Circulatory System

-BLOOD VESSELS AND CIRCULATION

Al-Farabi Kazakh National University
Higher School of Medicine

◆ PART I

LEARNING OUTCOMES

As a result of the lesson you will be able to:

- ***Describe the structure of a blood vessel;***
- ***Describe the types of arteries, capillaries, and veins;***
- ***Trace the general route usually taken by the blood from the heart and back again;***
- ***describe some variations on this route.***
- ***explain how blood in the veins is returned to the heart;***
- ***discuss the importance of physical activity in venous return;***
- ***discuss several causes of circulatory shock;***
- ***name and describe the stages of shock.***

Anatomy of Blood Vessels

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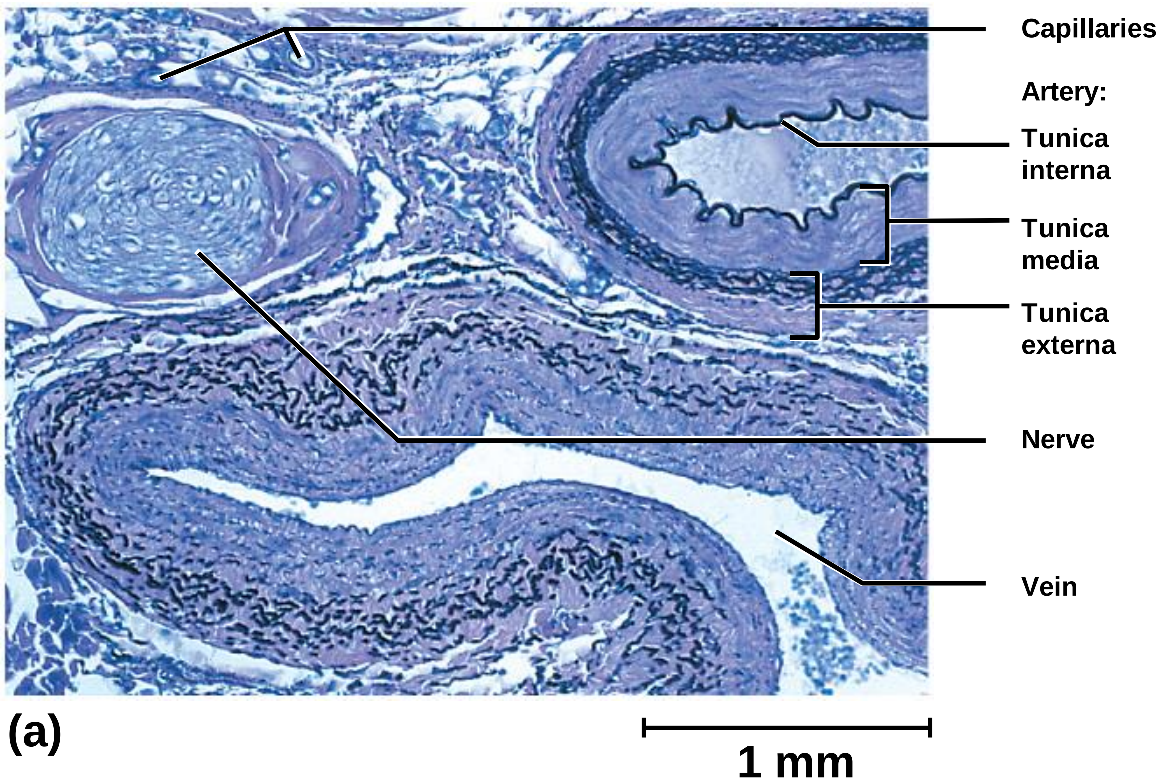

- **Arteries** carry blood away from heart
- **Veins** carry blood back to heart
- **Capillaries** connect smallest arteries to veins

Anatomy of Blood Vessels

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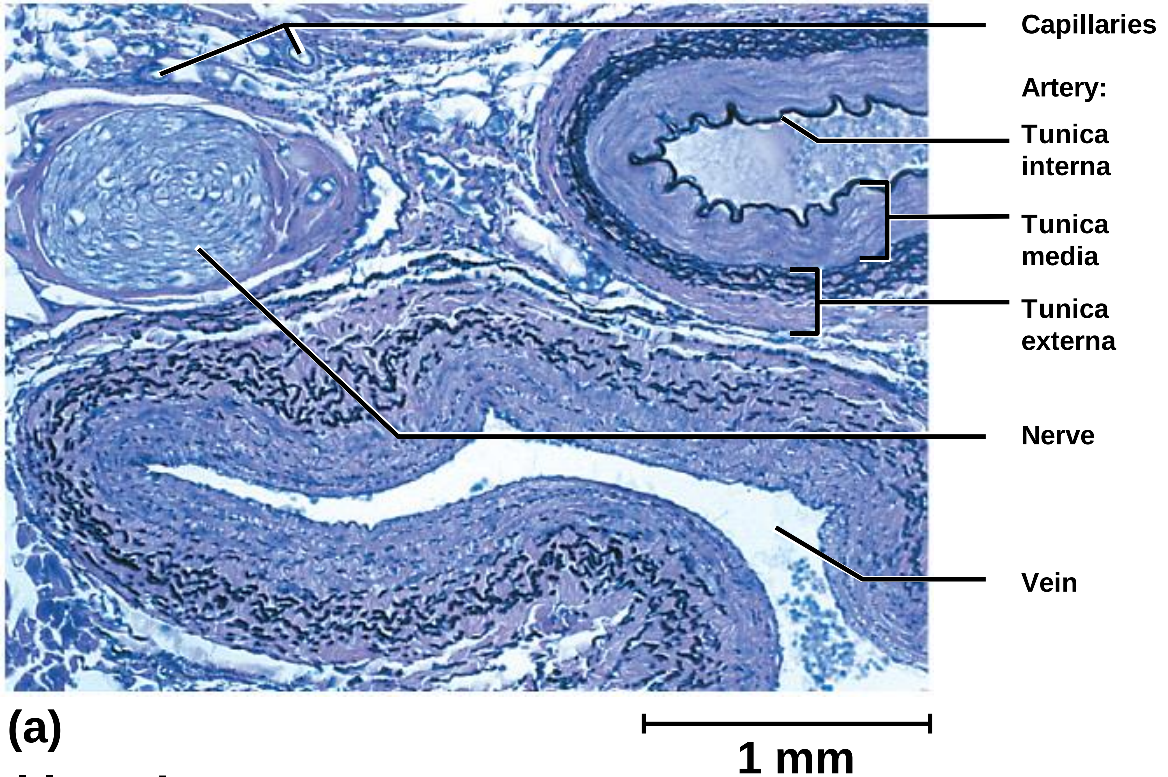


- **general location**
- **direction of blood flow**
- **histological structure of their walls - The walls of arteries and veins are composed of three layers called *tunics***

Vessel Wall

- **tunica interna** (tunica intima)
  - lines the blood vessel and is exposed to blood
  - **endothelium** – simple squamous epithelium overlying a basement membrane and a sparse layer of loose connective tissue
    - acts as a **selectively permeable barrier**
    - **secrete chemicals** that stimulate dilation or constriction of the vessel
    - normally **repels blood cells and platelets** that may adhere to it and form a clot
    - when tissue around vessel is inflamed, the endothelial cells **produce cell-adhesion molecules** that induce leukocytes to adhere to the surface
      - causes leukocytes to congregate in tissues where their defensive actions are needed

