Do You Know...

What Varicose Veins Look Like?

Varicose veins are distended and twisted veins, usually involving the superficial veins in the legs. Varicosities can develop in other veins. Hemorrhoids, for example, are varicose veins that affect the veins in the anal region. Persons who are alcoholic often develop varicose veins at the base of the esophagus—esophageal varices. These varices are apt to rupture, causing a massive life-threatening hemorrhage.



2+2 Sum It Up!

The arrangement and names of the major arteries and veins are summarized in Figures 18-4 and 18-5. All systemic arteries are direct or indirect branches of the aorta, the main artery that arises from the left ventricle. Most veins drain directly or indirectly into the superior and inferior venae cavae and then into the right atrium of the heart.

SPECIAL CIRCULATIONS

Most organs receive oxygen-rich blood from a single large artery, whereas oxygen-poor blood is drained by large veins. Several organs have circulations that are arranged differently. They include the blood supply to the head and brain, the blood supply to the liver, and the arrangement of the blood vessels in the unborn child (fetal circulation).

BLOOD SUPPLY TO THE HEAD AND BRAIN

The brain requires a continuous supply of blood; even a few minutes without oxygen causes brain damage. To ensure a rich supply of blood, the head is supplied by two pairs of arteries: carotid arteries and vertebral arteries (Figure 18-6, A).

