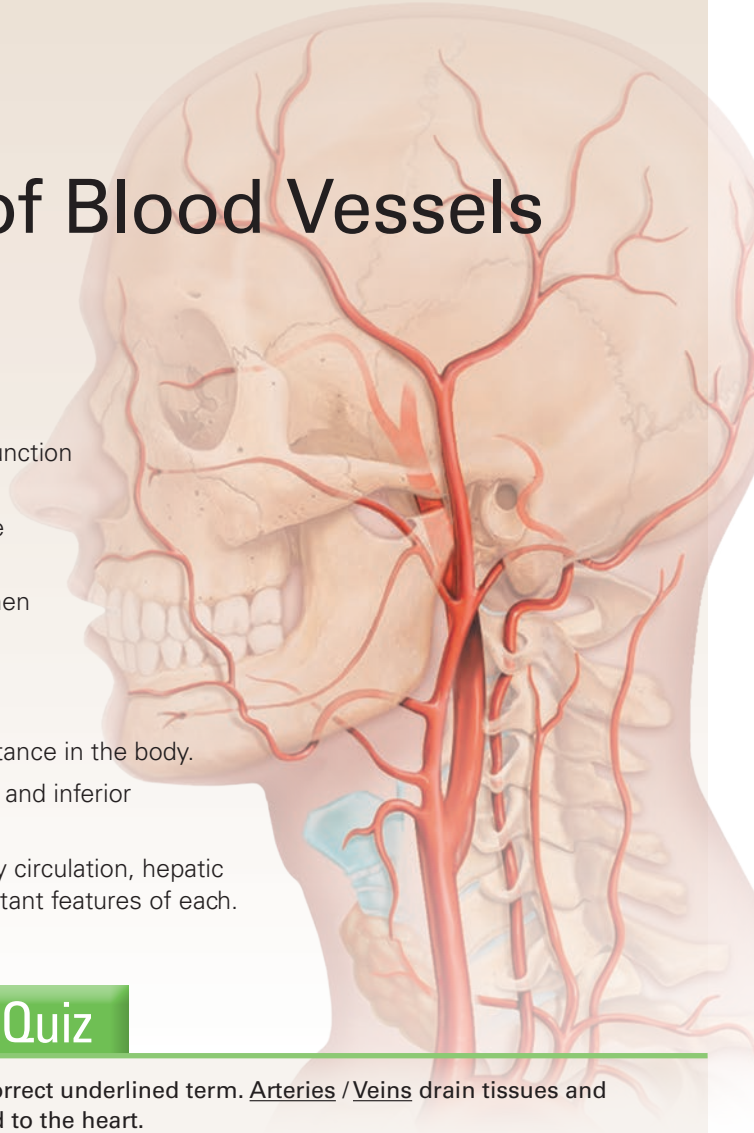
EXERCISE

32 Anatomy of Blood Vessels



Objectives

- ☐ Describe the tunics of blood vessel walls, and state the function of each layer.
- ☐ Correlate differences in artery, vein, and capillary structure with the functions of these vessels.
- ☐ Recognize a cross-sectional view of an artery and vein when provided with a microscopic view or appropriate image.
- ☐ List and identify the major arteries arising from the aorta, and indicate the body region supplied by each.
- ☐ Describe the cerebral arterial circle, and discuss its importance in the body.
- ☐ List and identify the major veins draining into the superior and inferior venae cavae, and indicate the body regions drained.
- ☐ Describe these special circulations in the body: pulmonary circulation, hepatic portal system, and fetal circulation, and discuss the important features of each.

Materials

- Compound microscope
- Prepared microscope slides showing cross sections of an artery and vein
- Anatomical charts of human arteries and veins (or a three-dimensional model of the human circulatory system)
- Anatomical charts of the following specialized circulations: pulmonary circulation, hepatic portal circulation, fetal circulation, arterial supply of the brain (or a brain model showing this circulation)

For instructions on animal dissections, see the dissection exercises (starting on p. 705) in the cat and fetal pig editions of this manual.

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Pre-Lab Quiz

1. Circle the correct underlined term. Arteries / Veins drain tissues and return blood to the heart.
2. Circle True or False. Gas exchange takes place between tissue cells and blood through capillary walls.
3. The _____ is the largest artery of the body.
   a. aorta **c.** femoral artery
   b. carotid artery **d.** subclavian artery
4. Circle the correct underlined term. The largest branch of the abdominal aorta, the renal / superior mesenteric artery, supplies most of the small intestine and the first half of the large intestine.
5. The anterior tibial artery terminates with the _____ artery, which is often palpated in patients with circulatory problems to determine the circulatory efficiency of the lower limb.
   a. dorsalis pedis **c.** obturator
   b. external iliac **d.** tibial
6. Circle the correct underlined term. Veins draining the head and upper extremities empty into the superior / inferior vena cava.
7. Located in the lower limb, the _____ is the longest vein in the body.
   a. external iliac **c.** great saphenous
   b. fibular **d.** internal iliac
8. Circle the correct underlined term. The renal / hepatic veins drain the liver.
9. The function of the _____ is to drain the digestive viscera and carry dissolved nutrients to the liver for processing.
   a. fetal circulation
   b. hepatic portal circulation
   c. pulmonary circulation system
10. Circle the correct underlined term. In the developing fetus, the umbilical artery / vein carries blood rich in nutrients and oxygen to the fetus.

Arteries, carrying blood away from the heart, and veins, which drain the tissues and return blood to the heart, function simply as conducting vessels or conduits. Only the tiny capillaries that connect the arterioles and venules and branch throughout the tissues directly serve the needs of the body's cells. It is through the capillary walls that exchanges are made between tissue cells and blood.

In this exercise you will examine the microscopic structure of blood vessels and identify the major arteries and veins of the systemic circulation and other special circulations.

Microscopic Structure of the Blood Vessels

Except for the microscopic capillaries, the walls of blood vessels are constructed of three coats, or *tunics* (**Figure 32.1**).

- **Tunica intima:** Lines the lumen of a vessel and is composed of a single thin layer of *endothelium,* subendothelial layer, and internal elastic membrane. Its cells fit closely together, forming an extremely smooth blood vessel lining that helps decrease resistance to blood flow.
- **Tunica media:** Middle coat, composed primarily of smooth muscle and elastin. The smooth muscle plays an active role in regulating the diameter of blood vessels, which in turn alters peripheral resistance and blood pressure.
- **Tunica externa:** Outermost tunic, composed of areolar or fibrous connective tissue. Its function is basically supportive and protective. In larger vessels, the tunica externa contains a system of tiny blood vessels, the **vasa vasorum.**

In general, the walls of arteries are thicker than those of veins. The tunica media in particular tends to be much heavier and contains substantially more smooth muscle and elastic tissue. Arteries, which are closer to the pumping action of the heart, must be able to expand as an increased volume of blood is propelled into them during systole and then recoil passively as the blood flows off into the circulation during diastole. The anatomical differences between the different types of vessels reflect their functional differences. **Table 32.1** summarizes the structure and function of various blood vessels.

Valves in veins act to prevent backflow of blood in much the same manner as the semilunar valves of the heart. The

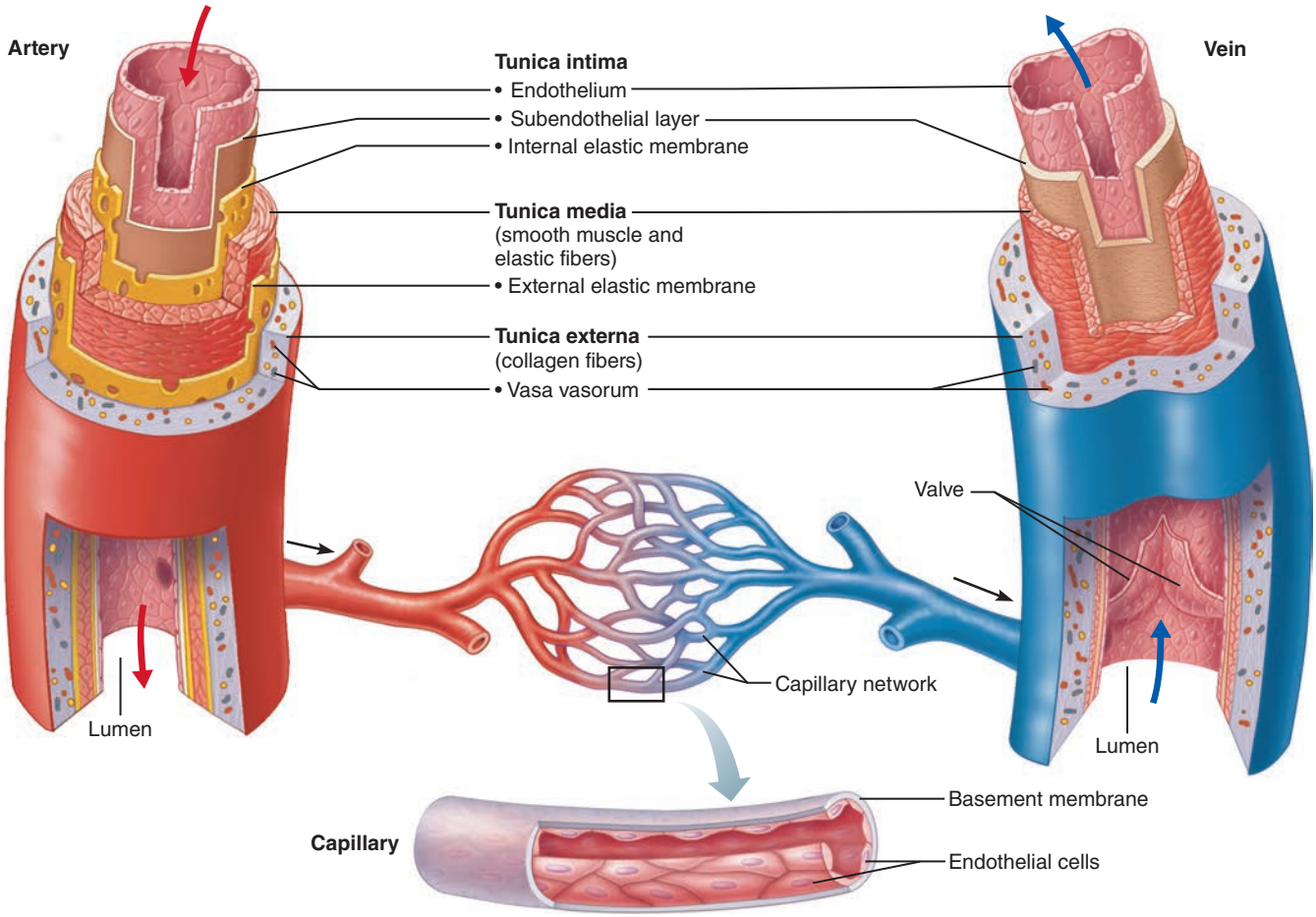

Figure 32.1 **Generalized structure of arteries, veins, and capillaries.**

Table 32.1 Summary of Blood Vessel Anatomy and Physiology

Type of vessel	Description	Average lumen diameter	Average wall thickness	Function
Elastic (conducting) arteries	Largest, most elastic arteries. Contain more elastic tissue than other arteries.	1.5 cm	1.0 mm	Act as a pressure reservoir, expanding and recoiling for continuous blood flow. Examples: aorta, brachiocephalic artery, and common carotid artery.
Muscular (distributing) arteries	Medium-sized arteries, accounting for most arteries found in the body. They have less elastic tissue and more smooth muscle than other arteries.	0.6 cm	1.0 mm	Better ability to constrict and less stretchable than elastic arteries. They distribute blood to specific areas of the body. Examples: brachial artery and radial artery.
Arterioles	Smallest arteries with a very thin tunica externa and only a few layers of smooth muscle in the tunica media.	37 μm	6 μm	Blood flows from arterioles into a capillary bed. They play a role in regulating the blood flow to specific areas of the body.
Capillaries	Contain only a tunica intima.	9 μm	0.5 μm	Provide for the exchange of materials (gases, nutrients, etc.) between the blood and tissue cells.
Venules	Smallest veins. All tunics are very thin, with at most two layers of smooth muscle and no elastic tissue.	20 μm	1 μm	Drain capillary beds and merge to form veins.
Veins	Contain more fibrous tissue in the tunica externa than corresponding arteries. The tunica media is thinner, with a larger lumen than the corresponding artery.	0.5 cm	0.5 mm	Low-pressure vessels; return blood to the heart. Valves prevent the backflow of the blood.

skeletal muscle "pump" also promotes venous return; as the skeletal muscles surrounding the veins contract and relax, the blood is milked through the veins toward the heart. Anyone who has been standing relatively still for an extended time has experienced swelling in the ankles, caused by blood pooling in their feet during the period of muscle inactivity. Pressure changes that occur in the thorax during breathing also aid the return of blood to the heart.

☐ To demonstrate how efficiently venous valves prevent backflow of blood, perform the following simple experiment. Allow one hand to hang by your side until the blood vessels on the dorsal aspect become distended. Place two fingertips against one of the distended veins and, pressing firmly, move the superior finger proximally along the vein and then release this finger. The vein will remain flattened and collapsed despite gravity. Then remove the distal fingertip and observe the rapid filling of the vein.