Vessel Wall

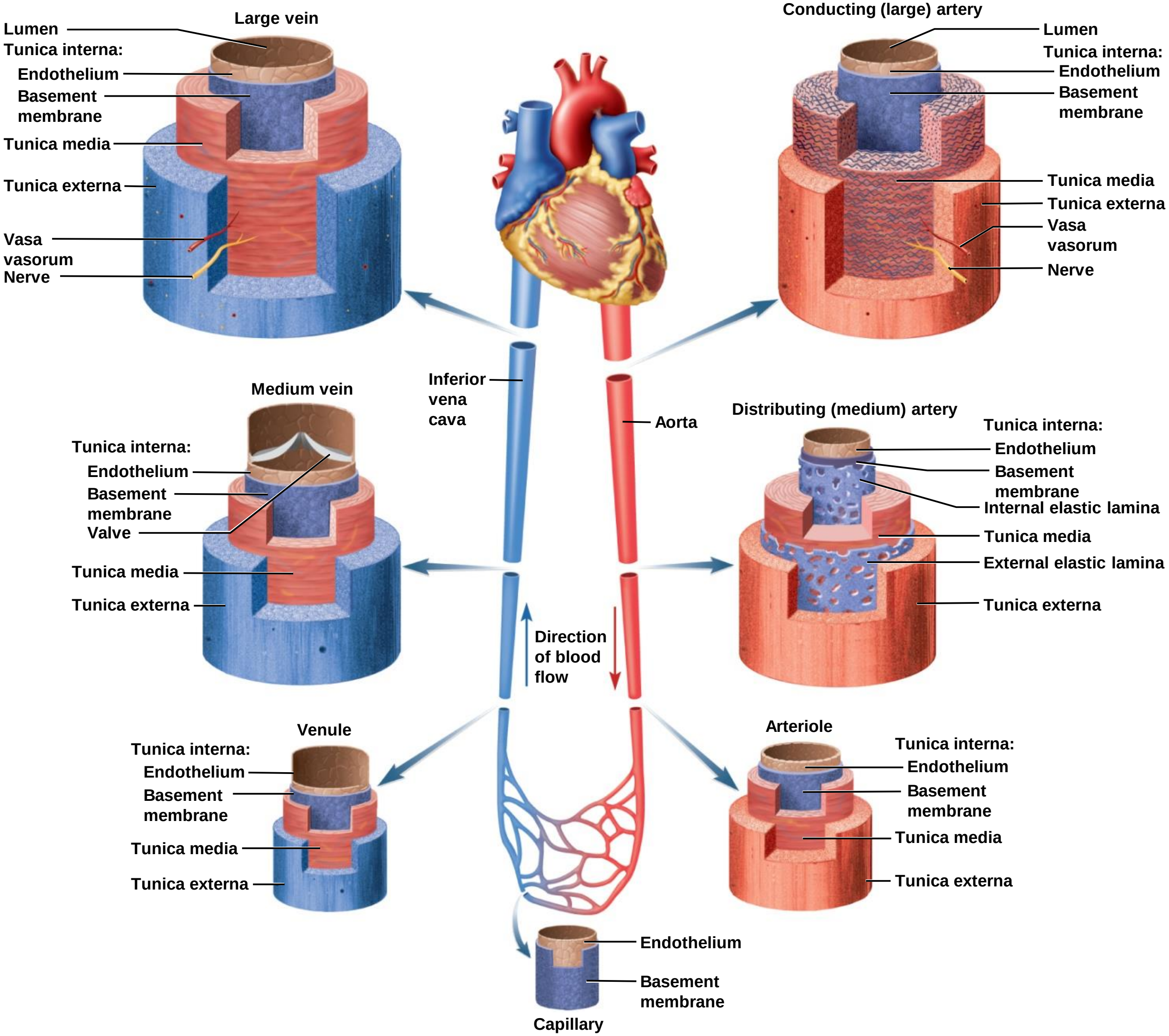
- **tunica media**
  - middle layer
  - consists of **smooth muscle**, collagen, and elastic tissue
  - strengthens vessel and prevents blood pressure from rupturing them
  - **vasomotion** – changes in diameter of the blood vessel brought about by smooth muscle

Vessel Wall

- **tunica externa** (tunica adventitia)
  - outermost layer
  - consists of loose connective tissue that often merges with that of neighboring blood vessels, nerves, or other organs
  - anchors the vessel and provides passage for small nerves, lymphatic vessels
  - **vasa vasorum** – small vessels that supply blood to at least the outer half of the larger vessels
    - blood from the lumen is thought to nourish the inner half of the vessel by diffusion

Large Vessels

Why do the arteries have so much more elastic tissue than the veins do?



Arteries

- **arteries** are sometimes called **resistance vessels** because they have relatively strong, resilient tissue structure that resists high blood pressure
  - **conducting (elastic** or **large) arteries**
    - biggest arteries
    - aorta, common carotid, subclavian, pulmonary trunk, and common iliac arteries
    - have a layer of elastic tissue, internal elastic lamina, at the border between interna and media
    - **external elastic lamina** at the border between media and externa
    - expand during systole, recoil during diastole which lessens fluctuations in blood pressure
  - **distributing (muscular** or **medium) arteries**
    - distributes blood to specific organs
    - brachial, femoral, renal, and splenic arteries
    - smooth muscle layers constitute three-fourths of wall thickness

Conducting (elastic or large) arteries

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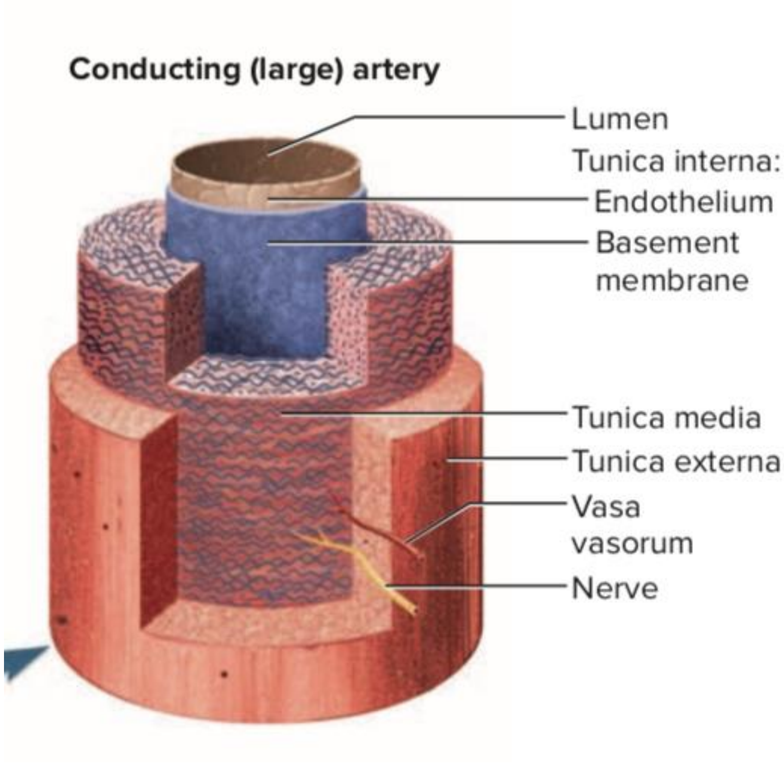

Distributing (muscular or **medium) arteries**

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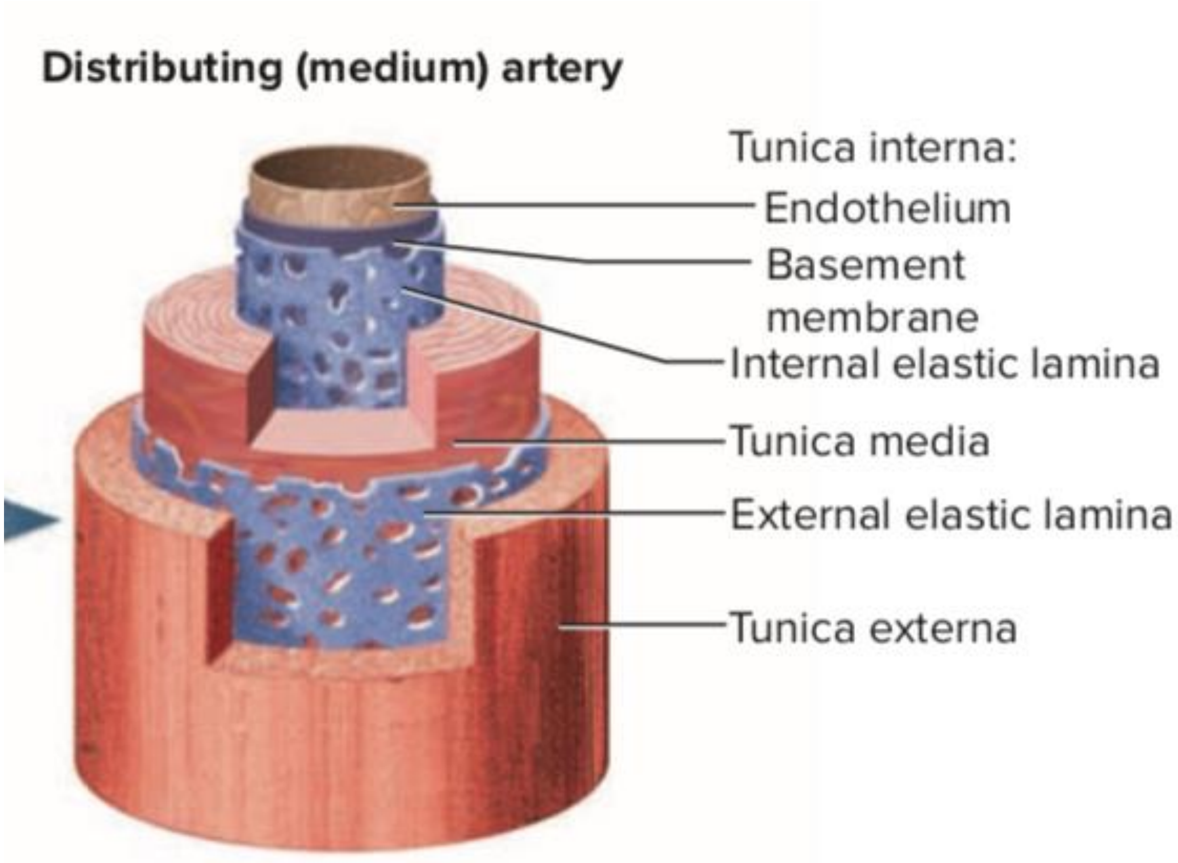
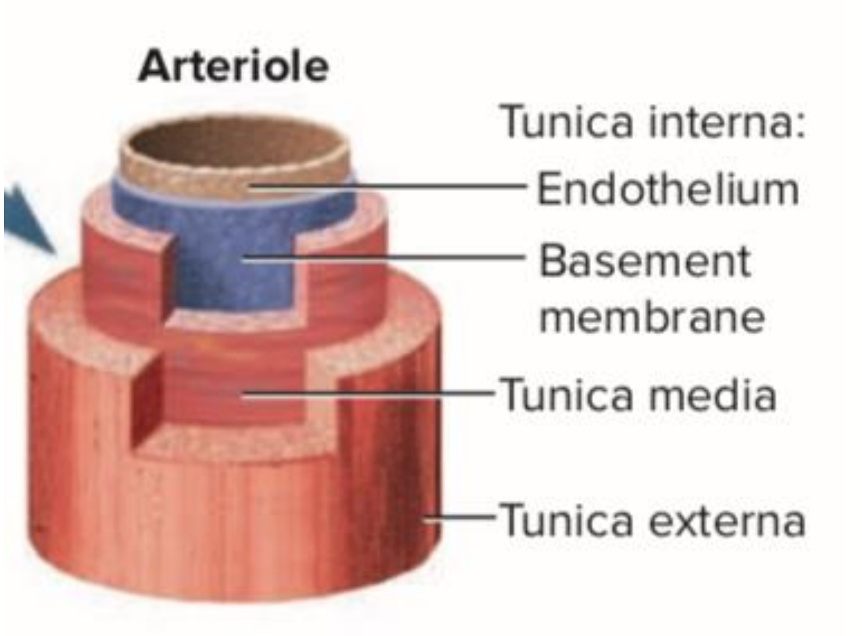