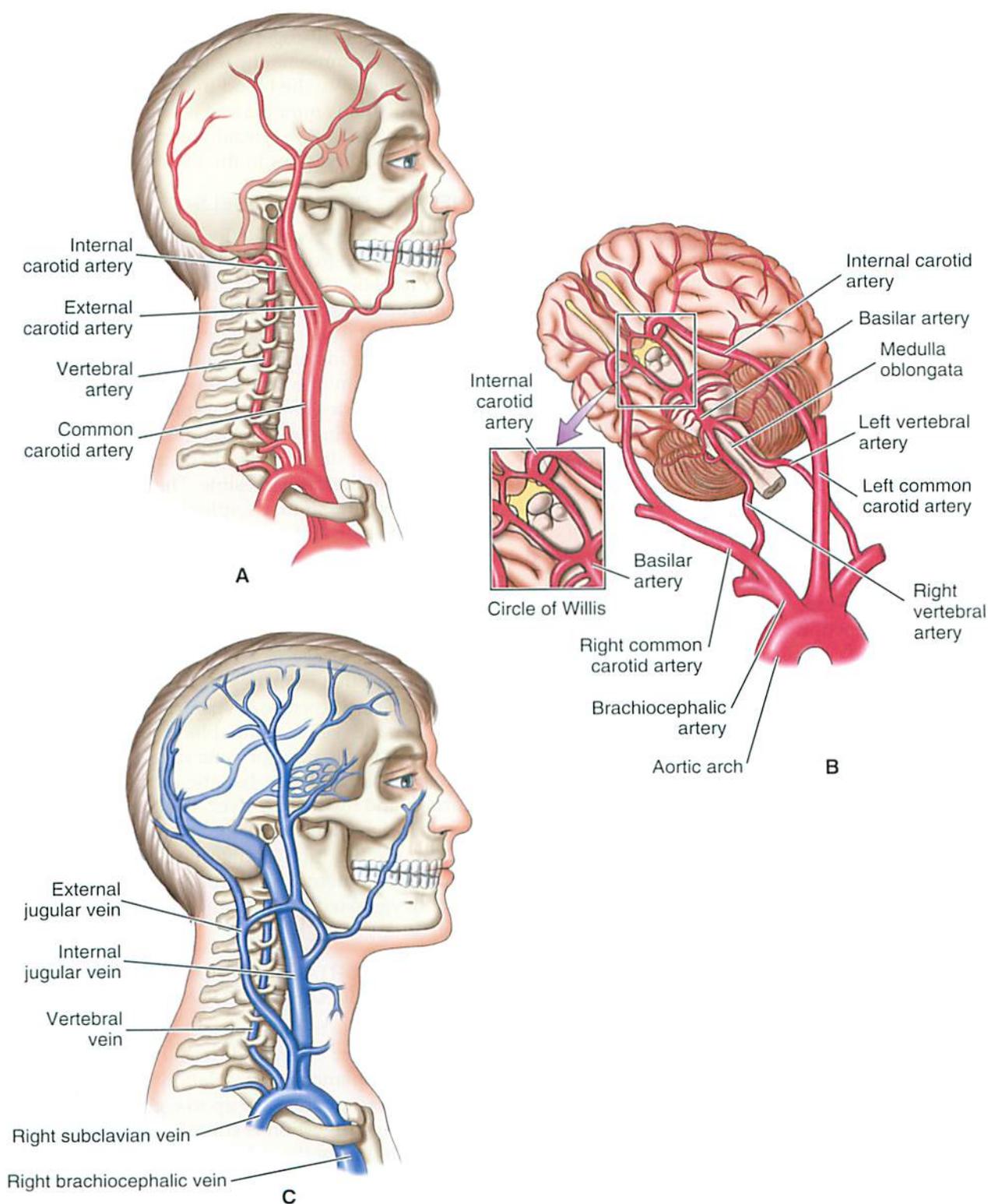


FIGURE 18-6 Blood supply to the head and the brain. **A**, The head is supplied by the common carotid and the vertebral arteries. **B**, The circle of Willis. **C**, Venous drainage of the brain and head.

ARTERIES OF THE HEAD AND NECK

The right common carotid artery arises from the brachiocephalic artery and the left common carotid artery arises directly from the aortic arch (see Figure 18-6, *B*) and ascends in the anterolateral neck. At about the

level of the mandible, the common carotid arteries split to form the external and internal carotid arteries. The external carotid arteries supply the superficial areas of the neck, face, and scalp. The internal carotid arteries extend to the front part of the brain. Once inside the

cranium, the internal carotid artery divides, sending numerous branches to various parts of the brain and to the basilar artery at the base of the brain. The internal carotid arteries supply most of the blood to the brain.

Vertebral arteries pass upward in the posterolateral neck from the subclavian arteries toward the brain. As the vertebral arteries extend up into the cranium, they join to form a single basilar artery (see Figure 18-6, B). Numerous branches from the basilar artery supply areas of the brain around the brain stem and cerebellum. Other branches of the basilar artery connect with branches of the internal carotid arteries.

The branches from the internal carotid arteries and basilar artery form a circle of arteries at the base of the brain. This circular arrangement of arteries is an anastomosis, or connection, called the *circle of Willis* (see Figure 18-6, B). Arising from the circle of Willis are *many* arteries that penetrate the brain and maintain its rich supply of blood.

Most of the blood supply to the brain runs through the internal carotid arteries. What about knotted or clotted carotids? If the carotid arteries become blocked, the vertebral arteries cannot supply sufficient blood to the brain, which results in impaired brain function. Impaired brain function is most often observed as a cognitive (thinking) impairment and dizziness.

VENOUS DRAINAGE OF THE HEAD AND BRAIN

The external and internal jugular veins are the two major veins that drain blood from the head and neck (see Figure 18-6, C). The external jugular veins are more superficial and drain blood from the posterior head and neck region. They empty into the subclavian veins. The internal jugular veins drain the anterior head, face, and neck. The deep internal jugular veins drain most of the blood from the venous sinuses of the brain. The internal jugular veins on each side of the neck join with the subclavian veins to form the brachiocephalic veins. The brachiocephalic veins empty blood into the SVC.

Re-Think

1. Explain the formation of the circle of Willis by the carotid and vertebral arteries.
2. What is the role of the jugular and subclavian veins?

BLOOD SUPPLY TO THE LIVER AND THE HEPATIC PORTAL CIRCULATION

The purpose of the hepatic portal circulation is to carry blood rich in digestive end products from the organs of digestion to the liver. Because it plays such a critical role in metabolism, the liver needs easy access to the digestive end products. As the blood flows through the liver, many of the nutrients are extracted from the

blood and modified in some way. For example, the liver prevents nitrogen from entering the general circulation as ammonia. Instead, the nitrogen is excreted by the liver into the blood in the form of urea. Urea is less toxic than ammonia and is easily eliminated by the kidneys. Thus, it is crucial that blood from the digestive organs first goes to the liver!

HEPATIC BLOOD VESSELS

The blood vessels of the liver have a unique arrangement. Three groups of blood vessels are associated with hepatic circulation: the portal vein, the hepatic veins, and the hepatic artery.

The portal vein is a large vein that carries blood from the organs of digestion to the liver (Figure 18-7). It is formed by the union of two large veins: the superior mesenteric vein and the splenic vein. The superior mesenteric vein receives blood from the small intestine (where most digestion and absorption occur) and the first part of the large intestine. The splenic vein receives blood from the stomach, spleen, and pancreas. In addition, the splenic vein receives blood from the inferior mesenteric vein, which drains the last part of the large intestine.