Check the box when you have completed this task.

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Activity 1

Examining the Microscopic Structure of Arteries and Veins

1. Obtain a slide showing a cross-sectional view of blood vessels and a microscope.
2. Scan the section to identify a thick-walled artery (use **Figure 32.2** as a guide). Very often, but not always, an arterial lumen will appear scalloped due to the constriction of its walls by the elastic tissue of the media.
3. Identify a vein. Its lumen may be elongated or irregularly shaped and collapsed, and its walls will be considerably thinner. Notice the difference in the relative amount of elastic fibers in the media of the two vessels. Also, note the thinness of the intima layer, which is composed of flat squamous cells.

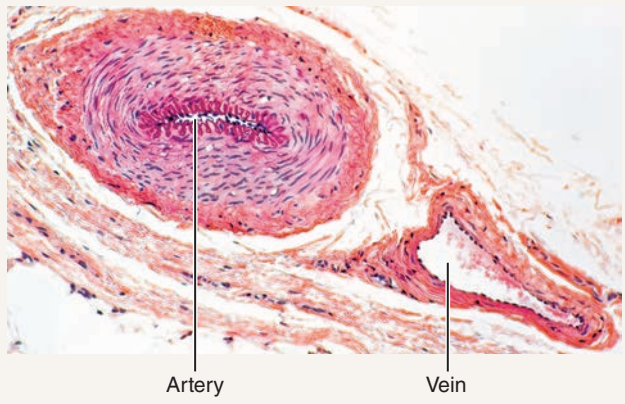


Figure 32.2 Photomicrograph of a muscular artery and the corresponding vein in cross section (76×).

Major Systemic Arteries of the Body

The **aorta** is the largest artery of the body. It has three main regions: ascending aorta, aortic arch, and descending aorta. Extending upward as the **ascending aorta** from the left ventricle, it arches posteriorly and to the left **(aortic arch)** and then courses downward as the **descending aorta** through the thoracic cavity. Called the **thoracic aorta** from T_5 to T_{12}, the descending aorta penetrates the diaphragm to enter the abdominal cavity just anterior to the vertebral column. As it enters the abdominal cavity, it becomes the **abdominal aorta.** The branches of the ascending aorta and aortic arch are summarized in **Table 32.2**, p. 476. Branches of the thoracic and abdominal aorta are summarized in Tables 32.3 and 32.4.

As you locate the arteries diagrammed on **Figure 32.3**, be aware of ways in which you can make your memorization task easier. In many cases, the name of the artery reflects the body region it travels through (axillary, subclavian, brachial, popliteal), the organ served (renal, hepatic), or the bone followed (tibial, femoral, radial, ulnar).

Aortic Arch

The **brachiocephalic** (literally, "arm-head") **trunk** is the first branch of the aortic arch (**Figure 32.4**). The other two major arteries branching off the aortic arch are the **left common carotid artery** and the **left subclavian artery.** The brachiocephalic trunk persists briefly before dividing into the **right common carotid artery** and the **right subclavian artery.**

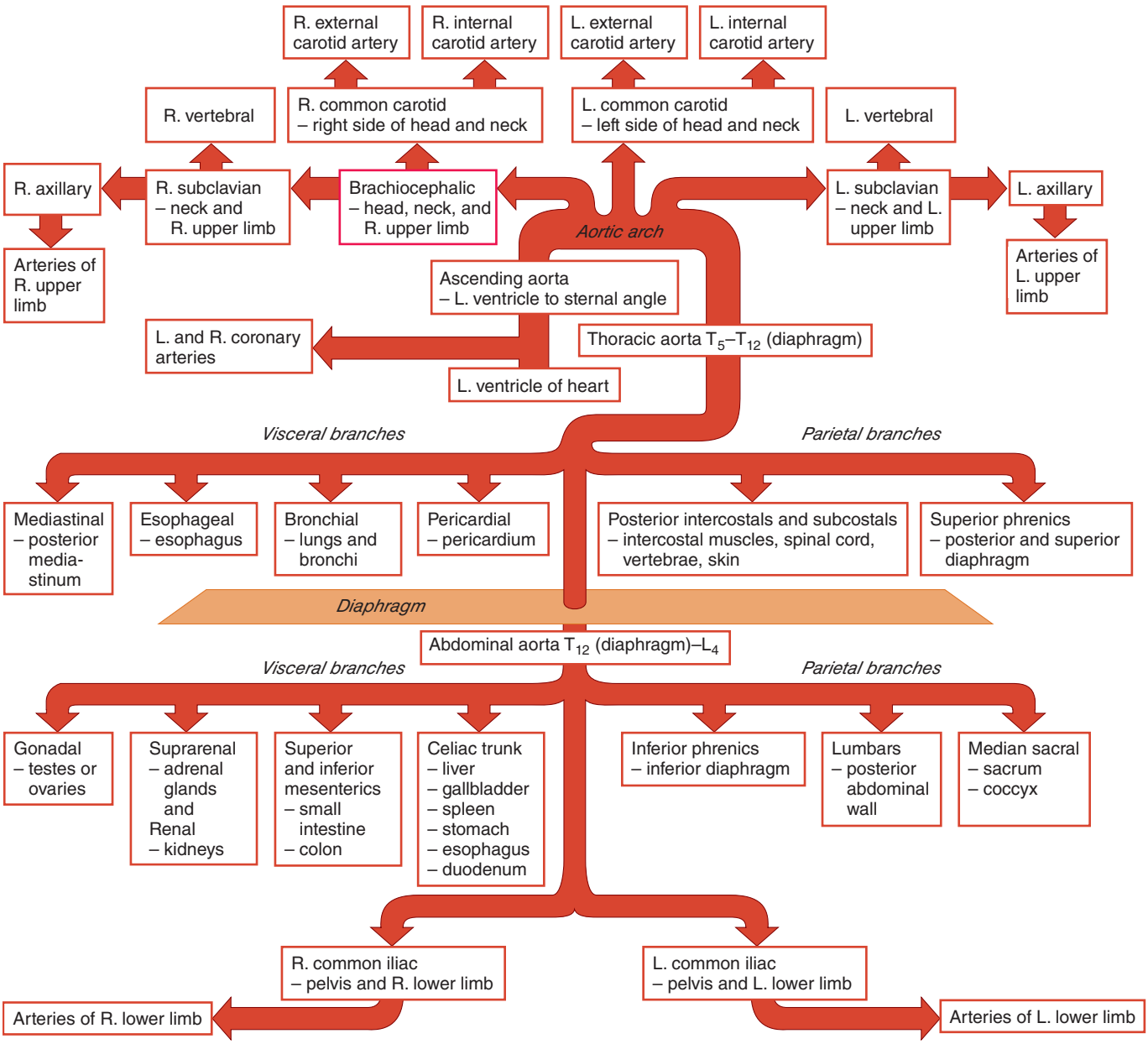
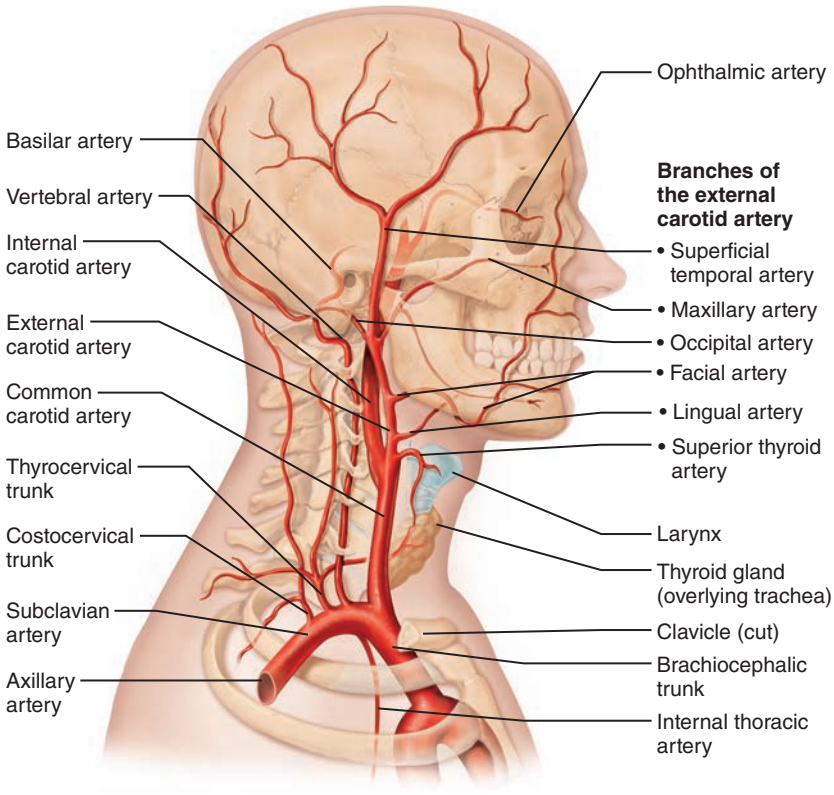


Figure 32.3 Schematic of the systemic arterial circulation. (R. = right, L. = left)



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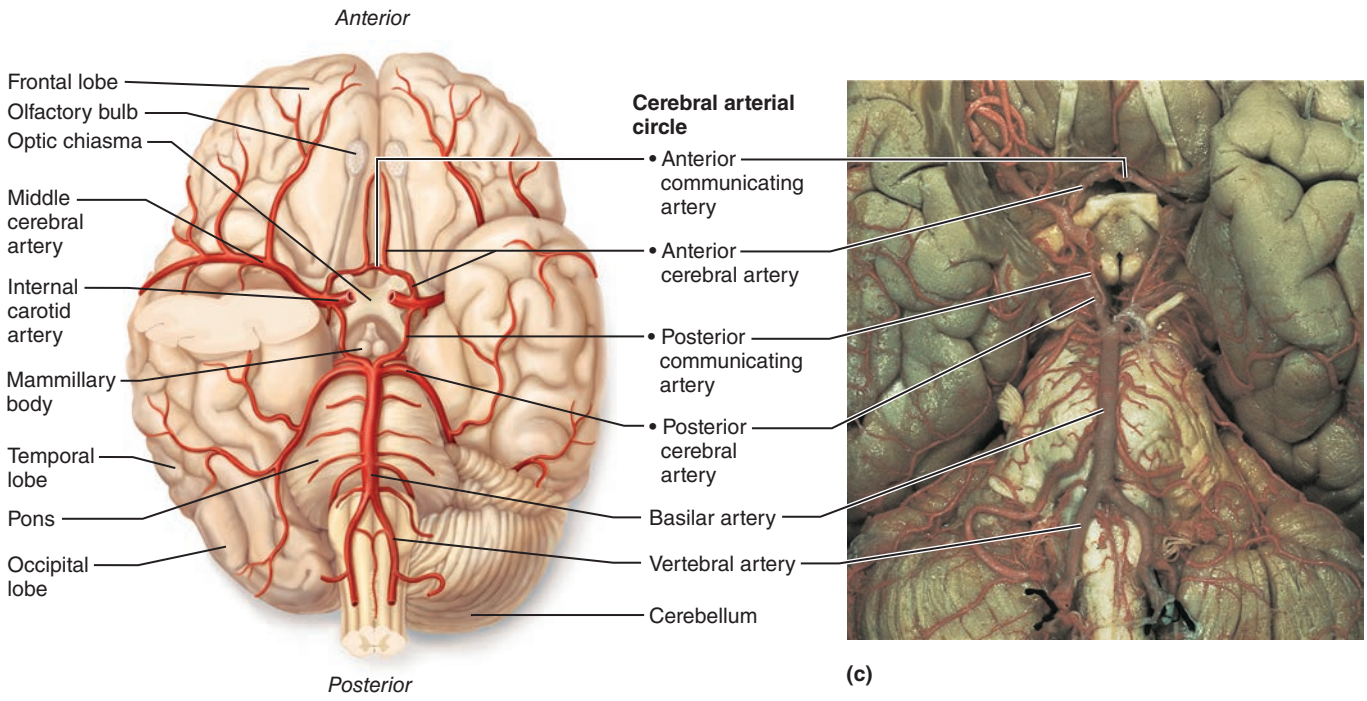

(b)

(c)

Figure 32.4 **Arteries of the head, neck, and brain. (a)** Right aspect. **(b)** Drawing of the cerebral arteries. Cerebellum is not shown on the left side of the figure. **(c)** Cerebral arterial circle (circle of Willis) in a human brain.

Table 32.2 The Aorta: Ascending Aorta and Aortic Arch (Figure 32.3)

Ascending aorta branches	Structures served
Right coronary artery	The myocardium of the heart (see Exercise 30)
Left coronary artery	The myocardium of the heart (see Exercise 30)
Aortic arch branches	**Structures served**
Brachiocephalic trunk (branches into right common carotid and right subclavian arteries)	Right common carotid artery – right side of the head and neck Right subclavian artery – right upper limb
Left common carotid artery	Left side of the head and neck
Left subclavian artery	Left upper limb

Arteries Serving the Head and Neck

The common carotid artery on each side divides to form an internal and an external carotid artery. The **internal carotid artery** serves the brain and gives rise to the **ophthalmic artery** that supplies orbital structures. The **external carotid artery** supplies the tissues external to the skull, largely via its **superficial temporal, maxillary, facial,** and **occipital** arterial branches. (Notice that several arteries are shown in the figure that are not described here.)