Resistance (small) arteries

- arterioles – smallest arteries
  - control amount of blood to various organs
- thicker tunica media in proportion to their lumen than large arteries and very little tunica externa



Metarterioles

- **metarterioles [*meta* = beyond, next in a series]**
  - short vessels that link arterioles to capillaries
  - muscle cells form a **precapillary sphincter** about entrance to capillary
    - constriction of these sphincters reduces or shuts off blood flow through their respective capillaries
    - diverts blood to other tissues

DEEPER INSIGHT 20.1

CLINICAL APPLICATION

Aneurysm

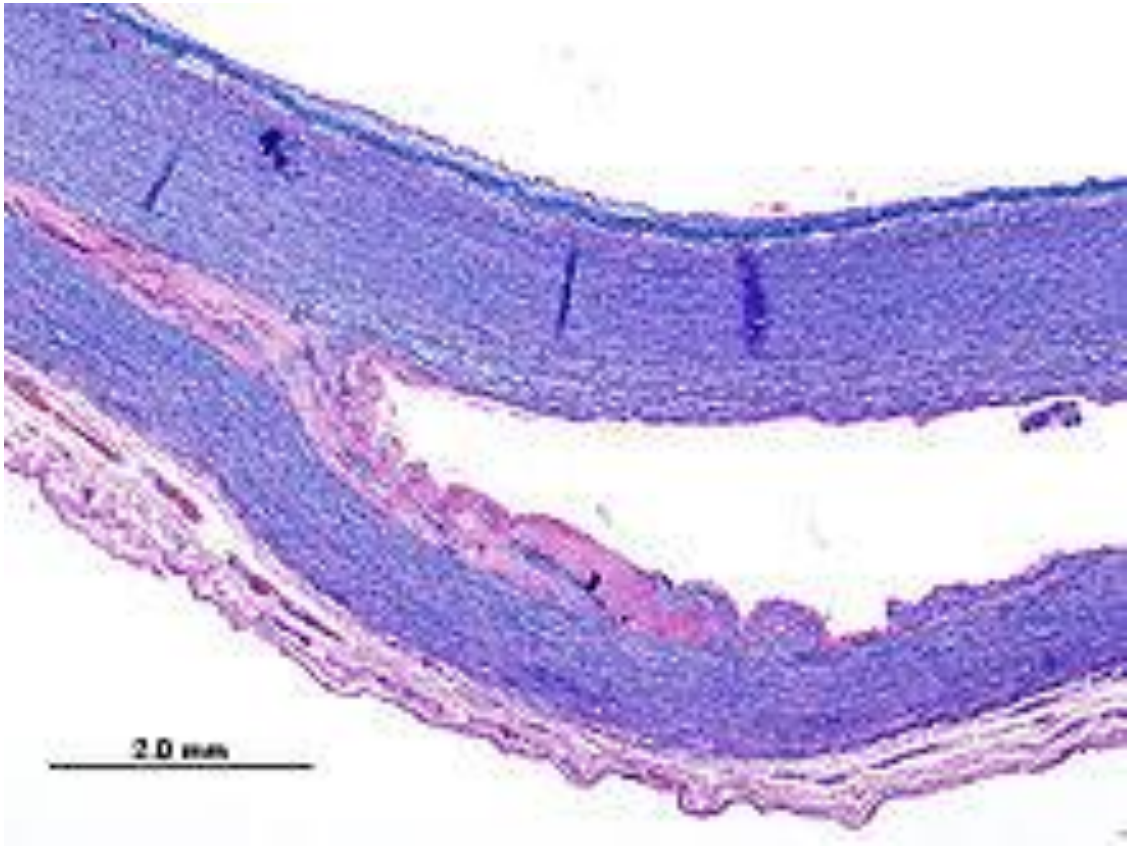
An *aneurysm* is a weak point in an artery or the heart wall. It forms a thin-walled, bulging sac that pulsates with each beat of the heart and may eventually rupture. In a *dissecting aneurysm,* blood accumulates between the tunics of an artery and separates them, usually because of degeneration of the tunica media. The most common sites of aneurysms are the abdominal aorta, renal arteries, and the arterial circle at the base of the brain. Even without hemorrhaging, aneurysms can cause pain or death by putting pressure on brain tissue, nerves, adjacent veins, pulmonary air passages, or the esophagus. Other consequences include neurological disorders, difficulty in breathing or swallowing, chronic cough, or congestion of the tissues with blood. Aneurysms sometimes result from congenital weakness of the blood vessels and sometimes from trauma or bacterial infections such as syphilis. The most common cause, however, is the combination of arteriosclerosis and hypertension.

Aneurysm

- **aneurysm** - weak point in an artery or the heart wall
  - forms a thin-walled, bulging sac that pulsates with each heartbeat and may rupture at any time

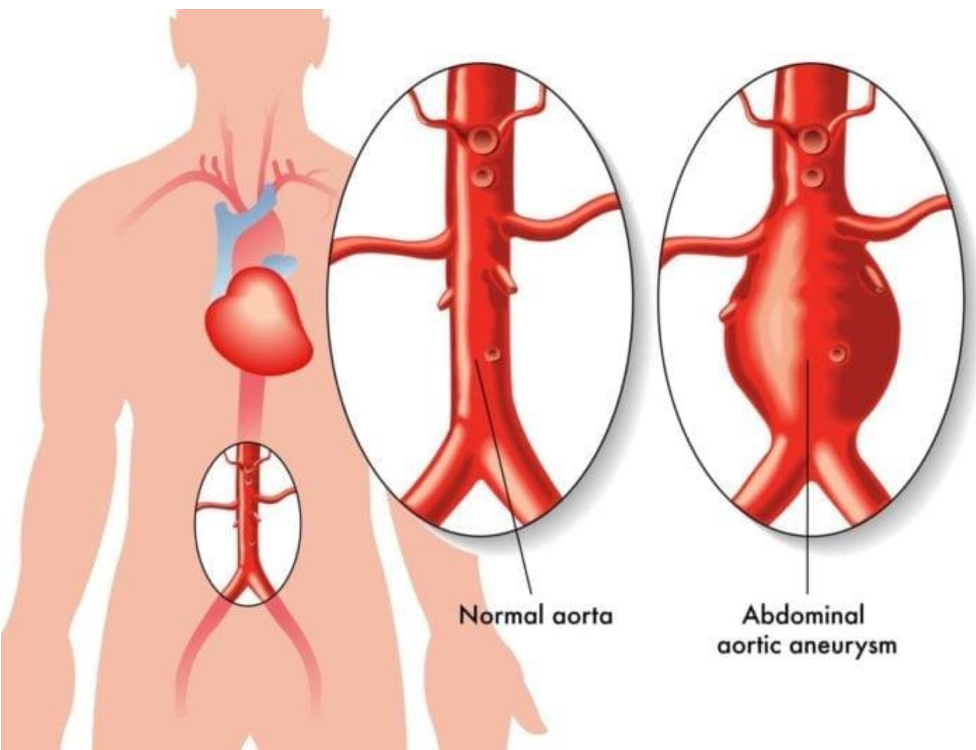
Aneurysm

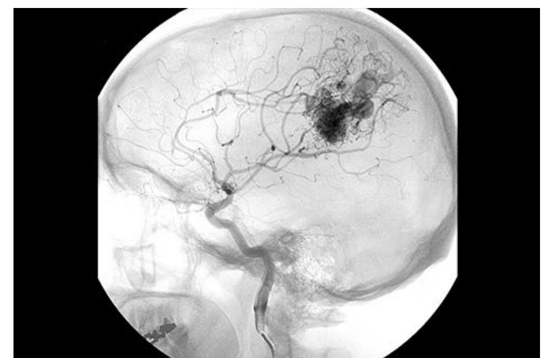
– **dissecting aneurysm -** blood accumulates between the tunics of the artery and separates them, usually because of degeneration of the tunica media