In addition to the portal vein, the liver has two other blood vessels: the hepatic artery and the hepatic veins. The hepatic artery is a branch of the celiac trunk, a large artery that branches off the abdominal aorta. The hepatic artery carries oxygen-rich blood to the liver. The hepatic veins drain blood from the liver and deliver it to the inferior vena cava.

Note that both the hepatic artery and portal vein carry blood toward the liver. The hepatic artery carries oxygen-rich blood, and the portal vein carries blood rich in the products of digestion to the liver but poor in oxygen content. Two thirds of the hepatic blood flow is unoxygenated blood and is delivered by the portal vein.

HEPATIC PORTAL CIRCULATION: A PART OF THE SPLANCHNIC CIRCULATION

The blood flow to the stomach, spleen, pancreas, intestines, and liver is referred to as the **splanchnic circulation**. The splanchnic circulation is very adjustable. Blood flow may increase up to eight times following a meal. When digestion is complete, the blood can then be diverted from the splanchnic blood vessels to other organs such as exercising skeletal muscles. Your mother was right: Do not go for a vigorous swim immediately after eating! Your splanchnic blood vessels are using the blood that your swimming skeletal muscles need. Cramping and drowning are possible. The splanchnic circulation also responds vigorously to a severe hemorrhage; the vessels constrict so intensely that they cause an ischemic or blood-deprived gut (intestines). The damaged gut is characterized by bloody diarrhea and absorption of toxins from the intestine into the blood, which is potentially lethal.

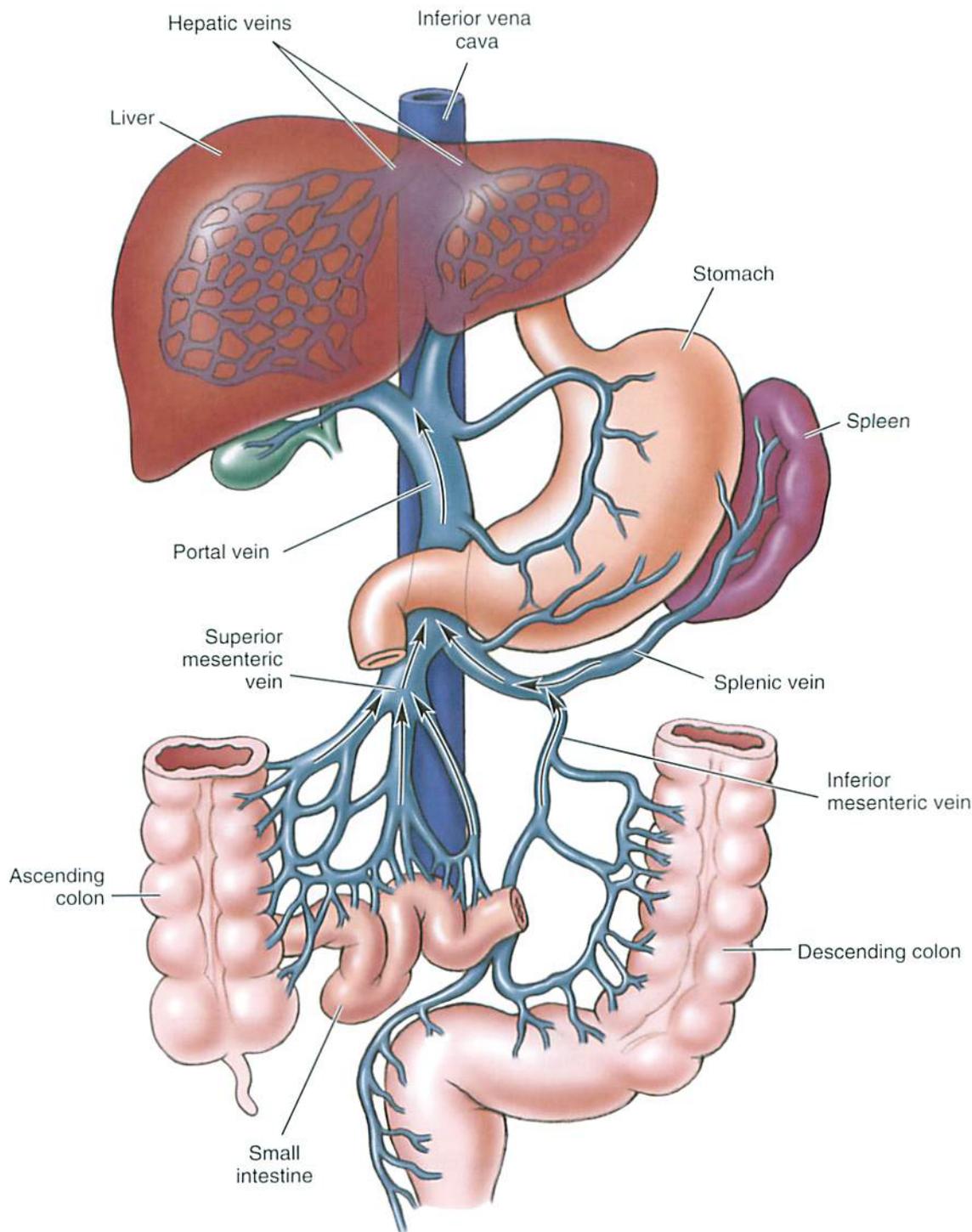


FIGURE 18-7 Hepatic portal circulation.