The right and left subclavian arteries each give off several branches to the head and neck. The first of these is the **vertebral artery,** which runs up the posterior neck to supply the cerebellum, part of the brain stem, and the posterior cerebral hemispheres. Issuing just lateral to the vertebral artery are the **thyrocervical trunk,** which mainly serves the thyroid gland and some scapular muscles, and the **costocervical trunk,** which supplies deep neck muscles and some of the upper intercostal muscles. In the armpit, the subclavian artery becomes the axillary artery, which serves the upper limb.

Arteries Serving the Brain

The brain is supplied by two pairs of arteries arising from the region of the aortic arch—the internal carotid arteries and the vertebral arteries. (Figure 32.4b is a diagram of the brain's arterial supply.)

Within the cranium, each internal carotid artery divides into **anterior** and **middle cerebral arteries,** which supply the bulk of the cerebrum. The right and left anterior cerebral arteries are connected by a short shunt called the **anterior communicating artery.** This shunt, along with shunts from each of the middle cerebral arteries, called the **posterior communicating arteries,** contribute to the formation of the **cerebral arterial circle** *(circle of Willis),* an arterial anastomosis at the base of the brain surrounding the pituitary gland and the optic chiasma.

The paired **vertebral arteries** diverge from the subclavian arteries and pass superiorly through the foramina of the transverse process of the cervical vertebrae to enter the skull through the foramen magnum. Within the skull, the vertebral arteries unite to form a single **basilar artery,** which continues superiorly along the ventral aspect of the brain stem, giving off branches to the pons, cerebellum, and inner ear. At the base of the cerebrum, the basilar artery divides to form the **posterior cerebral arteries.** These supply portions of the temporal and occipital lobes of the cerebrum and complete the cerebral arterial circle posteriorly.

The uniting of the blood supply of the internal carotid arteries and the vertebral arteries via the cerebral arterial circle is a protective device that theoretically provides an alternative set of pathways for blood to reach the brain tissue in the case of arterial occlusion or impaired blood flow anywhere in the system.

Arteries Serving the Thorax and Upper Limbs

As the **axillary artery** runs through the axilla, it gives off several branches to the chest wall and shoulder girdle (**Figure 32.5**). These include the **thoracoacromial artery** (to shoulder and pectoral region), the **lateral thoracic artery** (lateral chest wall), the **subscapular artery** (to scapula and dorsal thorax), and the **anterior** and **posterior circumflex humeral arteries** (to the shoulder and the deltoid muscle). At the inferior edge of the teres major muscle, the axillary artery becomes the **brachial artery** as it enters the arm. The brachial artery gives off a major branch, the **deep artery of the arm,** and as it nears the elbow it gives off several small branches. At the elbow, the brachial artery divides into the **radial** and **ulnar arteries,** which follow the same-named bones to supply the forearm and hand.

The **internal thoracic arteries** that arise from the subclavian arteries supply the mammary glands, most of the thorax wall, and anterior intercostal structures via their **anterior intercostal artery** branches. The first two pairs of **posterior intercostal arteries** arise from the costocervical trunk, noted above. The more inferior pairs arise from the thoracic aorta. (Not shown in Figure 32.5 are the small arteries that serve the diaphragm *[phrenic arteries],* esophagus *[esophageal arteries],* bronchi *[bronchial arteries],* and other structures of the mediastinum *[mediastinal* and *pericardial arteries].*)

Thoracic Aorta

The thoracic aorta is the superior portion of the descending aorta (Figure 32.5). It begins where the aortic arch ends and ends just as it pierces the diaphragm. The main branches of the thoracic aorta are summarized in **Table 32.3**.

Abdominal Aorta

Although several small branches of the descending aorta serve the thorax, the more major branches of the descending aorta are those serving the abdominal organs and ultimately the lower limbs (**Figure 32.6**, pp. 478–479). Most of the branches of the abdominal aorta serve the abdominal organs. The major branches of the abdominal aorta are summarized in **Table 32.4** on p. 479.

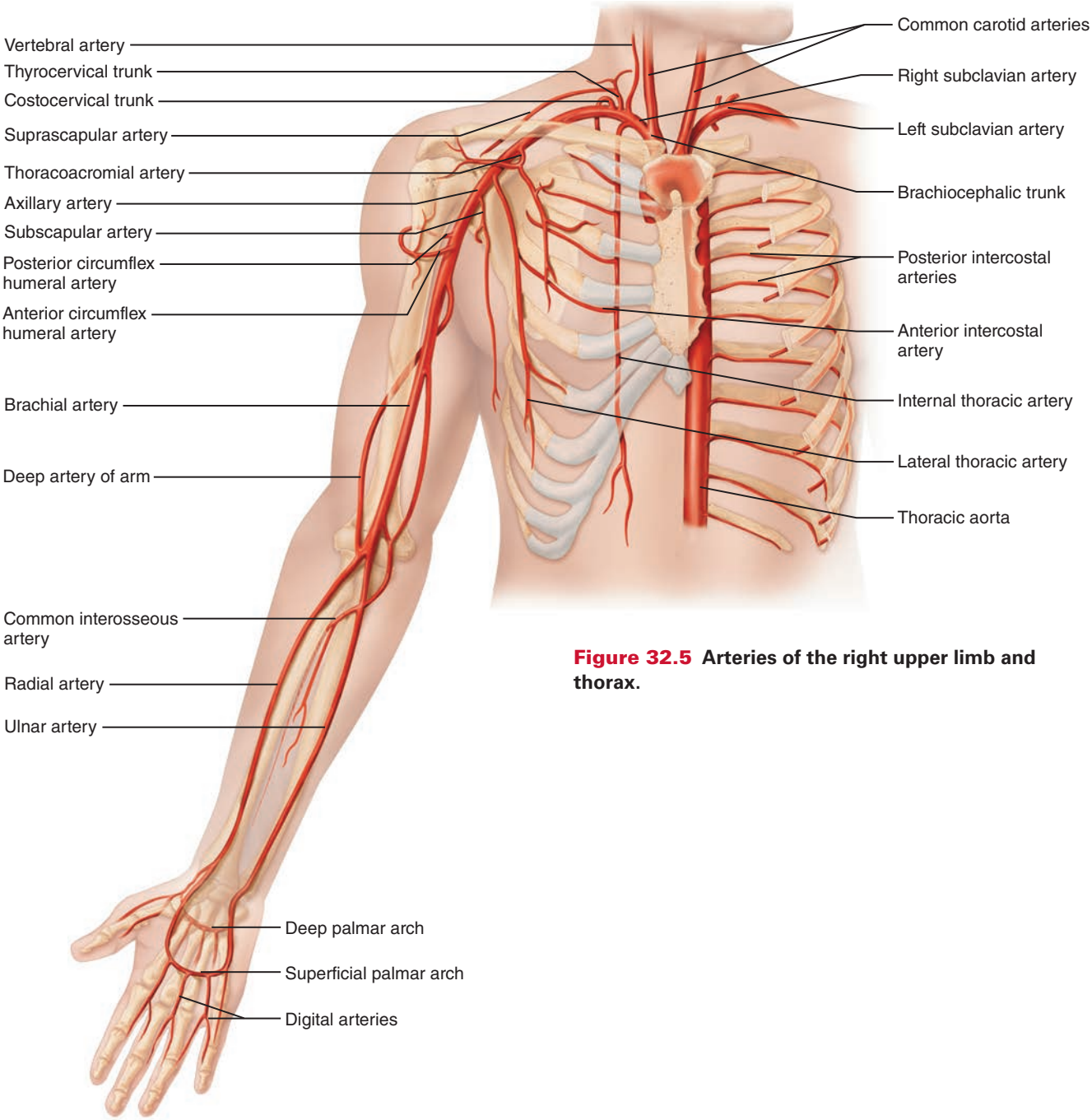

Figure 32.5 **Arteries of the right upper limb and thorax.**

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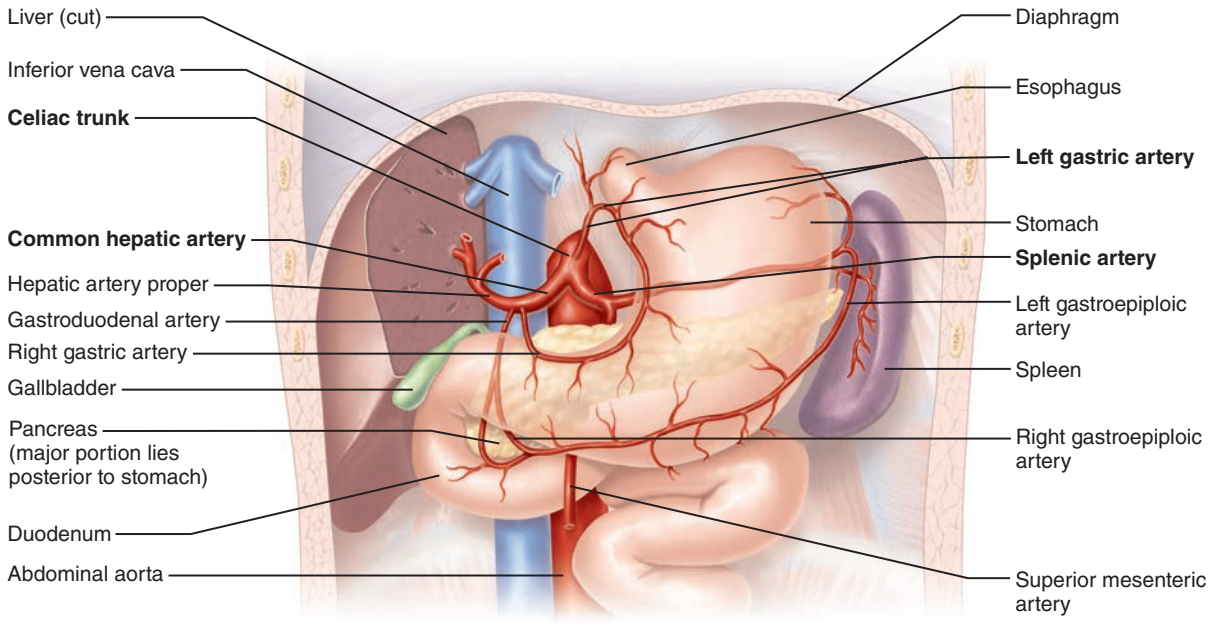
Table 32.3 **The Aorta: Thoracic Aorta (Figure 32.3)** (Note that many of these arteries vary in number from person to person)

Visceral thoracic aorta branches	Structures served
Pericardial arteries	Pericardium, the serous membrane of the heart
Bronchial arteries	Bronchi, bronchioles, and lungs
Esophageal arteries	Esophagus
Mediastinal arteries	Posterior mediastinum
Parietal thoracic aorta branches	**Structures served**
Posterior intercostal arteries (inferior pairs)	Intercostal muscles, spinal cord, vertebrae, and skin
Subcostal arteries	Intercostal muscles, spinal cord, vertebrae, and skin
Superior phrenic arteries	Posterior, superior part of the diaphragm



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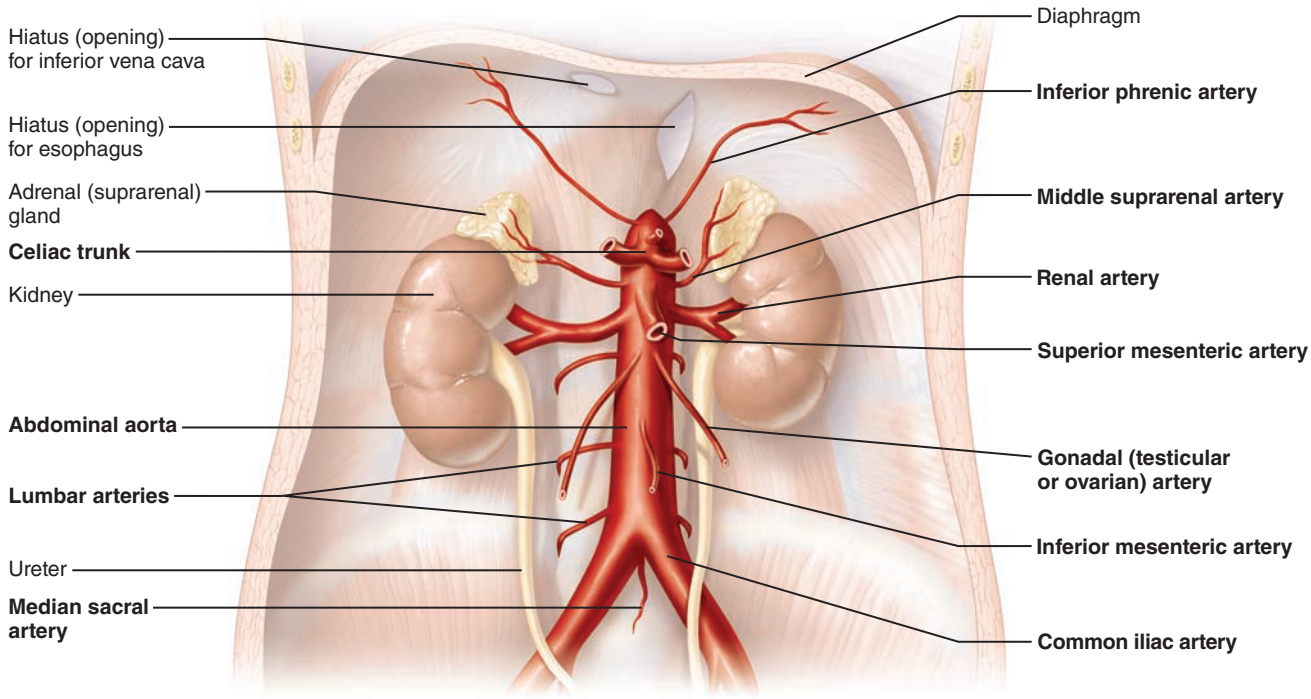