Aneurysm

– **most common sites**: abdominal aorta, renal arteries, and arterial circle at the base of the brain
– can cause pain by putting pressure on other structures
– can rupture causing hemorrhage
– result from congenital weakness of the blood vessels or result of trauma or bacterial infections such as syphilis
  • most common cause is atherosclerosis and hypertension





Arterial Sense Organs

- sensory structures in the walls of certain vessels that monitor blood pressure and chemistry
  - transmit information to brainstem that serves to regulate heart rate, vasomotion, and respiration
  - **carotid sinuses –** baroreceptors (pressure sensors)
    - in walls of internal carotid artery
    - monitors blood pressure – signaling brainstem
      - decreased heart rate and vessels dilation in response to high blood pressure
  - **carotid bodies** - chemoreceptors
    - oval bodies near branch of common carotids
    - monitor blood chemistry
    - mainly transmit signals to the brainstem respiratory centers
    - adjust respiratory rate to stabilize pH, CO_2, and O_2
  - **aortic bodies -** chemoreceptors
    - one to three in walls of aortic arch
    - same function as carotid bodies

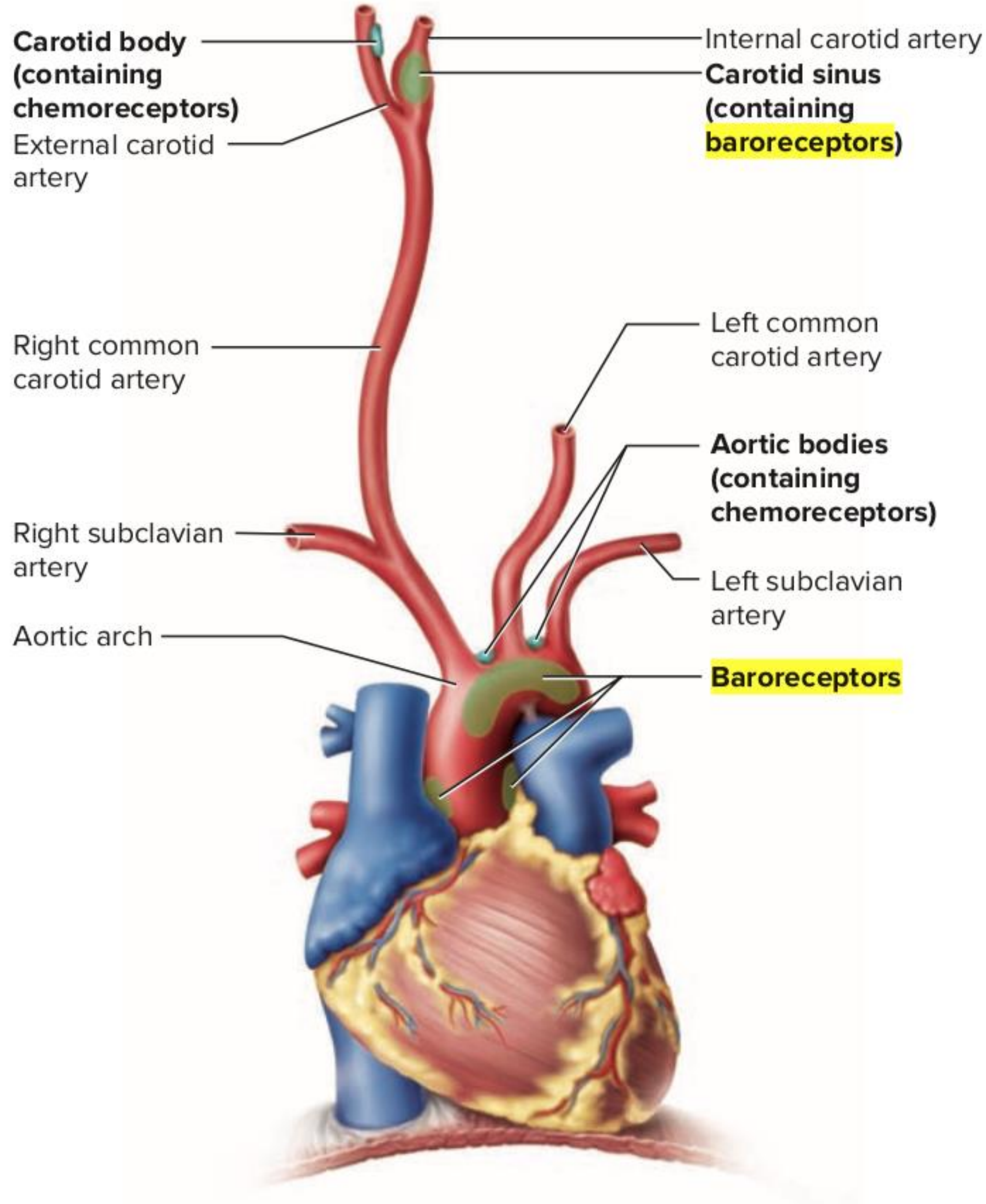
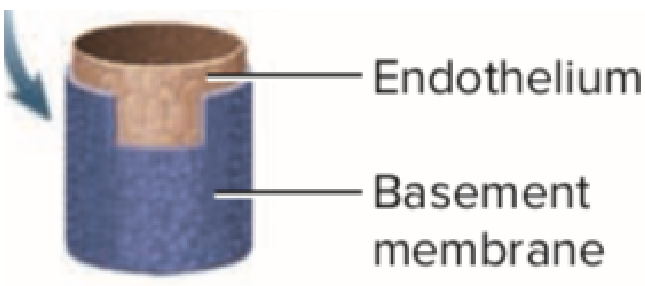


FIGURE 20.3 Baroreceptors and Chemoreceptors in the Arteries Superior to the Heart. The structures shown here in the right carotid arteries are repeated in the left carotids. APR

Discuss why it is advantageous to have baroreceptors in the aortic arch and carotid sinus rather than in some other location such as the common iliac arteries.

Capillaries

- **capillaries** - site where nutrients, wastes, and hormones pass between the blood and tissue fluid through the walls of the vessels (exchange vessels)
  - the ‘business end’ of the cardiovascular system
  - composed of **endothelium and basal lamina**
  - absent or scarce in tendons, ligaments, epithelia, cornea and lens of the eye



Capillary

Capillaries

- **three capillary types** distinguished by ease with which substances pass through their walls and by structural differences that account for their greater or lesser permeability

Three Types of Capillaries

- **continuous capillaries** - occur in most tissues
  - **endothelial cells** have **tight junctions** forming a continuous tube with **intercellular clefts**
    - allow passage of solutes such as glucose
  - **pericytes** wrap around the capillaries and contain the same contractile protein as muscle
    - contract and regulate blood flow

- **fenestrated capillaries** - kidneys, small intestine
  - organs that require rapid absorption or filtration
  - endothelial cells riddled with holes called **filtration pores (fenestrations)**
    - spanned by very thin glycoprotein layer
    - allows passage of only small molecules

- **sinusoids (discontinuous capillaries)** - liver, bone marrow, spleen
  - irregular blood-filled spaces with large fenestrations
  - allow proteins (albumin), clotting factors, and new blood cells to enter the circulation

Continuous Capillary

Identify some organs that have this type of capillary rather than continuous capillaries.