? Re-Think

1. List the blood vessels of the hepatic portal circulation.
2. What is the purpose of the hepatic portal circulation?

FETAL CIRCULATION

Look at your “belly button,” or umbilicus. At one time, you had a long umbilical cord, a lifeline that attached

you to a structure called the *placenta* embedded in the wall of your mother’s uterus. Why was this attachment necessary? As a fetus, you were submerged in amniotic fluid and were unable to eat or breathe. All your nutrients and oxygen had to be supplied by your mother. Your mother also absorbed much of the waste produced by your tiny body and eliminated it through her excretory organs. The exchange of your nutrients, gases, and waste occurred at the placenta.

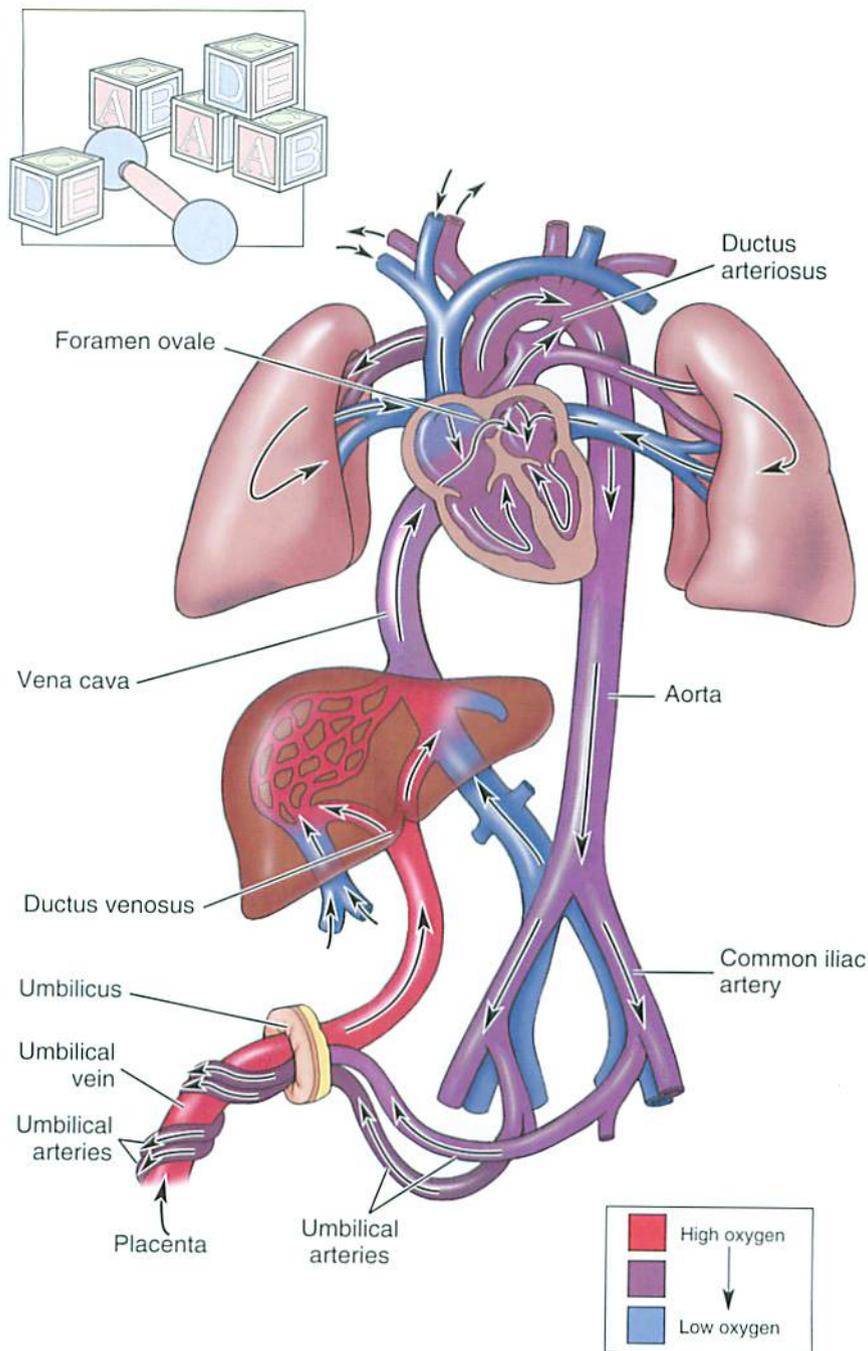


FIGURE 18-8 Fetal circulation.