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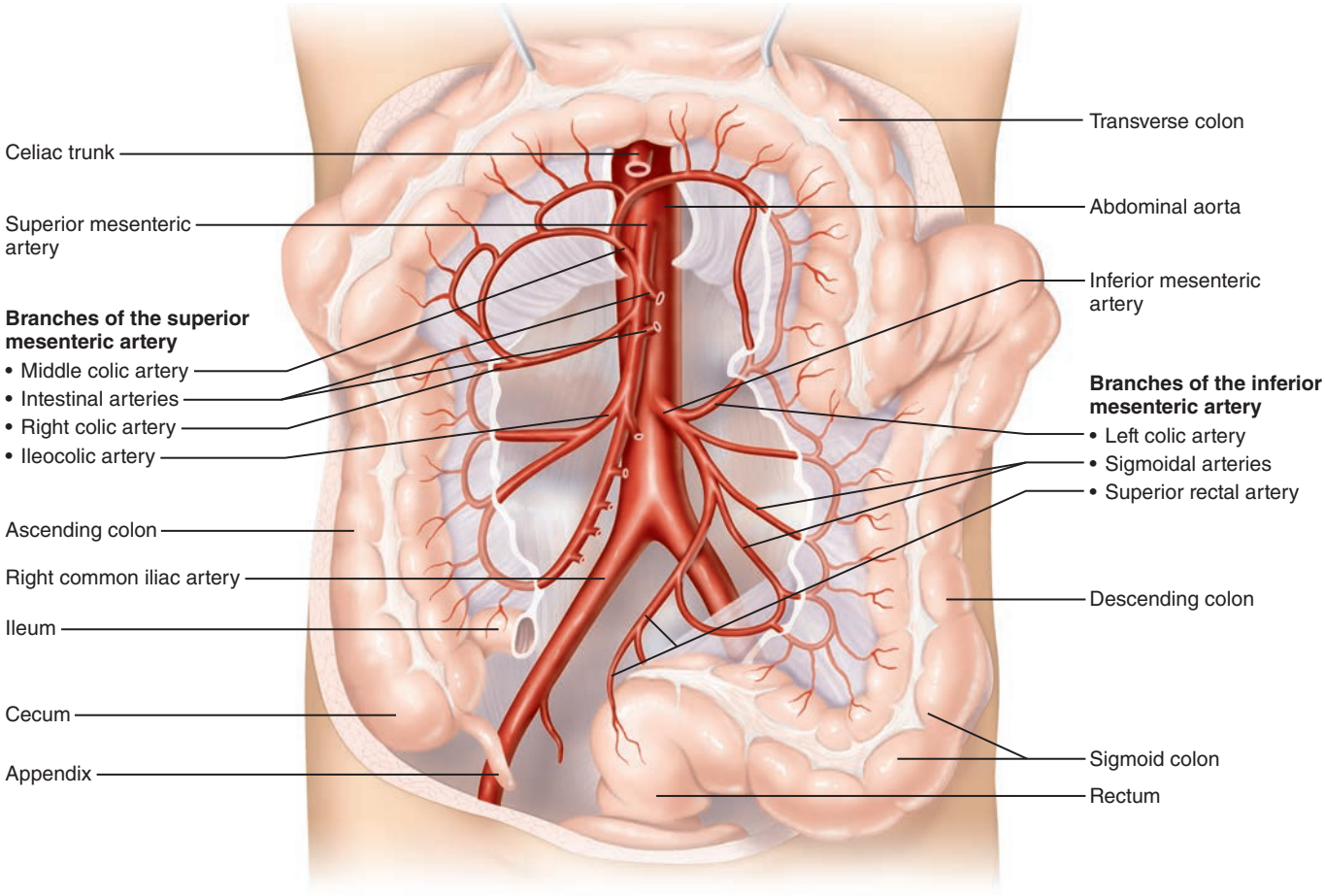
Figure 32.6 Arteries of the abdomen. (a) The celiac trunk and its major branches. **(b)** Major branches of the abdominal aorta.



(c)

Figure 32.6 *(continued)* **(c)** Distribution of the superior and inferior mesenteric arteries, transverse colon pulled superiorly.

Table 32.4 The Aorta: Abdominal Aorta (Figure 32.6)

Branches	Structures served
Inferior phrenic arteries	Inferior surface of the diaphragm
Celiac trunk: left gastric artery	Stomach and esophagus
Celiac trunk: splenic artery	Branches to the spleen; short gastric arteries branch to the stomach; and the left gastroepiploic artery branches to the stomach
Celiac trunk: common hepatic artery	Branches into the hepatic artery proper (its branches serve the liver, gallbladder, and stomach) and the gastroduodenal artery (its branches serve the stomach, pancreas, and duodenum)
Superior mesenteric artery	Most of the small intestine and the first part of the large intestine
Middle suprarenal arteries	Adrenal glands that sit on top of the kidneys
Renal arteries	Kidneys
Gonadal arteries	Ovarian arteries (female) – ovaries Testicular arteries (male) – testes
Inferior mesenteric artery	Distal portion of the large intestine
Lumbar arteries	Posterior abdominal wall
Median sacral artery	Sacrum and coccyx
Common iliac arteries	The distal abdominal aorta splits to form the left and right common iliac arteries, which serve the pelvic organs, lower abdominal wall, and the lower limbs

Arteries Serving the Lower Limbs

Each of the common iliac arteries extends for about 5 cm (2 inches) into the pelvis before it divides into the internal and external iliac arteries (**Figure 32.7**). The **internal iliac artery** supplies the gluteal muscles via the **superior** and **inferior gluteal arteries,** and the adductor muscles of the medial thigh via the **obturator artery,** as well as the external genitalia and perineum (via the *internal pudendal artery,* not illustrated).

The **external iliac artery** supplies the anterior abdominal wall and the lower limb. As it continues into the thigh, its name changes to **femoral artery.** Proximal branches of the femoral artery, the **circumflex femoral arteries,** supply the head and neck of the femur and the hamstring muscles. The femoral artery gives off a deep branch, the **deep artery of the thigh** (also called the *deep femoral artery*), which is the main supply to the thigh muscles (hamstrings, quadriceps, and adductors). In the knee region, the femoral artery briefly becomes the **popliteal artery;** its subdivisions—the **anterior** and **posterior tibial arteries**—supply the leg, ankle, and foot. The posterior tibial, which supplies flexor muscles, gives off one main branch, the **fibular artery,** that serves the lateral calf (fibular muscles). It then divides into the **lateral** and **medial plantar arteries,** which supply blood to the sole of the foot. The anterior tibial artery supplies the extensor muscles and terminates with the **dorsalis pedis artery.** The dorsalis pedis supplies the dorsum of the foot and continues on as the **arcuate artery,** which issues the **dorsal metatarsal arteries** to the metatarsus of the foot. The dorsalis pedis is often palpated in patients with circulation problems of the leg to determine the circulatory efficiency to the limb as a whole.

☐ Palpate your own dorsalis pedis artery.

Check the box when you have completed this task.

Activity 2

Locating Arteries on an Anatomical Chart or Model

Now that you have identified the arteries in Figures 32.3–32.7, attempt to locate and name them (without a reference) on a large anatomical chart or three-dimensional model of the vascular system.

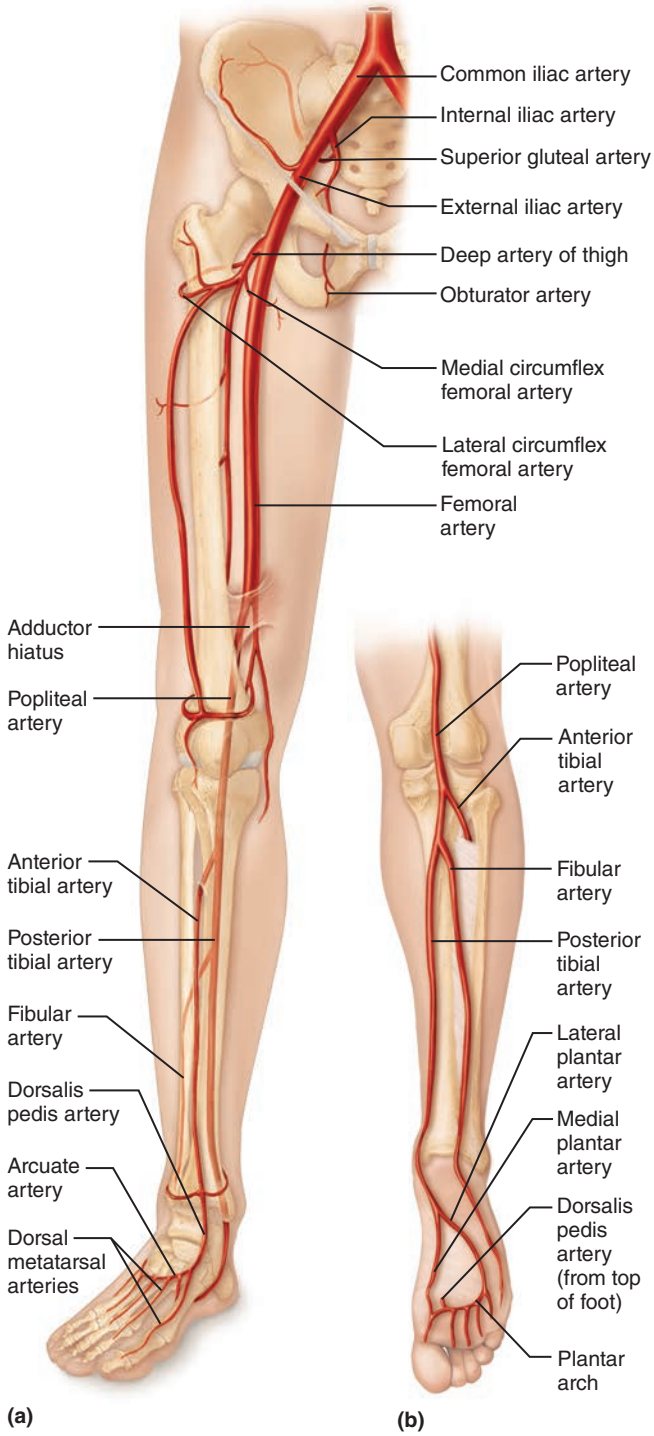


Figure 32.7 **Arteries of the right pelvis and lower limb.** **(a)** Anterior view. **(b)** Posterior view.

Major Systemic Veins of the Body

Arteries are generally located in deep, well-protected body areas. However, many veins follow a more superficial course and are often easily seen and palpated on the body surface. Most deep veins parallel the course of the major arteries, and in many cases the naming of the veins and arteries is identical except for the designation of the vessels as veins. Whereas the major systemic arteries branch off the aorta, the veins tend to converge on the venae cavae, which enter the right atrium of the heart. Veins draining the head and upper extremities empty into the **superior vena cava,** and those draining the lower body empty into the **inferior vena cava.** **Figure 32.8**, a schematic of the systemic veins and their relationship to the venae cavae, will get you started.