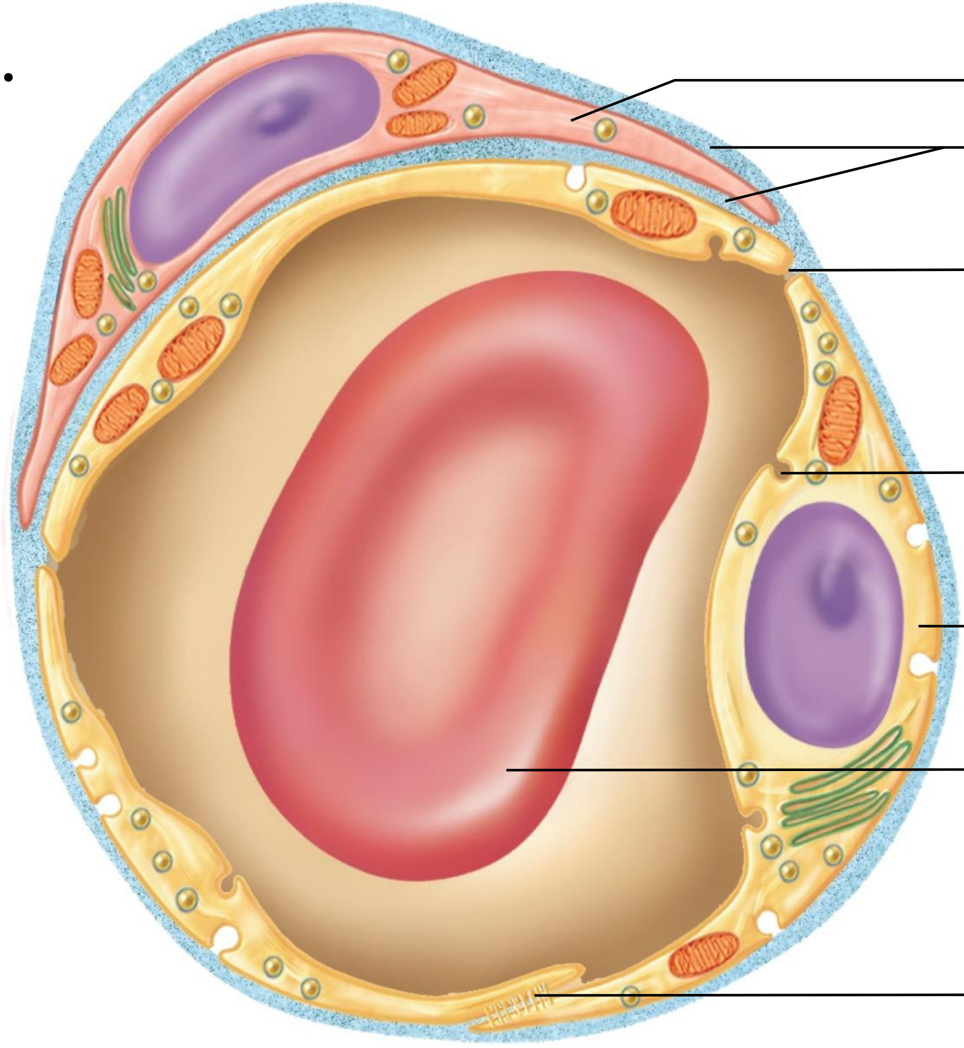


Figure 20.5

Fenestrated Capillary

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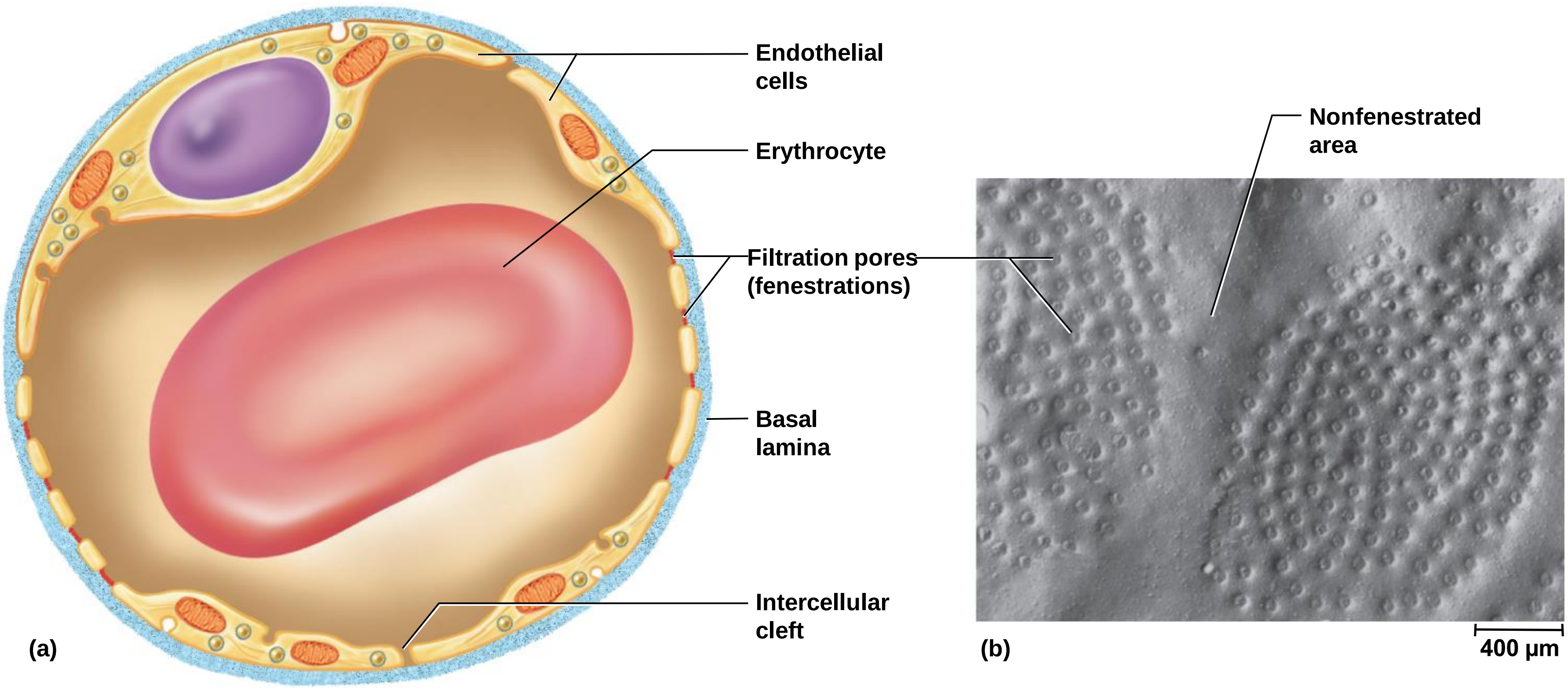

b: Courtesy of S. McNutt

Figure 20.6a

Figure 20.6b

Sinusoid in Liver

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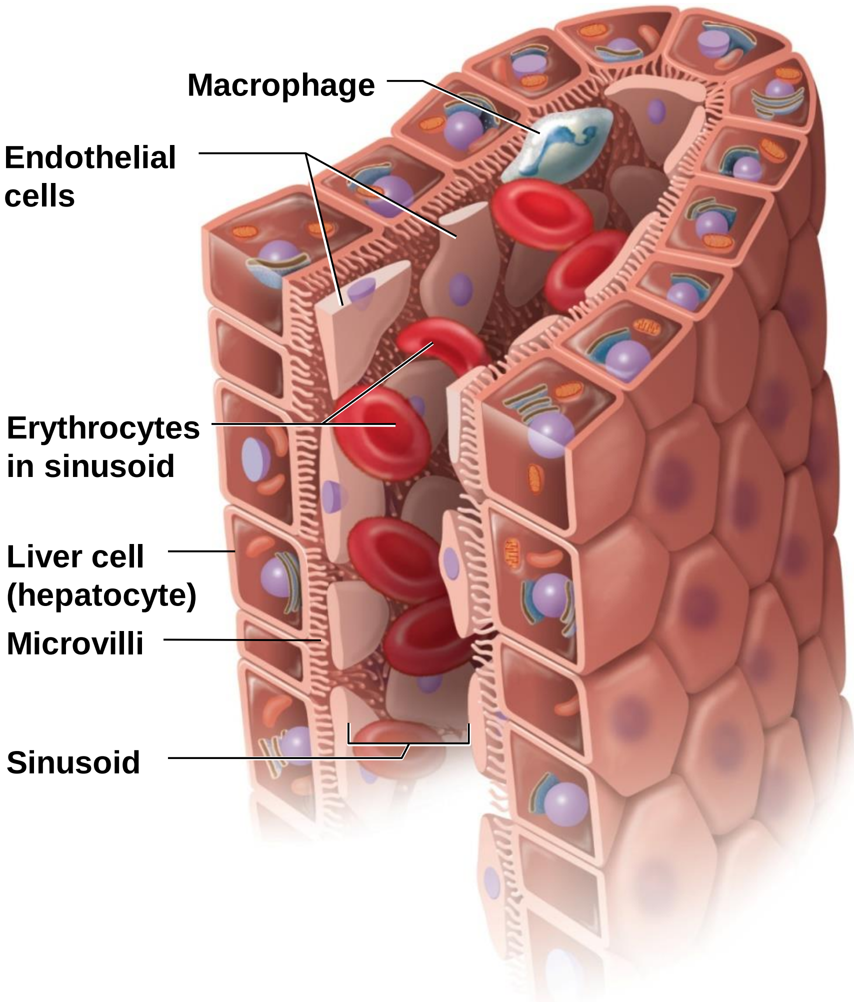