Because of these special needs, the fetal heart and circulation have several modifications that make them different from “life on the outside” (Figure 18-8). The following modifications are described and summarized in Table 18-2:

- **Umbilical blood vessels.** The umbilical cord contains three blood vessels: one large umbilical vein and two smaller umbilical arteries. The umbilical vein carries blood rich in oxygen and nutrients from the placenta to the fetus. The two umbilical arteries carry carbon dioxide and other waste from the fetus to the placenta. NOTE: In the fetal circulation, the umbilical vein carries oxygen-rich blood, whereas it

is the umbilical arteries that carry oxygen-poor blood.

- **Ductus venosus.** Blood flows through the umbilical vein into the fetus. Within the body of the fetus, the umbilical vein branches. Some blood flows through one branch to the fetal liver. Most of the blood, however, bypasses the liver and flows through the ductus venosus into the IVC. After birth, the ductus venosus closes and serves no further purpose.

Because the deflated fetal lungs are not used for gas exchange, they have no need for blood to be pumped through the pulmonary circulation. Two modifications in the fetal heart and large vessels reroute most of the

Table 18-2 Special Features in the Fetal Circulation

STRUCTURE	LOCATION	FUNCTION
Umbilical arteries (two)	Umbilical cord	Transport unoxygenated blood from fetus to the placenta
Umbilical vein (one)	Umbilical cord	Transports oxygenated blood from the placenta to the fetus
Ductus venosus	Between the umbilical vein and inferior vena cava	Carries blood from the umbilical vein to the inferior vena cava; allows some of the blood to bypass the liver
Foramen ovale	Septum between the right and left atria	Allows blood to flow directly from the right atrium into the left atrium to bypass the pulmonary circulation
Ductus arteriosus	Between the pulmonary artery and aorta	Allows blood in the pulmonary artery to flow directly into the descending aorta to bypass the pulmonary circulation

blood past the lungs. These are the foramen ovale and the ductus arteriosus:

- *Foramen ovale*. The foramen ovale (foh-RAY-men oh-VAL-ee) is an opening in the interatrial septum of the heart. This opening allows most of the blood to flow from the right atrium directly into the left atrium.
- *Ductus arteriosus*. Although most blood flows through the foramen ovale into the left atrium, some blood enters the right ventricle and is pumped into the pulmonary artery. How does this blood bypass the lungs? The fetal heart has a short tube called the *ductus arteriosus* (DUK-tus ar-teer-ee-OH-sus) that connects the pulmonary artery with the aorta. Blood pumped into the pulmonary artery bypasses the lungs by flowing through the ductus arteriosus directly into the aorta. After birth, these fetal structures close.

Why is it not a good idea for a pregnant woman to take aspirin or a similar drug, such as indomethacin? Naturally secreted prostaglandins help keep the ductus arteriosus open. Drugs such as aspirin and indomethacin block prostaglandin synthesis, thereby causing a premature closure of the ductus arteriosus. This can be lethal for the baby!

Occasionally, the fetal structures do not close after birth and appear as congenital heart defects. For example, the ductus arteriosus may fail to close, thereby allowing blood to shunt continuously from the aorta to the pulmonary artery. A patent ductus arteriosus (PDA) creates a left-to-right shunt. Fortunately, a PDA is easily corrected.

See Figure 18-8 for color coding of the fetal veins and arteries. Blood vessels carrying oxygenated blood are in red; these are usually the arteries. Vessels carrying unoxygenated blood are in blue; these are usually veins. Note, however, that the umbilical vein is red, indicating oxygenated blood. The umbilical arteries are blue, indicating unoxygenated blood.

Note the color of the upper portion of the vena cava. The adult venae cavae are colored blue because they contain unoxygenated blood. The fetal venae cavae,

however, are violet, indicating that the blood is a mixture of unoxygenated blood (coming from the metabolizing fetal tissue) and oxygenated blood (coming from the umbilical vein). Note also the color of the blood in the fetal aorta; it is not the bright red that is characteristic of the adult aorta. The adult aorta carries only oxygenated blood, but the fetal aorta mixes oxygenated and unoxygenated blood.