Veins Draining into the Inferior Vena Cava

The inferior vena cava, a much longer vessel than the superior vena cava, returns blood to the heart from all body regions

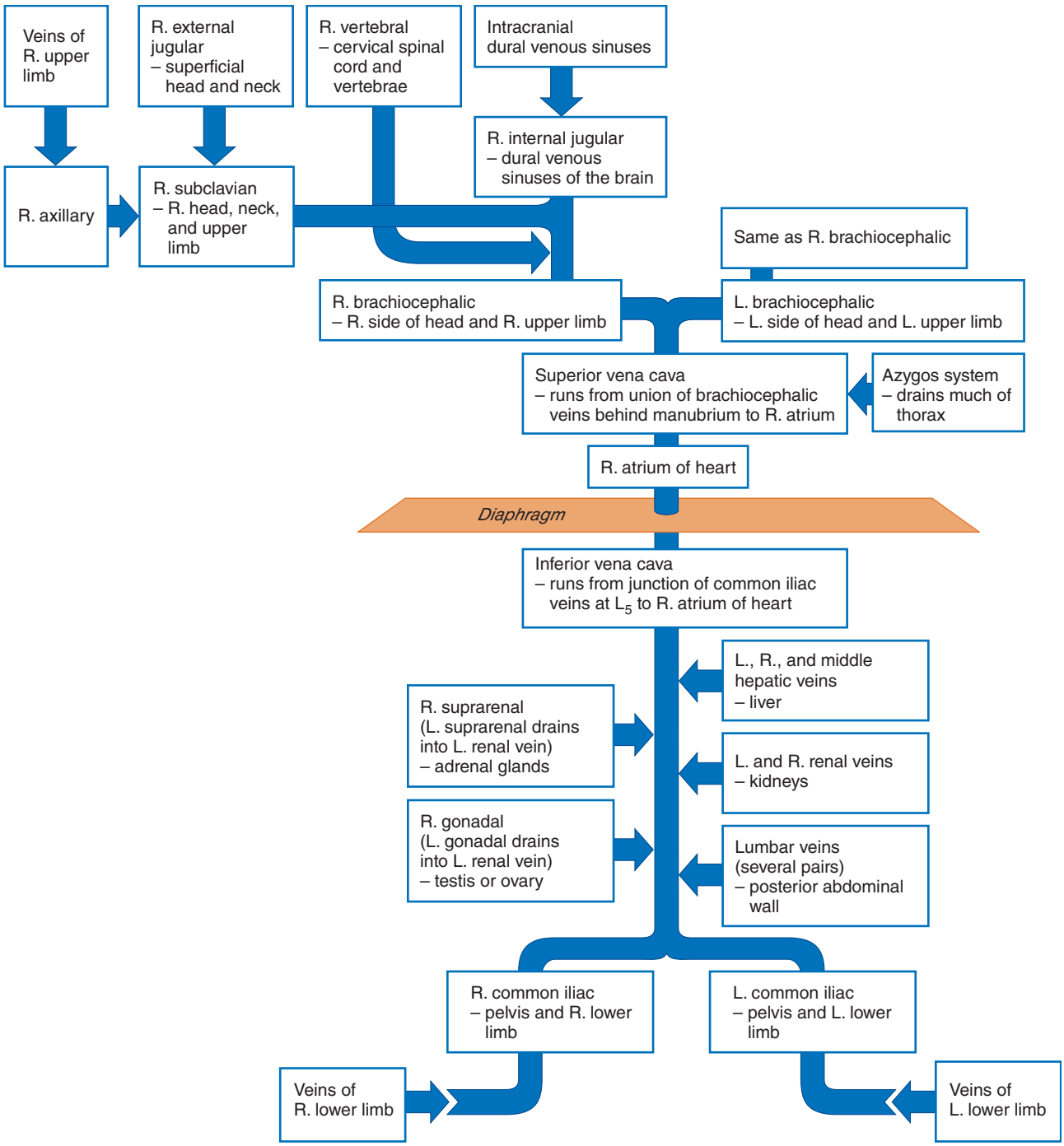


Figure 32.8 **Schematic of systemic venous circulation.**

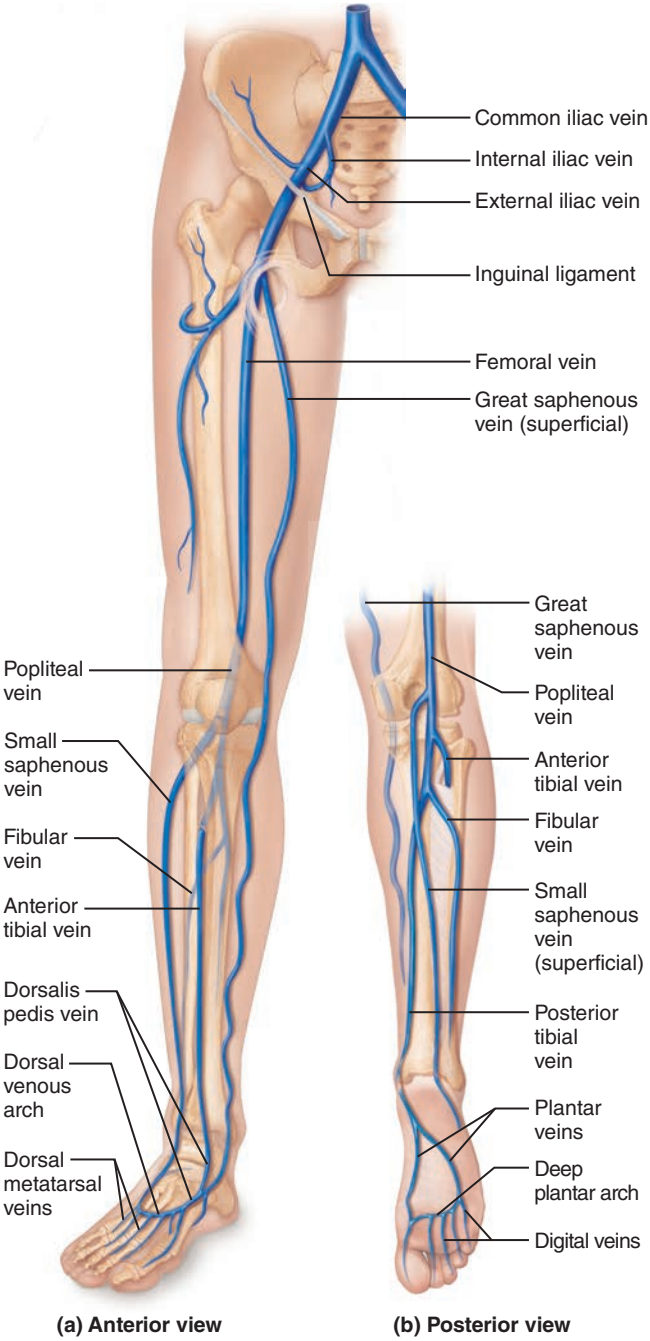


Figure 32.9 Veins of the right pelvis and lower limb. **(a)** Anterior view. **(b)** Posterior view.

below the diaphragm (see Figure 32.8). It begins in the lower abdominal region with the union of the paired **common iliac veins,** which drain venous blood from the legs and pelvis.

Veins of the Lower Limbs

Each common iliac vein is formed by the union of the **internal iliac vein,** draining the pelvis, and the **external iliac vein,** which receives venous blood from the lower limb (**Figure 32.9**). Veins of the leg include the **anterior** and **posterior tibial veins,** which serve the calf and foot. The anterior tibial vein is a superior continuation of the **dorsalis pedis vein** of the foot. The posterior tibial vein is formed by the union of the **medial** and **lateral plantar veins,** and ascends deep in the calf muscles. It receives the **fibular vein** in the calf and then joins with the anterior tibial vein at the knee to produce the **popliteal vein,** which crosses the back of the knee. The popliteal vein becomes the **femoral vein** in the thigh; the femoral vein in turn becomes the external iliac vein in the inguinal region.

The **great saphenous vein,** a superficial vein, is the longest vein in the body. Beginning in common with the **small saphenous vein** from the **dorsal venous arch,** it extends up the medial side of the leg, knee, and thigh to empty into the femoral vein. The small saphenous vein runs along the lateral aspect of the foot and through the calf muscle, which it drains, and then empties into the popliteal vein at the knee (Figure 32.9b).

Veins of the Abdomen

Moving superiorly in the abdominal cavity (**Figure 32.10**), the inferior vena cava receives blood from the posterior abdominal wall via several pairs of **lumbar veins,** and from the right ovary or testis via the **right gonadal vein.** (The **left gonadal [ovarian or testicular] vein** drains into the left renal vein superiorly.) The paired **renal veins** drain the kidneys. Just above the right renal vein, the **right suprarenal vein** (receiving blood from the adrenal gland on the same side) drains into the inferior vena cava, but its partner, the **left suprarenal vein,** empties into the left renal vein inferiorly. The **hepatic veins** drain the liver. The unpaired veins draining the digestive tract organs empty into a special vessel, the hepatic portal vein, which carries blood to the liver to be processed before it enters the systemic venous system. (The hepatic portal system is discussed separately on p. 486.)

Veins Draining into the Superior Vena Cava

Veins draining into the superior vena cava are named from the superior vena cava distally, *but remember that the flow of blood is in the opposite direction*.

Veins of the Head and Neck

The **right** and **left brachiocephalic veins** drain the head, neck, and upper extremities and unite to form the superior vena cava (**Figure 32.11**). Notice that although there is only one brachiocephalic artery, there are two brachiocephalic veins.

Branches of the brachiocephalic veins include the internal jugular, vertebral, and subclavian veins. The **internal jugular veins** are large veins that drain the superior sagittal sinus and other **dural sinuses** of the brain. As they run inferiorly, they receive blood from the head and neck via the **superficial temporal** and **facial veins.** The **vertebral veins** drain the posterior aspect of the head including the cervical vertebrae and spinal cord. The **subclavian veins** receive venous blood from the upper extremity. The **external jugular vein** joins the subclavian vein near its origin to return the venous drainage of the extracranial (superficial) tissues of the head and neck.

Veins of the Upper Limb and Thorax

As the subclavian vein passes through the axilla, it becomes the **axillary vein** and then the **brachial vein** as it courses along the posterior aspect of the humerus (**Figure 32.12**, p. 484). The brachial vein is formed by the union of the deep **radial** and **ulnar veins** of the forearm. The superficial venous

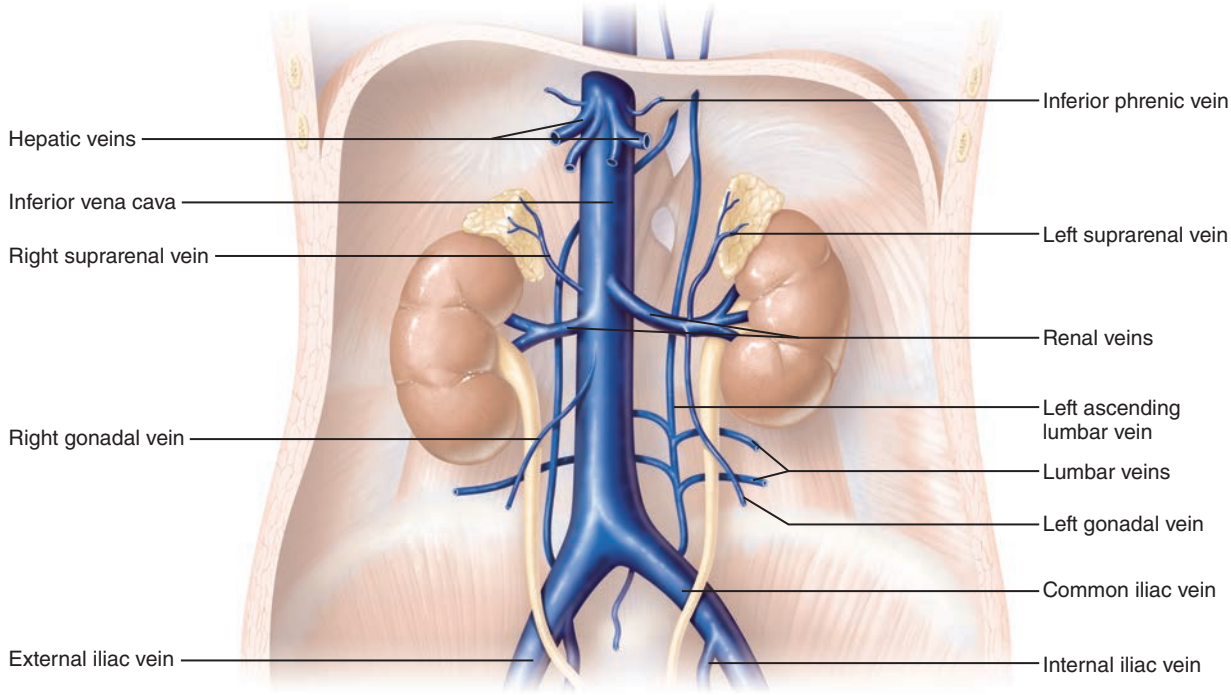


Figure 32.10 Venous drainage of abdominal organs not drained by the hepatic portal vein.