Figure 20.7

Capillary Beds

- capillaries organized into networks called **capillary beds**
  - usually supplied by a single **metarteriole**
- **thoroughfare channel** - metarteriole that continues through capillary bed to venule
- **precapillary sphincters** control which beds are well perfused
  - **when sphincters open**
    - capillaries are well perfused with blood and engage in exchanges with the tissue fluid
  - **when sphincters closed**
    - blood bypasses the capillaries
    - flows through thoroughfare channel to venule
- three-fourths of the bodies capillaries are shut down at a given time

Capillary Bed Sphincters Open

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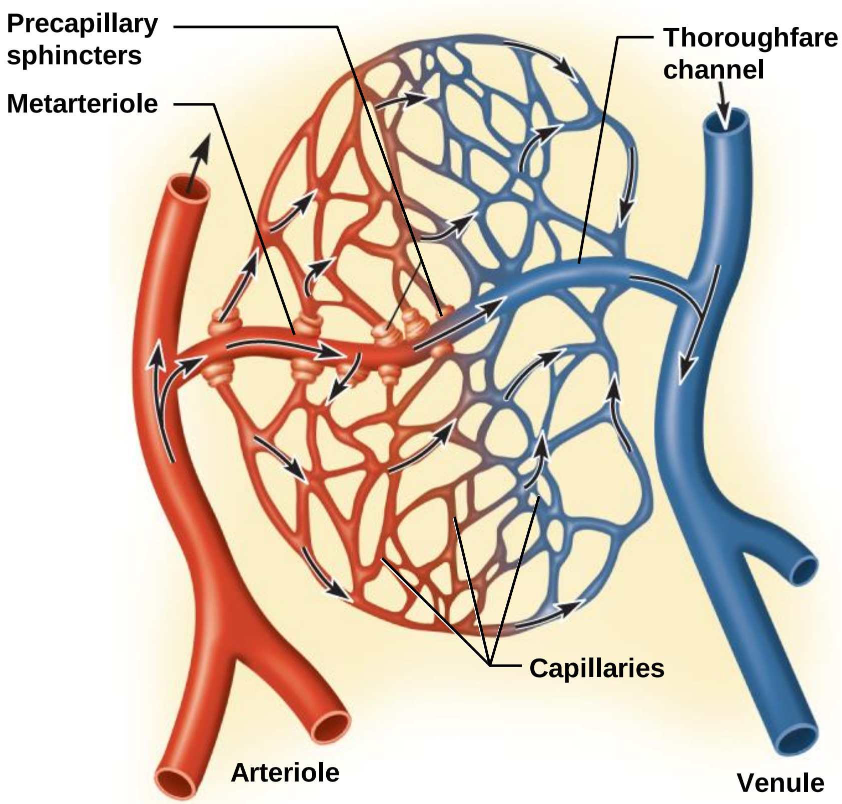

(a) Sphincters open

Figure 20.3a

when sphincters are open, the capillaries are well perfused

three-fourths of the capillaries of the body are shut down

Capillary Bed Sphincters Closed

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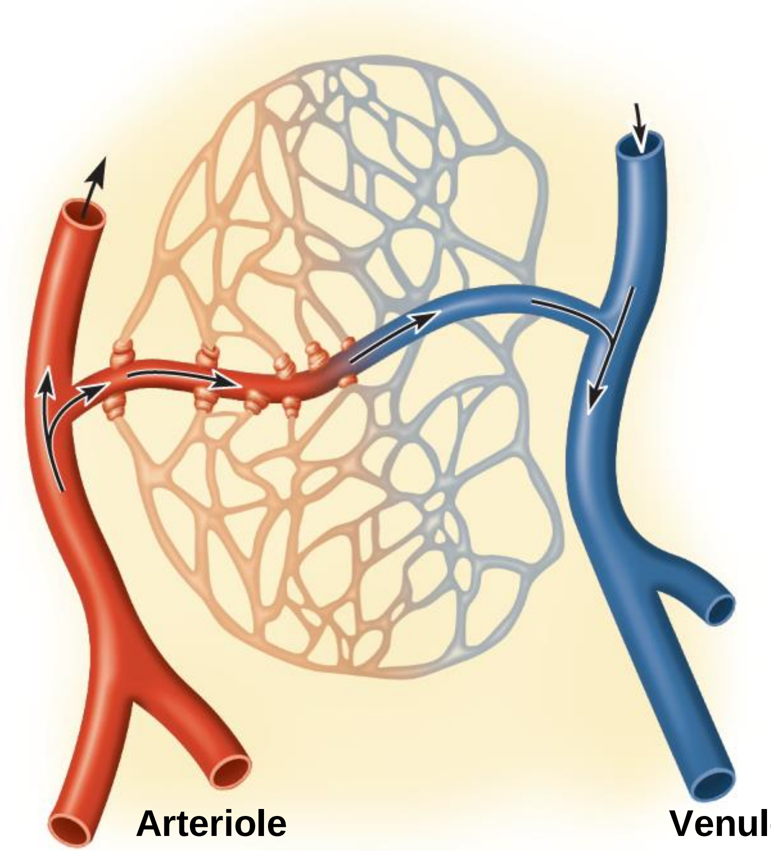

(b) Sphincters closed

Figure 20.3b

when the sphincters are closed, little to no blood flow occurs (skeletal muscles at rest)

Veins (Capacitance Vessels)

What anatomical fact allows the veins to contain so much more blood than the arteries do?

- greater capacity for blood containment than arteries
- thinner walls, flaccid, less muscular and elastic tissue
- collapse when empty, expand easily
- have steady blood flow
- merge to form larger veins
- subjected to relatively low blood pressure
  - remains 10 mm Hg with little fluctuation

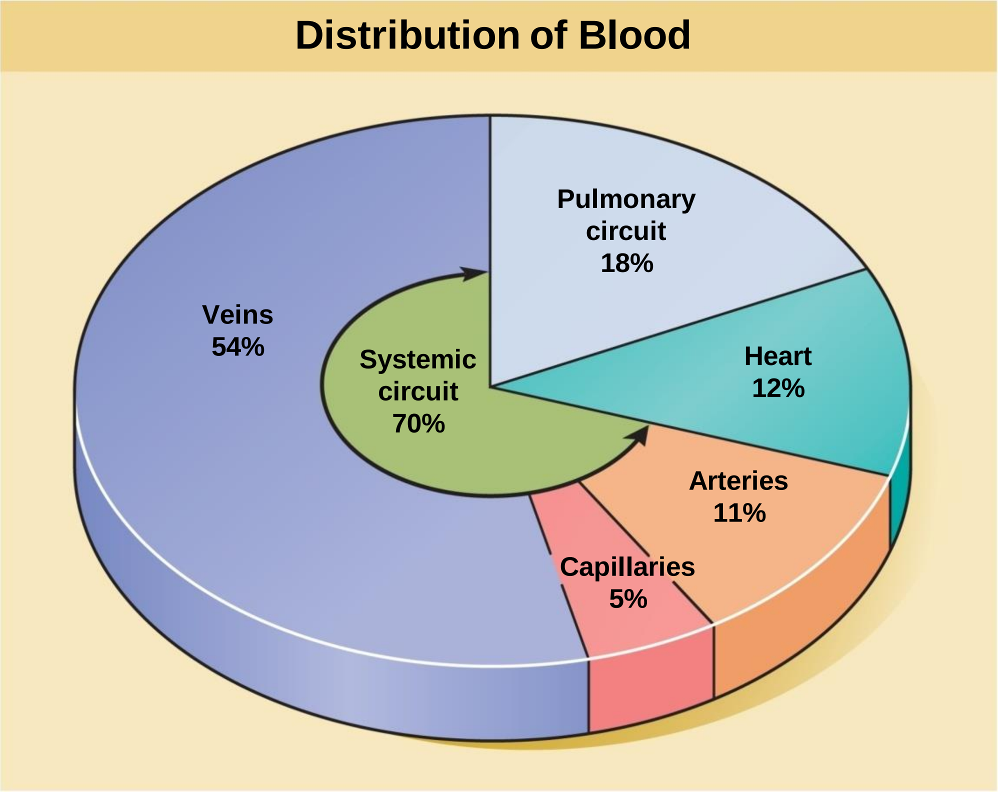

Figure 20.8

Blood Flow Pathway

- **postcapillary venules** – smallest veins
  - even more porous than capillaries so also exchange fluid with surrounding tissues
  - tunica interna with a few fibroblasts and no muscle fibers
  - most leukocytes emigrate from the bloodstream through venule walls