? Re-Think

1. List three structural modifications of the fetal circulation.
2. To what maternal structure do the umbilical blood vessels attach?

PULSE

WHAT IS A PULSE?

The ventricles pump blood into the arteries about 72 times/min. The blood causes an alternating expansion and recoil of the arteries with each beat of the heart. This alternating expansion and recoil creates a pressure wave (similar to vibration), which travels through all the arteries. This wave is called the *pulse*.

Because it is caused by the rhythmic contraction of the ventricles of the heart, the pulse is often described as a “heartbeat that can be felt at the wrist.” Although a pulse can be felt in any artery lying close to the surface of the body, the site most often used to feel the pulse is the radial artery in the wrist area. Determine your own radial pulse and then try feeling a pulse at any of the nine “pulse points” identified in Figure 18-9.

WHAT CAN YOU LEARN ABOUT A PATIENT BY FEELING THE PULSE?

By feeling a person’s pulse, you can determine the heart rate. A normal heart rate is about 72 beats/min. You can also determine if the heart is beating regularly (rhythmically) or irregularly.

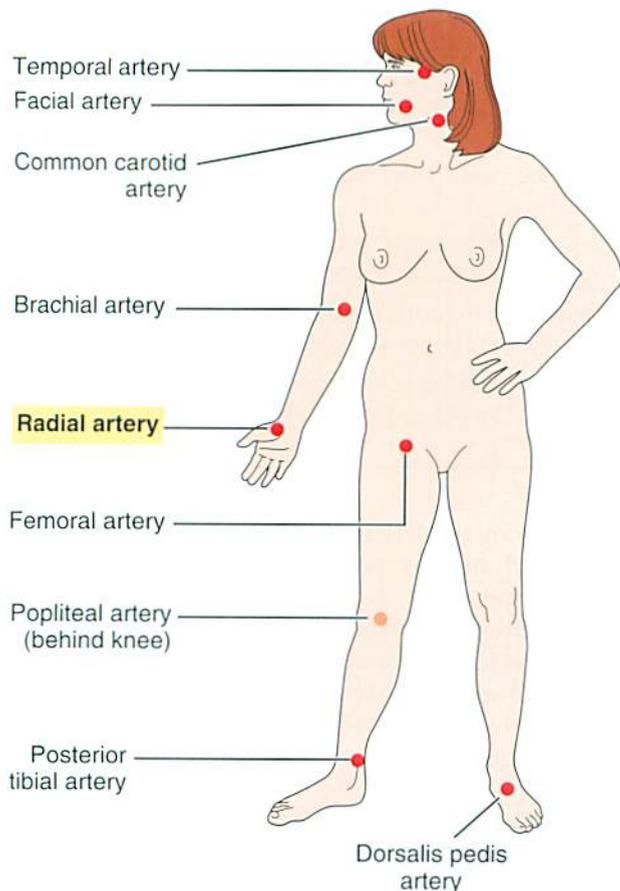


FIGURE 18-9 Pulse points.

You can also assess the pulse for its strength. Does the pulse feel strong or weak? At times, the heart contracts so weakly that the heartbeat cannot be felt over the radial artery; this happens in a person who has lost a lot of blood and is in shock. A pulse may also be described as full or bounding as happens in a person with excess blood volume. It is also possible that you may not be able to detect a pulse in a particular artery. The pulse may be absent if the artery is blocked or occluded. For example, if a person has poor arterial circulation to the feet, as occurs with many diabetic persons, the dorsalis pedis pulse may be undetectable. Thus, a correct assessment of the pulse can provide much useful information about the patient's condition.

2+2 Sum It Up!

There are three special circulations: circulation to the head and brain, the hepatic portal circulation, and the fetal circulation. The brain receives oxygen-rich blood from the circle of Willis, formed by branches of the internal carotid and basilar artery (merger of the vertebral arteries). The purpose of the hepatic portal circulation is to deliver blood rich in digestive end products to the liver for metabolic processing. The fetal circulation has three modifications that allow the fetus to "live under water": the ductus venosus, foramen ovale, and ductus arteriosus. The fetus "breathes and feeds" at the placenta. The pulse is described as a "heartbeat that can be felt at the wrist." Numerous pulse points can be used to assess the pulse.

Note: The As You Age box and the Medical Terminology and Disorders table appear in Chapter 19.

Get Ready for Exams!