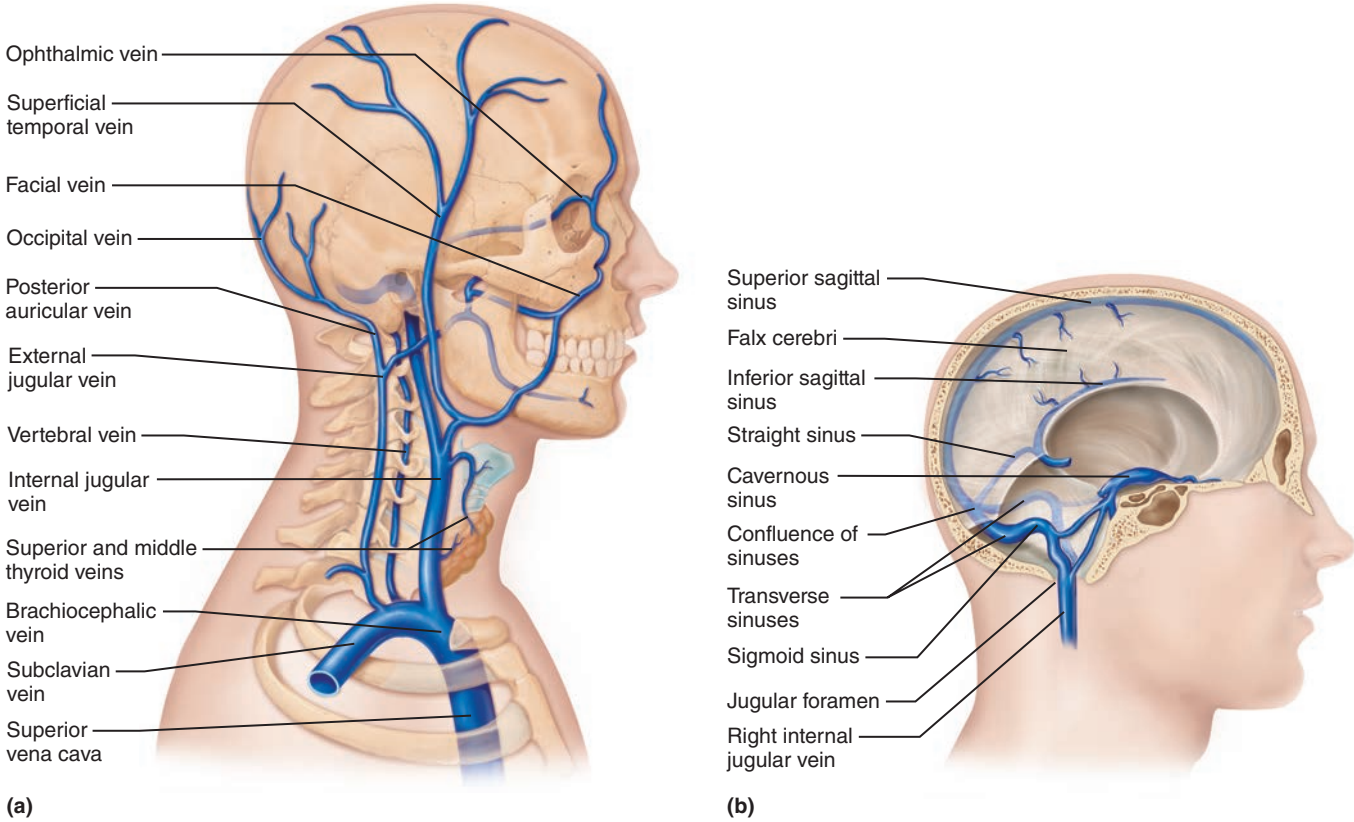


Figure 32.11 Venous drainage of the head, neck, and brain. (a) Veins of the head and neck, right superficial aspect. **(b)** Dural sinuses of the brain, right aspect.

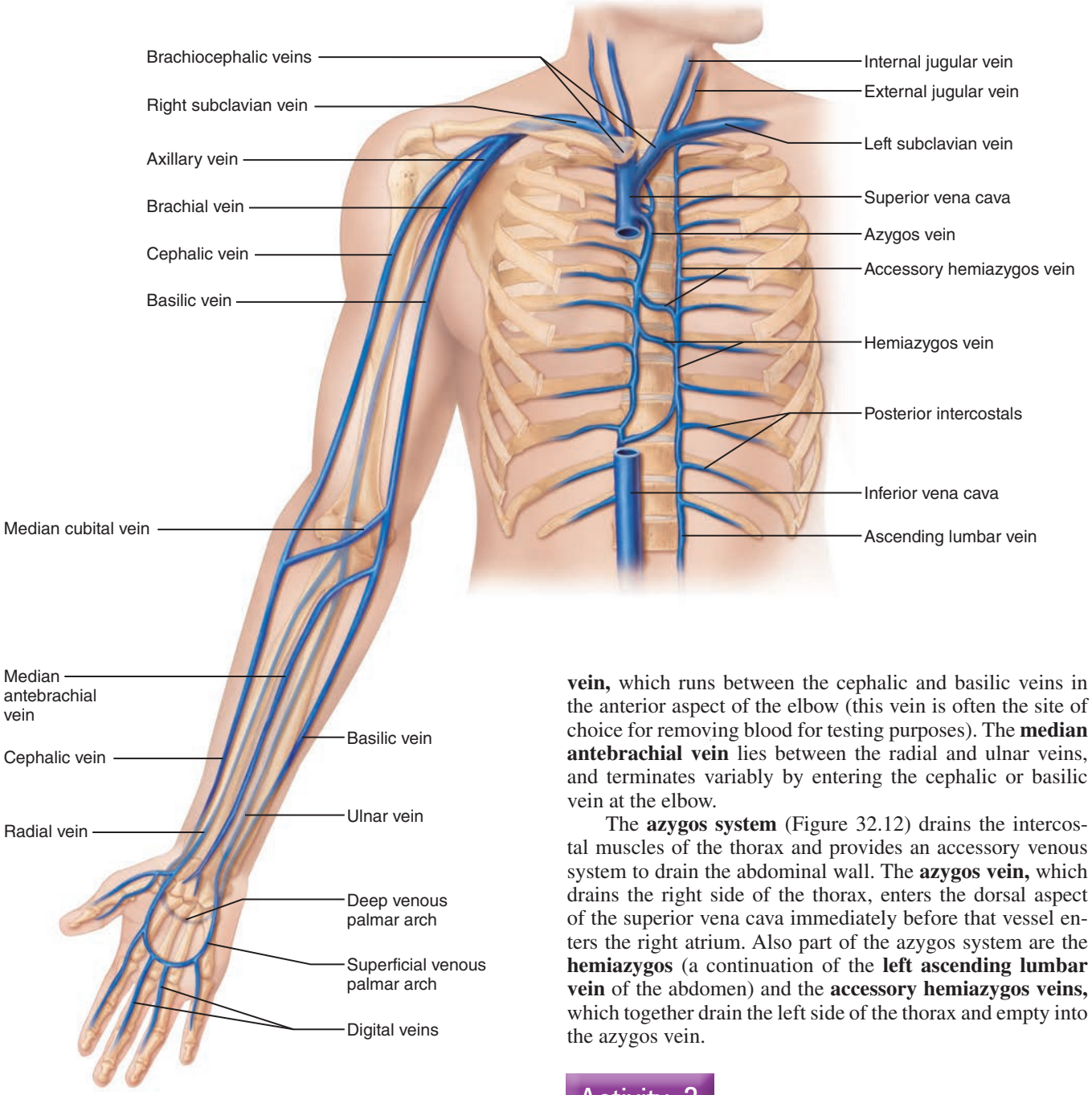


Figure 32.12 Veins of the thorax and right upper limb. For clarity, the abundant branching and anastomoses of these vessels are not shown.

drainage of the arm includes the **cephalic vein,** which courses along the lateral aspect of the arm and empties into the axillary vein; the **basilic vein,** found on the medial aspect of the arm and entering the brachial vein; and the **median cubital vein,** which runs between the cephalic and basilic veins in the anterior aspect of the elbow (this vein is often the site of choice for removing blood for testing purposes). The **median antebrachial vein** lies between the radial and ulnar veins, and terminates variably by entering the cephalic or basilic vein at the elbow.

The **azygos system** (Figure 32.12) drains the intercostal muscles of the thorax and provides an accessory venous system to drain the abdominal wall. The **azygos vein,** which drains the right side of the thorax, enters the dorsal aspect of the superior vena cava immediately before that vessel enters the right atrium. Also part of the azygos system are the **hemiazygos** (a continuation of the **left ascending lumbar vein** of the abdomen) and the **accessory hemiazygos veins,** which together drain the left side of the thorax and empty into the azygos vein.

Activity 3

Identifying the Systemic Veins

Identify the important veins of the systemic circulation on the large anatomical chart or model without referring to the figures.

Special Circulations

Pulmonary Circulation

The pulmonary circulation (discussed previously in relation to heart anatomy on p. 448) differs in many ways from systemic circulation because it does not serve the metabolic needs of the body tissues with which it is associated (in this case, lung tissue). It functions instead to bring the blood into close contact with the alveoli of the lungs to permit gas exchanges that rid the blood of excess carbon dioxide and replenish its supply of vital oxygen. The arteries of the pulmonary circulation are structurally much like veins, and they create a low-pressure bed in the lungs. (If the arterial pressure in the systemic circulation is 120/80, the pressure in the pulmonary artery is likely to be approximately 24/8.) The functional blood supply of the lungs is provided by the **bronchial arteries** (not shown), which diverge from the thoracic portion of the descending aorta.

Pulmonary circulation begins with the large **pulmonary trunk,** which leaves the right ventricle and divides into the **right** and **left pulmonary arteries** about 5 cm (2 inches) above its origin. The right and left pulmonary arteries plunge into the lungs, where they subdivide into **lobar arteries** (three on the right and two on the left). The lobar arteries accompany the main bronchi into the lobes of the lungs and branch extensively within the lungs to form arterioles, which finally terminate in the capillary networks surrounding the alveolar sacs of the lungs. Diffusion of the respiratory gases occurs across the walls of the alveoli and **pulmonary capillaries.** The pulmonary capillary beds are drained by venules, which converge to form sequentially larger veins and finally the four **pulmonary veins** (two leaving each lung), which return the blood to the left atrium of the heart.

Activity 4

Identifying Vessels of the Pulmonary Circulation

Find the vessels of the pulmonary circulation in **Figure 32.13** and on an anatomical chart (if one is available).

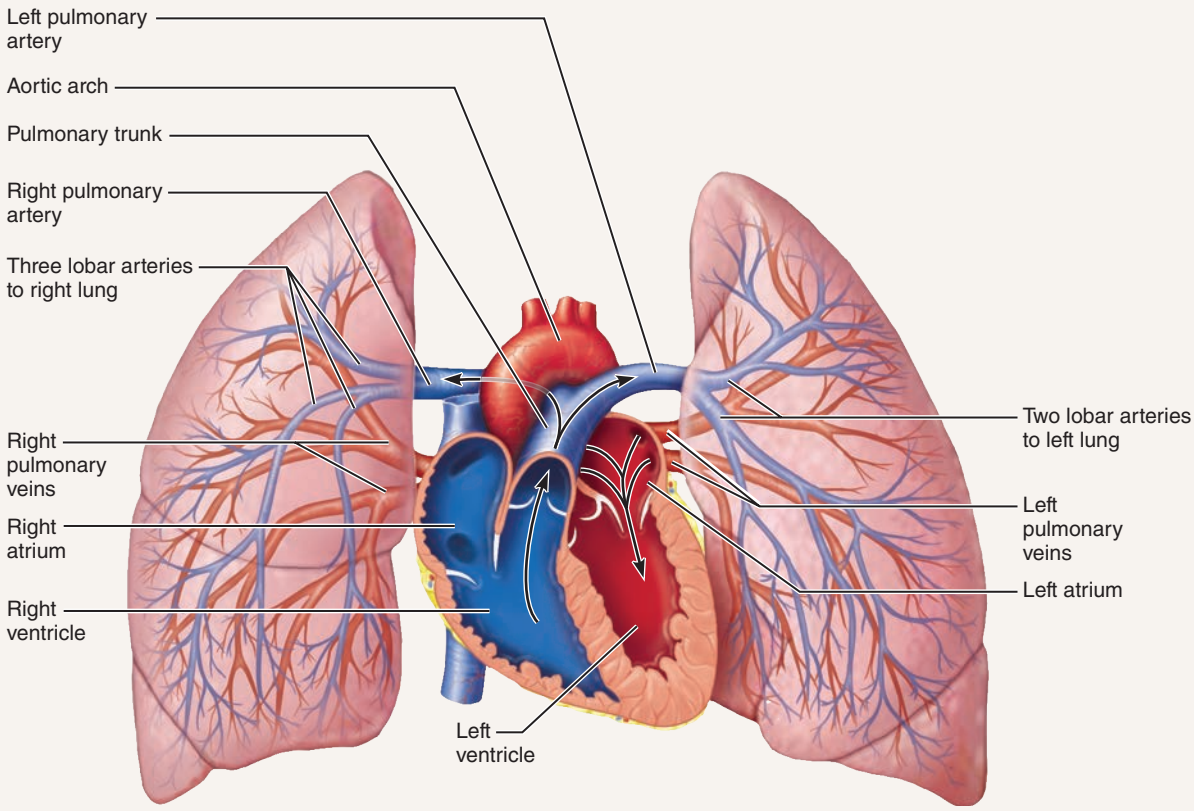


Figure 32.13 The pulmonary circulation. The pulmonary arterial system is shown in blue to indicate that the blood it carries is relatively oxygen-poor. The pulmonary venous drainage is shown in red to indicate that the blood it transports is oxygen-rich.

Group Challenge

Fix the Blood Trace

Several artery or vein sequences are listed below. Working in small groups, decide whether each sequence of blood vessels is correct or whether a blood vessel is missing. If correct, simply write "all correct." If incorrect, list the missing vessel, and draw an insertion mark ("v") on the arrow to indicate where the vessel would be located in the sequence. Refrain from using a figure or other reference to help with your decision. Instead, try to find the answers by working together. Note: The missing vessel will not be at the beginning or end of the sequence.