- **muscular venules** – up to 1 mm in diameter
  - 1 or 2 layers of smooth muscle in tunica media
  - have a thin tunica externa

- **medium veins** – up to 10 mm in diameter
  - thin tunica media and thick tunica externa
  - tunica interna forms **venous valves**
  - **varicose veins** result in part from the failure of these valves
  - skeletal muscle pump propels venous blood back toward the heart

Blood Flow Pathway

- **venous sinuses**
  - veins with especially thin walls, large lumens, and no smooth muscle
  - **dural venous sinus** and **coronary sinus** of the heart
  - not capable of vasomotion
- **large veins** – larger than 10 mm
  - some smooth muscle in all three tunics
  - thin tunica media with moderate amount of smooth muscle
  - tunica externa is thickest layer
    - contains longitudinal bundles of smooth muscle
  - venae cavae, pulmonary veins, internal jugular veins, and renal veins

Varicose Veins

- blood pools in the lower legs in people who stand for long periods stretching the veins
  - cusps of the valves pull apart in enlarged superficial veins further weakening vessels
  - blood backflows and further distends the vessels, their walls grow weak and develop into **varicose veins**
- hereditary weakness, obesity, and pregnancy also promote problems
- **hemorrhoids** are varicose veins of the anal canal

Circulatory Routes

- simplest and most common route
  - heart $\rightarrow$ arteries $\rightarrow$ arterioles $\rightarrow$ capillaries $\rightarrow$ venules $\rightarrow$ veins
  - passes through only **one network of capillaries** from the time it leaves the heart until the time it returns
- **portal system**
  - blood flows through **two consecutive capillary** networks before returning to heart
    - between hypothalamus and anterior pituitary
    - in kidneys
    - between intestines to liver

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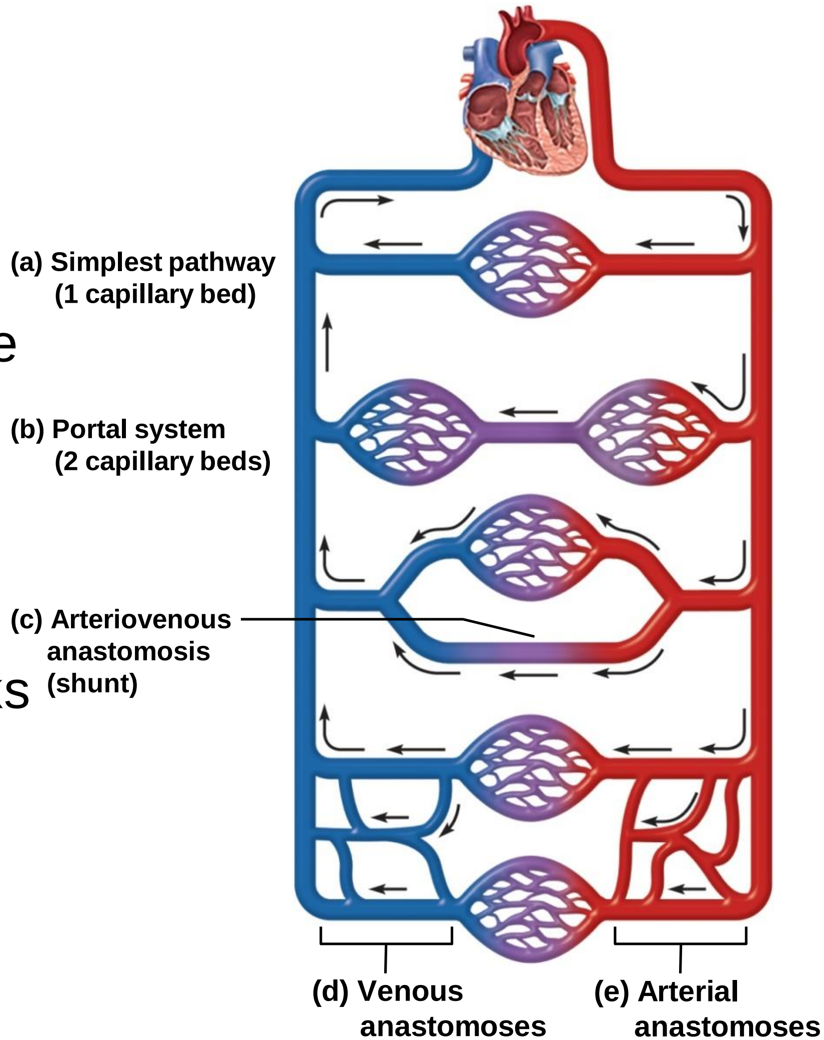

Figure 20.9

Anastomoses

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- **anastomosis** – the point where two blood vessels merge
- **arteriovenous anastomosis** (shunt)
  - artery flows directly into vein bypassing capillaries
- **venous anastomosis**
  - most common
  - one vein empties directly into another
  - reason vein blockage less serious than an arterial blockage
- **arterial anastomosis**
  - two arteries merge
  - provides **collateral (alternative) routes** of blood supply to a tissue
  - coronary circulation and around joints

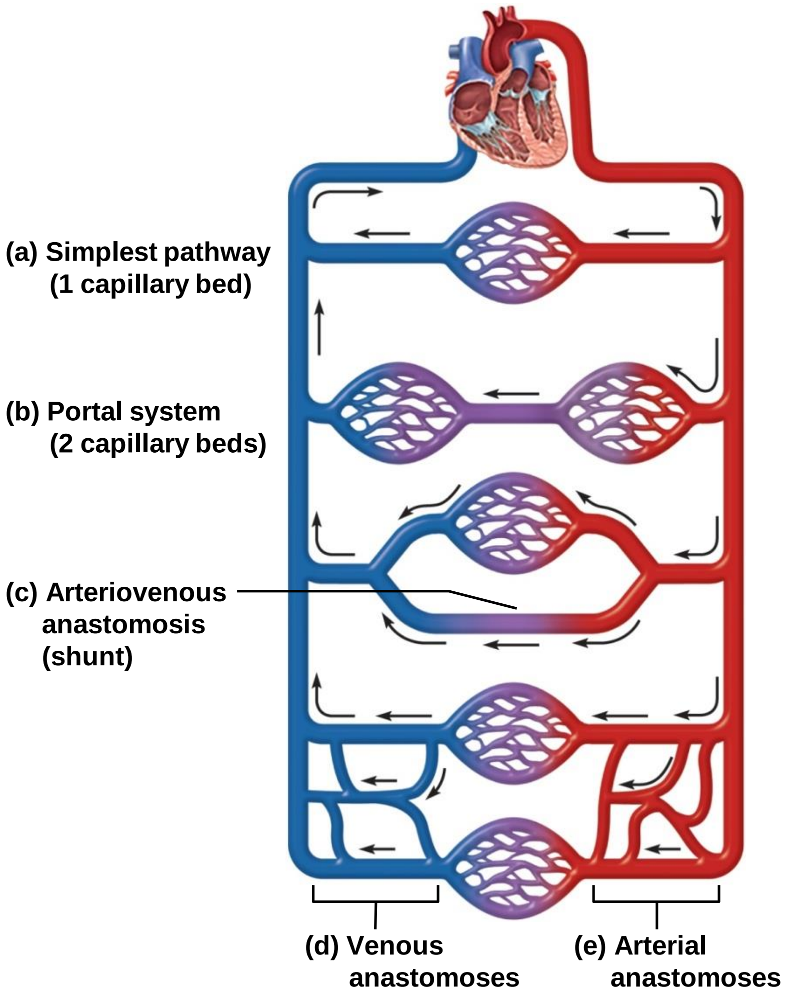

Figure 20.9

Principles of Blood Flow

- blood supply to a tissue can be expressed in terms of **flow** and **perfusion**
  - **blood flow** – the amount of blood flowing through an organ, tissue, or blood vessel in a given time (ml/min)
  - **perfusion** – the flow per given volume or mass of tissue in a given time (ml/min/g)
- at rest, total flow is quite constant, and is equal to the cardiac output (5.25 L/min)
- important for delivery of nutrients and oxygen, and removal of metabolic wastes
- **hemodynamics**
  - physical principles of blood flow based on **pressure** and **resistance**
    - F is proportional to $\Delta P/R$, (F = flow, ΔP = difference in pressure, R = resistance to flow)
    - the greater the pressure difference between two points, the greater the flow; the greater the resistance the less the flow