Summary Outline

The circulatory system is a series of blood vessels that begin and end in the heart. The circulatory system delivers blood to all the body's cells and then returns the blood to the heart.

I. Circles, Circuits, and Circulations

- The heart and blood vessels form a circle.
- There are two circulations: pulmonic and systemic.

II. Blood Vessels

- Naming the blood vessels
 - Arteries carry blood away from the heart; the smallest arteries are the arterioles.
 - Capillaries connect arteries and veins; a capillary is close to every cell in the body.
 - Veins carry blood back to the heart; small veins are called *venules*.
- Layers of blood vessels
 - The tunica intima is the smooth, innermost layer.
 - The tunica media is the middle layer, which contains elastic tissue and smooth muscle.

- The tunica adventitia is the outermost layer of connective tissue.
- Blood vessels: what they do
 - Arteries conduct blood from the heart to the organs and are called *conductance vessels*.
 - The arterioles constrict and dilate, thereby determining resistance to the flow of blood. The arterioles are called *resistance vessels*.
 - Capillaries are concerned with the exchange of water and dissolved substances between the blood and tissue fluid. Capillaries are called *exchange vessels*.
 - Veins and venules return blood to the heart from the body. The veins also store blood and are therefore called *capacitance vessels*. Veins also contain valves.

III. Major Arteries of the Systemic Circulation

- The major arteries include the aorta and the arteries arising directly and indirectly from the aorta.
- See Figure 18-4 for the names and locations of the major arteries.

IV. Major Veins of the Systemic Circulation

- A. The major veins include the venae cavae and the veins that directly and indirectly empty into the superior and inferior venae cavae.
- B. See Figure 18-5 for the names and locations of the major veins.

V. Special Circulations

- A. The head and brain are supplied by two sets of arteries: the carotid arteries and the vertebral arteries. The internal carotid arteries and the basilar artery (merger of the vertebral arteries) form the circle of Willis. Blood from the head and brain drains into the jugular veins.
- B. The blood supply of the liver is composed of the portal vein, hepatic artery, and hepatic veins. The hepatic artery brings oxygen-rich blood to the liver. The portal vein carries blood from the digestive tract to the liver. The hepatic veins carry blood from the liver to the inferior vena cava.
- C. The fetal circulation has several unique features. The fetus uses the placenta as lungs. The umbilical blood vessels carry blood between the placenta and the fetus. Three special structures (modifications) are the ductus venosus, foramen ovale, and ductus arteriosus.

VI. The Pulse

- A. The pulse is caused by the alternating expansion and recoil of the artery creating a pressure wave.
- B. The pulse is often described as a "heartbeat that can be felt at the wrist."
- C. Figure 18-9 identifies the pulse points.

Review Your Knowledge**Matching: Blood Vessels: Structure and Function**

Directions: Match the following words with their descriptions below. Some words may be used more than once.

- a. large arteries
 - b. arterioles
 - c. capillaries
 - d. veins
1. ___ Exchange vessels
 2. ___ Resistance vessels
 3. ___ Composed of a single layer of epithelium sitting on a basement membrane
 4. ___ The most numerous of the blood vessels
 5. ___ Capacitance vessels
 6. ___ Blood pressure is lowest in these blood vessels.
 7. ___ Generally colored blue and contain valves
 8. ___ These are the strongest of the blood vessels.
 9. ___ Blood pressure is highest in these blood vessels.
 10. ___ Connect the arteries and veins

Matching: Names of Blood Vessels

Directions: Match the following words with their descriptions below. Some words may be used more than once.

- a. aorta
 - b. inferior vena cava
 - c. carotids
 - d. circle of Willis
 - e. portal vein
 - f. hepatic artery
 - g. jugular
 - h. brachial artery
 - i. renal artery
 - j. median cubital vein
 - k. saphenous
 - l. radial artery
 - m. coronaries
1. ___ Carries oxygen-rich blood to the liver
 2. ___ Carries oxygen-rich blood to the kidneys
 3. ___ Carries blood that is rich in digestive end products to the liver
 4. ___ Classified as ascending, arch, and descending
 5. ___ The superior mesenteric and splenic veins merge to form this vein.
 6. ___ Classified as thoracic and abdominal
 7. ___ Vein in the arm that is used to "draw" a sample of blood
 8. ___ Main vein that drains the brain
 9. ___ Arterial blood supply at the base of the brain
 10. ___ Arteries that ascend along the anterolateral neck to the brain
 11. ___ Longest superficial vein in the thigh and leg
 12. ___ The common iliac veins drain into this blood vessel.
 13. ___ Blood pressure is usually taken over this artery.
 14. ___ This artery is usually used in "taking a pulse."
 15. ___ These arteries supply the myocardium.