1. aortic arch → R. subclavian artery → R. axillary artery → R. brachial artery → R. radial artery → R. superficial palmar arch

_____

2. abdominal aorta → R. common iliac artery → R. femoral artery → R. popliteal artery → R. anterior tibial artery → R. dorsalis pedis artery

_____

3. ascending aorta → aortic arch → L. common carotid artery → L. internal carotid artery → L. anterior cerebral artery

_____

4. R. median antebrachial vein → R. basilic vein → R. axillary vein → R. brachiocephalic vein → superior vena cava

_____

Fetal Circulation

In a developing fetus, the lungs and digestive system are not yet functional, and all nutrient, excretory, and gaseous exchanges occur through the placenta (**Figure 32.14a**). Nutrients and oxygen move across placental barriers from the mother's blood into fetal blood, and carbon dioxide and other metabolic wastes move from the fetal blood supply to the mother's blood.

Activity 5

Tracing the Pathway of Fetal Blood Flow

Trace the pathway of fetal blood flow using Figure 32.14a and an anatomical chart (if available). Locate all the named vessels. Identify the named remnants of the foramen ovale and fetal vessels (refer to Figure 32.14b).

Fetal blood travels through the umbilical cord, which contains three blood vessels: one large umbilical vein and two smaller umbilical arteries. The **umbilical vein** carries blood rich in nutrients and oxygen to the fetus; the **umbilical arteries** carry blood laden with carbon dioxide and waste from the fetus to the placenta. The umbilical arteries, which transport blood away from the fetal heart, meet the umbilical vein at the *umbilicus* and wrap around the vein within the cord en route to their placental attachments. Newly oxygenated blood flows in the umbilical vein superiorly toward the fetal heart. Some of this blood perfuses the liver, but the larger proportion is ducted through the relatively nonfunctional liver to the inferior vena cava via a shunt vessel called the **ductus venosus,** which carries the blood to the right atrium of the heart.

Because fetal lungs are nonfunctional and collapsed, two shunting mechanisms ensure that blood almost entirely bypasses the lungs. Much of the blood entering the right atrium is shunted into the left atrium through the **foramen ovale,** a flaplike opening in the interatrial septum. The left ventricle then pumps the blood out the aorta to the systemic circulation. Blood that does enter the right ventricle and is pumped out of the pulmonary trunk encounters a second shunt, the **ductus arteriosus,** a short vessel connecting the pulmonary trunk and the aorta. Because the collapsed lungs present an extremely high-resistance pathway, blood more readily enters the systemic circulation through the ductus arteriosus.

The aorta carries blood to the tissues of the body; this blood ultimately finds its way back to the placenta via the umbilical arteries. The only fetal vessel that carries highly oxygenated blood is the umbilical vein. All other vessels contain varying degrees of oxygenated and deoxygenated blood.

At birth, or shortly after, the foramen ovale closes and becomes the **fossa ovalis,** and the ductus arteriosus collapses and is converted to the fibrous **ligamentum arteriosum** (Figure 32.14b). Lack of blood flow through the umbilical vessels leads to their eventual obliteration, and the circulatory pattern becomes that of the adult. Remnants of the umbilical arteries persist as the **medial umbilical ligaments** on the inner surface of the anterior abdominal wall; the occluded umbilical vein becomes the **ligamentum teres** (or **round ligament** of the liver); and the ductus venosus becomes a fibrous band called the **ligamentum venosum** on the inferior surface of the liver.

Hepatic Portal Circulation

Blood vessels of the hepatic portal circulation drain the digestive viscera, spleen, and pancreas and deliver this blood to the liver for processing via the **hepatic portal vein** (formed by the union of the splenic and superior mesenteric veins). If a meal has recently been eaten, the hepatic portal blood will be nutrient-rich. The liver is the key body organ involved in maintaining proper sugar, fatty acid, and amino acid concentrations in the blood, and this system ensures that these substances pass through the liver before entering the systemic circulation. As blood travels through the liver sinusoids, some of the nutrients are removed to be stored or processed in various ways for release to the general circulation. At the same time, the hepatocytes are detoxifying alcohol and other possibly harmful chemicals present in the blood, and the liver's macrophages are removing bacteria and other debris from the passing blood. The liver in turn is drained by the hepatic veins that enter the inferior vena cava.

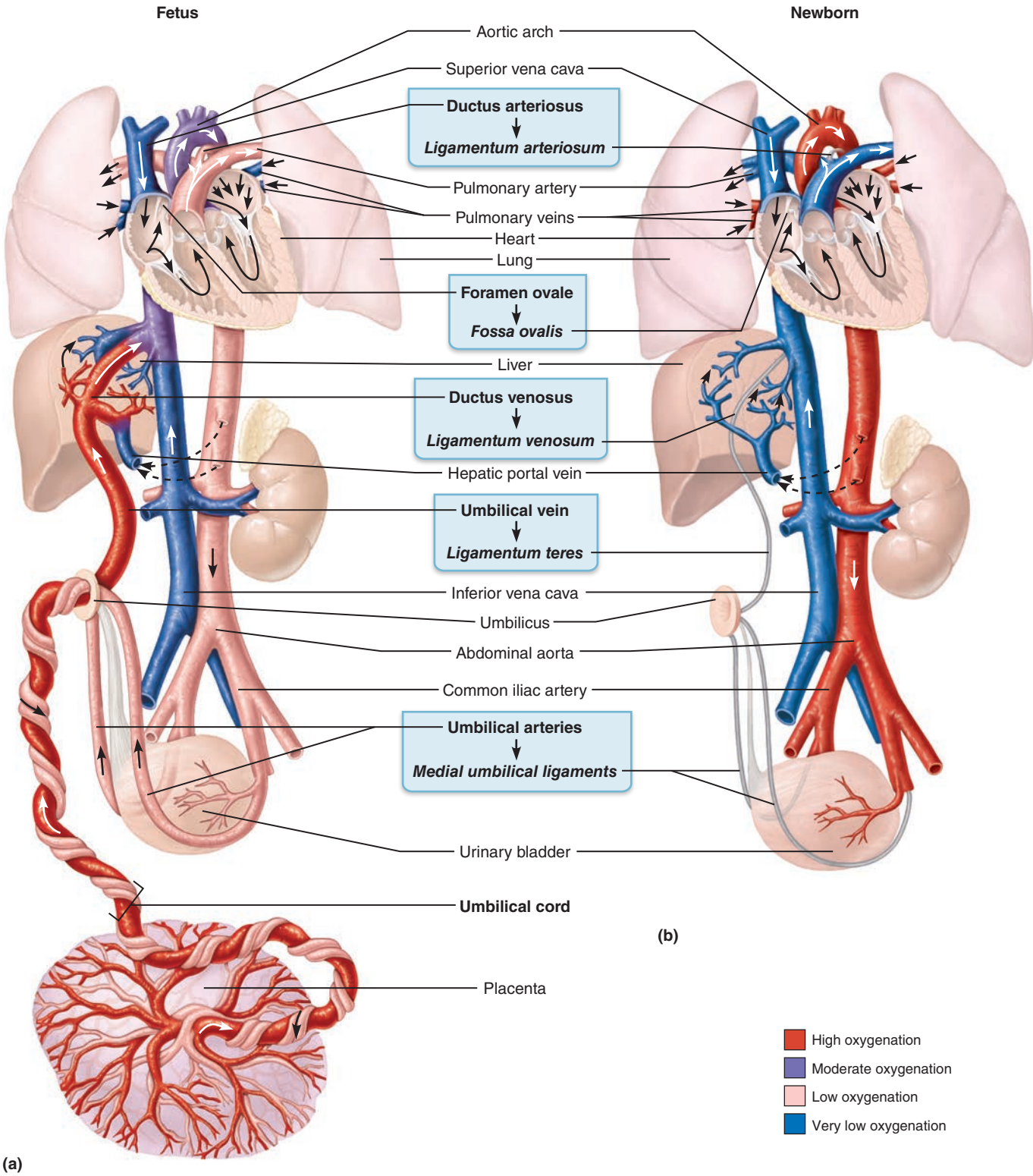


Figure 32.14 Circulation in the fetus and newborn. Arrows indicate direction of blood flow. Arrows in the blue boxes go from the fetal structure to what it becomes after birth (the postnatal structure). **(a)** Special adaptations for embryonic and fetal life. The umbilical vein (red) carries oxygen- and nutrient-rich blood from the placenta to the fetus. The umbilical arteries (pink) carry waste-laden blood from the fetus to the placenta. **(b)** Changes in the cardiovascular system at birth. The umbilical vessels are occluded, as are the liver and lung bypasses (ductus venosus and arteriosus, and the foramen ovale).

Activity 6

Tracing the Hepatic Portal Circulation

Locate on **Figure 32.15** and on an anatomical chart of the hepatic portal circulation (if available), the vessels named below.

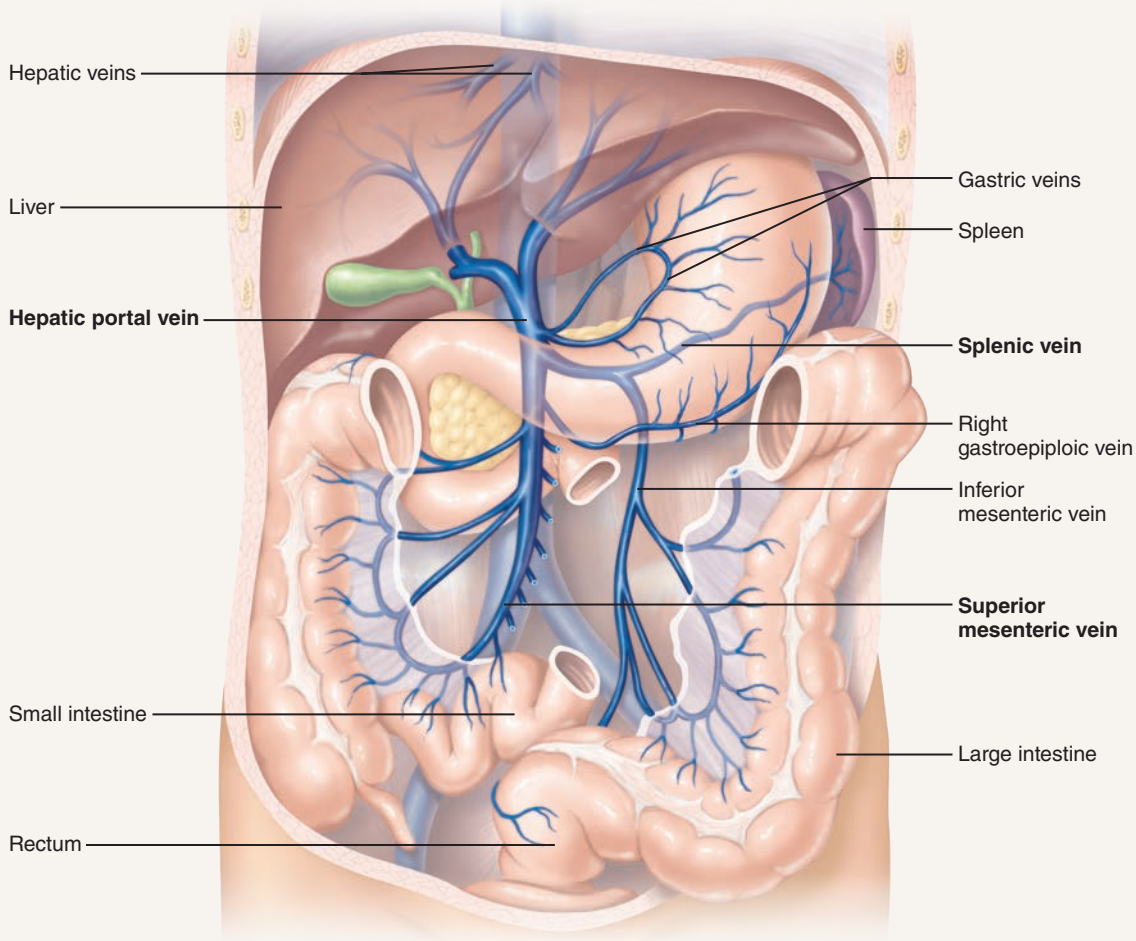


Figure 32.15 Hepatic portal circulation.

The **splenic vein** carries blood from the spleen, parts of the pancreas, and the stomach. The splenic vein unites with the **superior mesenteric vein** to form the hepatic portal vein. The superior mesenteric vein drains the small intestine, part of the large intestine, and the stomach. The **inferior mesenteric vein,** which drains the distal portion of the large intestine and rectum, empties into the splenic vein just before the splenic vein merges with the superior mesenteric vein.

For instructions on animal dissections, see the dissection exercises (starting on p. 705) in the cat and fetal pig editions of this manual.