Matching: Fetal Circulation

Directions: Match the following words with their descriptions below.

- a. umbilical arteries
 - b. umbilical vein
 - c. ductus arteriosus
 - d. ductus venosus
 - e. foramen ovale
1. ___ Carry blood from the fetus to the placenta
 2. ___ Opening that connects the right and left atria in the fetal circulation
 3. ___ Structure that connects the pulmonary artery and the aorta in the fetal circulation
 4. ___ Structure that partially bypasses the fetal liver
 5. ___ Carries oxygen-rich blood from the placenta to the fetus

Multiple Choice

1. Which of the following is not true about the capillaries?
 - a. They are called the *exchange vessels*.
 - b. Capillary membranes have holes or pores.
 - c. They connect the arteries and the veins.
 - d. They have valves.

2. The common carotid
 - a. supplies oxygenated blood to the brain.
 - b. is the main vein that drains the brain.
 - c. is part of the hepatic portal system.
 - d. ascends along the posterolateral neck to the brain to form the basilar artery.
3. The purpose of the hepatic portal system is to
 - a. provide the fetus with oxygenated blood.
 - b. deliver blood that is rich in digestive end products to the liver.
 - c. drain unoxygenated blood from the brain.
 - d. deliver oxygenated blood to the liver.
4. Which statement is true about the fetal circulation?
 - a. The umbilical arteries deliver oxygenated blood to the fetus.
 - b. The umbilical vein delivers oxygenated blood to the fetus.
 - c. The ductus venosus connects the right and left fetal atria.
 - d. The ductus arteriosus bypasses the fetal liver.
5. Which of the following is descriptive of the aorta?
 - a. It is the largest and strongest of the arteries.
 - b. It carries unoxygenated blood and is therefore colored blue.
 - c. It is lined with large valves.
 - d. Blood pressure in the aorta is lower than blood pressure in the veins.
6. The portal vein, hepatic vein, and celiac trunk are most associated with the
 - a. stomach.
 - b. pancreas.
 - c. small intestine.
 - d. liver.
7. The superior mesenteric vein and the splenic vein
 - a. drain directly into the superior vena cava.
 - b. drain the brain.
 - c. merge to form the portal vein.
 - d. carry venous blood from the liver to the inferior vena cava.
8. The common iliac arteries, renal arteries, and celiac trunk
 - a. are branches of the descending aorta.
 - b. are branches of the abdominal aorta.
 - c. carry oxygenated blood.
 - d. All of the above are true.
9. The median cubital vein, brachial vein, and radial vein
 - a. carry oxygenated blood.
 - b. are color-coded red.
 - c. are located in the upper extremities.
 - d. are prone to varicosities.
10. Both the brachiocephalic artery and the left common carotid artery
 - a. arise from the arch of the aorta.
 - b. arise from the abdominal aorta.
 - c. drain into the superior vena cava.
 - d. receive blood from the jugulars.

Go Figure

1. According to Figures 18-1 and 18-2
 - a. Blood is pumped by the heart to arteries → veins → capillaries → back to the right side of the heart.
 - b. The capillaries are closer to the individual cells than is the aorta.
 - c. Capillaries have a more elastic wall than the aorta.
 - d. The venae cavae deliver blood to the capillaries.
2. According to Figures 18-3 and 18-4
 - a. The ascending aorta gives rise to the common iliac arteries.
 - b. Both common carotid arteries arise directly from the arch of the aorta.
 - c. The abdominal aorta is part of the descending aorta.
 - d. The thoracic aorta gives rise to the renal arteries.
3. According to Figures 18-5 and 18-7
 - a. The portal vein bypasses the liver and drains directly into the inferior vena cava.
 - b. The superior mesenteric vein and splenic vein merge to form the portal vein.
 - c. The hepatic vein drains into the portal vein.
 - d. The inferior vena cava delivers blood to the saphenous veins.
4. According to Figure 18-6
 - a. The jugulars are part of the circle of Willis.
 - b. The vertebral arteries carry blood to the facial structures.
 - c. The internal carotids deliver oxygenated blood to the circle of Willis.
 - d. All blood delivered to the circle of Willis comes from the internal carotid arteries.
5. According to Figure 18-8
 - a. The ductus venosus is the hole in the fetal interatrial septum.
 - b. The umbilical vein carries oxygenated from the placenta to the fetus.
 - c. The foramen ovale is the fetal structure that connects the pulmonary artery with the aorta.
 - d. The fetal heart is color-coded blue and red as in the adult heart.