EXERCISE 32

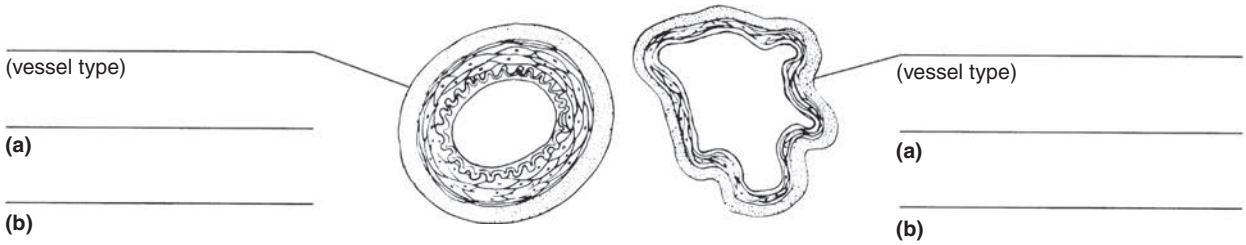
REVIEW SHEET

Anatomy of Blood Vessels

Name _____ Lab Time/Date _____

Microscopic Structure of the Blood Vessels

1. Cross-sectional views of an artery and of a vein are shown here. Identify each; on the lines to the sides, note the structural details that enabled you to make these identifications:



Now describe each tunic more fully by selecting its characteristics from the key below and placing the appropriate key letters on the answer lines.

Tunica intima _____ Tunica media _____ Tunica externa _____

Key:

a. innermost tunic
b. most superficial tunic
c. thin tunic of capillaries
d. regulates blood vessel diameter
e. contains smooth muscle and elastin
f. has a smooth surface to decrease resistance to blood flow

2. Why are valves present in veins but not in arteries? _____

3. Name two events *occurring within the body* that aid in venous return.

_____ and _____

4. Considering their functional differences, why do you think the walls of arteries are proportionately thicker than those of the corresponding veins? _____

Major Systemic Arteries and Veins of the Body

5. Use the key on the right to identify the arteries or veins described on the left. Some terms are used more than once.

_____ 1. the arterial system has one of these; the venous system has two

_____ 2. these arteries supply the myocardium

_____, _____ 3. two paired arteries serving the brain

_____ 4. longest vein in the lower limb

_____ 5. artery on the dorsum of the foot

_____ 6. main artery that serves the thigh muscles

_____ 7. supplies the diaphragm

_____ 8. formed by the union of the radial and ulnar veins

_____, _____ 9. two superficial veins of the arm

_____ 10. artery serving the kidney

_____ 11. veins draining the liver

_____ 12. artery that supplies the distal half of the large intestine

_____ 13. drains the pelvic organs

_____ 14. what the external iliac artery becomes on entry into the thigh

_____ 15. artery that branches into radial and ulnar arteries

_____ 16. supplies most of the small intestine

_____ 17. join to form the inferior vena cava

_____ 18. an arterial trunk that has three major branches, which run to the liver, spleen, and stomach

_____ 19. major artery serving the tissues external to the skull

_____, _____, _____, _____ 20. four veins serving the leg

_____ 21. artery generally used to take the pulse at the wrist

Key:

a. anterior tibial
b. basilic
c. brachial
d. brachiocephalic
e. celiac trunk
f. cephalic
g. common carotid
h. common iliac
i. coronary
j. deep artery of the thigh
k. dorsalis pedis
l. external carotid
m. femoral
n. fibular
o. great saphenous
p. hepatic
q. inferior mesenteric
r. internal carotid
s. internal iliac
t. phrenic
u. posterior tibial
v. radial
w. renal
x. subclavian
y. superior mesenteric
z. vertebral

6. What is the function of the cerebral arterial circle?

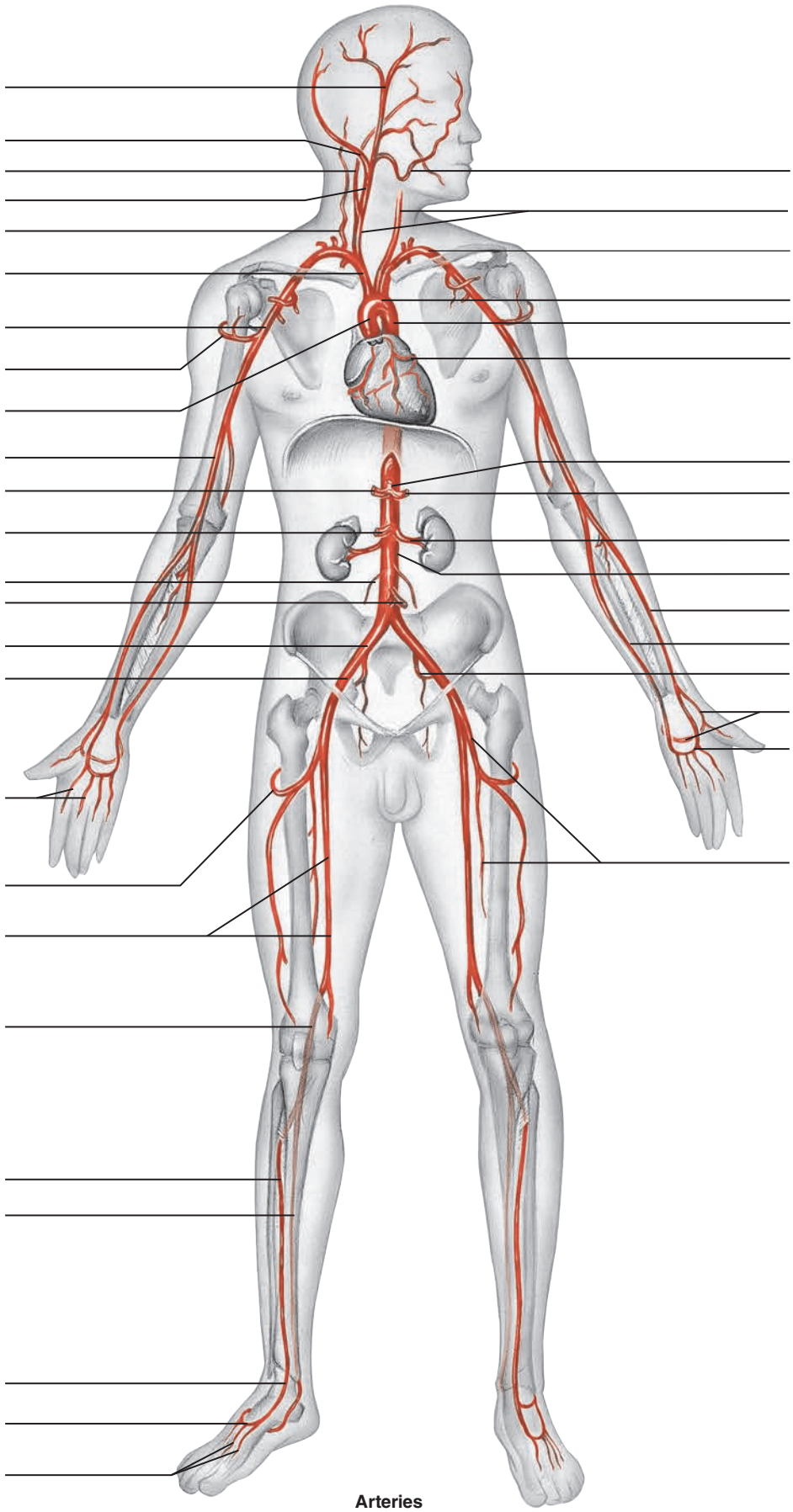
_____

7. The anterior and middle cerebral arteries arise from the _____ artery. They serve the _____ of the brain.

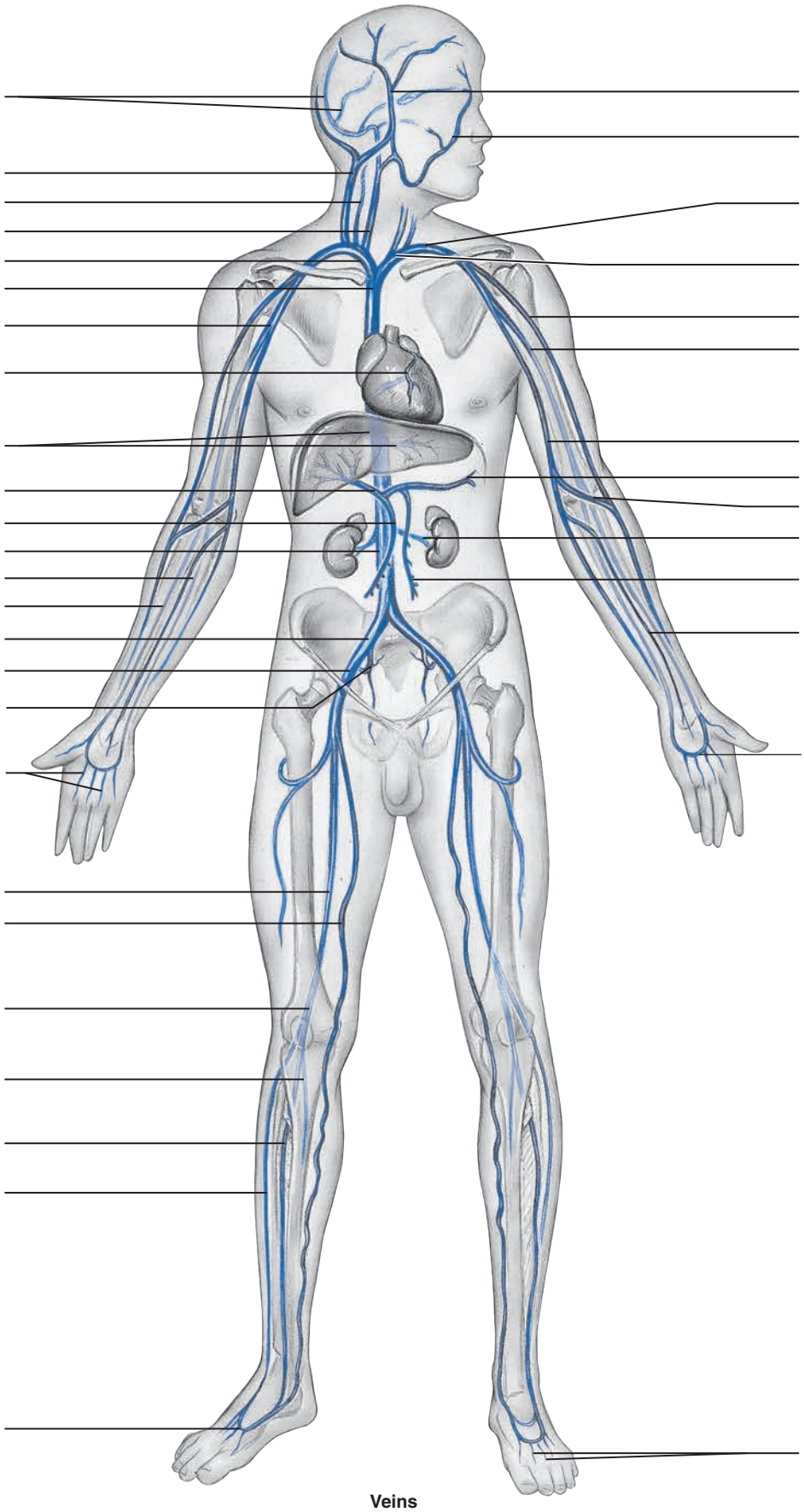
8. Trace the pathway of a drop of blood from the aorta to the left occipital lobe of the brain, noting all structures through which it flows. _____

_____

9. The human arterial and venous systems are diagrammed on this page and the next. Identify all indicated blood vessels.



Arteries



Veins

10. Trace the blood flow for each of the following situations.

a. from the capillary beds of the left thumb to the capillary beds of the right thumb:_____

b. from the mitral valve to the tricuspid valve by way of the great toe: _____

Pulmonary Circulation

11. Trace the pathway of a carbon dioxide gas molecule in the blood from the inferior vena cava until it leaves the bloodstream. Name all structures (vessels, heart chambers, and others) passed through en route.

12. Trace the pathway of oxygen gas molecules from an alveolus of the lung to the right ventricle of the heart. Name all structures through which it passes. **Circle the areas of gas exchange**. _____

13. Most arteries of the adult body carry oxygen-rich blood, and the veins carry oxygen-poor blood.

How does this differ in the pulmonary arteries and veins? _____

14. How do the arteries of the pulmonary circulation differ structurally from the systemic arteries? What condition is indicated by this anatomical difference? _____

Fetal Circulation

15. For each of the following structures, first indicate its function in the fetus; and then note its fate (what happens to it or what it is converted to after birth). **Circle the blood vessel that carries the most oxygen-rich blood.**

Structure	Function in fetus	Fate and postnatal structure
Umbilical artery		
Umbilical vein		
Ductus venosus		
Ductus arteriosus		
Foramen ovale		

16. What organ serves as a respiratory/digestive/excretory organ for the fetus? _____

Hepatic Portal Circulation

17. What is the source of blood in the hepatic portal system? _____

_____

18. Why is this blood carried to the liver before it enters the systemic circulation? _____

_____

19. The hepatic portal vein is formed by the union of the _____ and the _____.

The _____ vein carries blood from the _____, _____ and _____.

The _____ vein drains the _____, _____, and _____.

The _____ vein empties into the splenic vein and drains the _____ and _____.

20. Trace the flow of a drop of blood from the small intestine to the right atrium of the heart, noting all structures encountered or passed through on the way. _____

_____