Mechanisms of Venous Return

- **venous return** – the flow of blood back to the heart
  - **pressure gradient**
    - blood pressure is the most important force in venous return
    - 7-13 mm Hg venous pressure towards heart
    - venules (12-18 mm Hg) to **central venous pressure –** point where the venae cavae enter the heart (~5 mm Hg)
  - **gravity** drains blood from head and neck
  - **skeletal muscle pump** in the limbs
    - contracting muscle squeezed out of the compressed part of the vein
  - **thoracic (respiratory) pump**
    - inhalation - thoracic cavity expands and thoracic pressure decreases, abdominal pressure increases forcing blood upward
      - central venous pressure fluctuates
    - 2mm Hg- inhalation, 6mm Hg-exhalation
    - blood flows faster with inhalation
  - **cardiac suction** of expanding atrial space

Skeletal Muscle Pump

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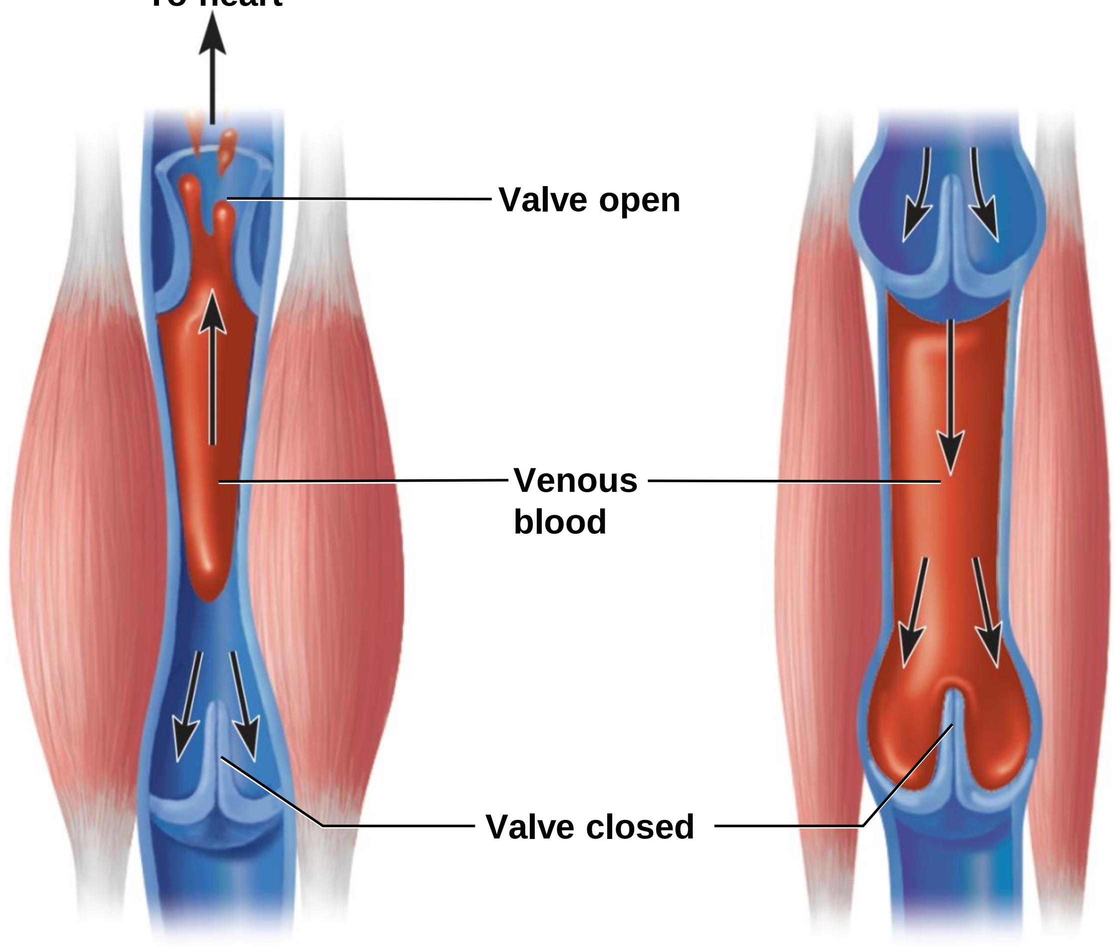

(a) Contracted skeletal muscles

(b) Relaxed skeletal muscles

Figure 20.19 a-b

Venous Return and Physical Activity

- **exercise increases venous return** in many ways:
  - heart beats faster, harder increasing CO and BP
  - vessels of skeletal muscles, lungs, and heart dilate and increase flow
  - increased respiratory rate, increased action of thoracic pump
  - increased skeletal muscle pump
- **venous pooling** occurs with inactivity
  - venous pressure not enough force blood upward
  - with prolonged standing, CO may be low enough to cause dizziness
    - prevented by tensing leg muscles, activate skeletal muscle pump
  - jet pilots wear pressure suits

Circulatory Shock

- **circulatory shock** – any state in which cardiac output is insufficient to meet the body's metabolic needs
  - **cardiogenic shock** - inadequate pumping of heart (MI)
  - **low venous return (LVR)** – cardiac output is low because too little blood is returning to the heart
    - three principal forms
      1. **hypovolemic shock** - most common
         -loss of blood volume: trauma, burns, dehydration
      2. **obstructed venous return shock**
         -tumor or aneurysm compresses a vein
      3. **venous pooling (vascular) shock**
         -next slide

Vascular Shock and Others

- **venous pooling (vascular) shock**
  - long periods of standing, sitting or widespread vasodilation
  - **neurogenic shock** - loss of vasomotor tone, vasodilation
    - causes from emotional shock to brainstem injury
- **septic shock**
  - bacterial toxins trigger vasodilation and increased capillary permeability
- **anaphylactic shock**
  - severe immune reaction to antigen, histamine release, generalized vasodilation, increased capillary permeability

Responses to Circulatory Shock

- compensated shock
- decompensated shock

Compensated Shock

- **compensated shock** – several homeostatic mechanisms bring about **spontaneous recovery**
- decreased BP triggers baroreflex and production of angiotensin II, both counteract shock by stimulating vasoconstriction
- if person faints and falls to horizontal position, gravity restores blood flow to brain
  - quicker if feet are raised

Decompensated shock

- if compensating mechanisms inadequate, several life-threatening positive feedback loops occur
  - poor cardiac output results in **myocardial ischemia** and **infarction**
    - further weakens the heart and reduces output
  - slow circulation can lead to **disseminated intravascular coagulation**
    - vessels become congested with clotted blood
    - venous return grows worse
  - **ischemia and acidosis of brainstem** depresses vasomotor and cardiac centers
    - lose of vasomotor tone, further dilation, and further drop in BP and cardiac output
  - **damage to cardiac and brain tissue** may be too great to survive

Circulatory System

-BLOOD VESSELS AND CIRCULATION

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◆ PART II

LEARNING OUTCOMES

As a result of the lesson you will be able to:

- ***Explain the relationship between blood pressure, resistance, and flow;***
- ***Describe how blood pressure is expressed and how pulse pressure and mean arterial pressure are calculated;***
- ***describe three factors that determine resistance to blood flow;***
- ***explain how vessel diameter influences blood pressure and flow; and***
- ***describe some local, neural, and hormonal influences on vessel diameter.***

Principles of Blood Flow

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Blood Pressure

- blood pressure (bp) – the force that blood exerts against a vessel wall
- measured at **brachial artery** of arm using **sphygmomanometer**
- two pressures are recorded:
  - **systolic pressure**: peak arterial BP taken during ventricular contraction (ventricular systole)
  - **diastolic pressure**: minimum arterial BP taken during ventricular relaxation (diastole) between heart beats
- normal value, young adult: **120/75 mm Hg**
- **pulse pressure** – difference between systolic and diastolic pressure
  - important measure of stress exerted on small arteries by pressure surges generated by the heart
- **mean arterial pressure (MAP)** – the mean pressure one would obtain by taking measurements at several intervals throughout the cardiac cycle
  - diastolic pressure + (1/3 of pulse pressure)
  - average blood pressure that most influences risk level for edema, fainting (syncope), atherosclerosis, kidney failure, and aneurysm

Abnormalities of Blood Pressure

- **hypertension** – high blood pressure
  - chronic is resting BP > 140/90
  - consequences
    - can weaken small arteries and cause aneurysms

- **hypotension** – chronic low resting BP
  - caused by blood loss, dehydration, anemia

APPLY WHAT YOU KNOW

Explain how the histological structure of large arteries relates to their ability to stretch during systole and recoil during diastole.

Blood Pressure

- one of the body's chief mechanisms in preventing excessive blood pressure is the ability of the arteries to **stretch and recoil** during the cardiac cycle

- importance of arterial elasticity
  - expansion and recoil maintains steady flow of blood throughout cardiac cycle, smoothes out pressure fluctuations and decreases stress on small arteries

- BP rises with age
  - arteries less distensible and absorb less systolic force

- BP determined by **cardiac output, blood volume** and **peripheral resistance**
  - resistance hinges on blood viscosity, vessel length, and vessel radius

BP Changes With Distance

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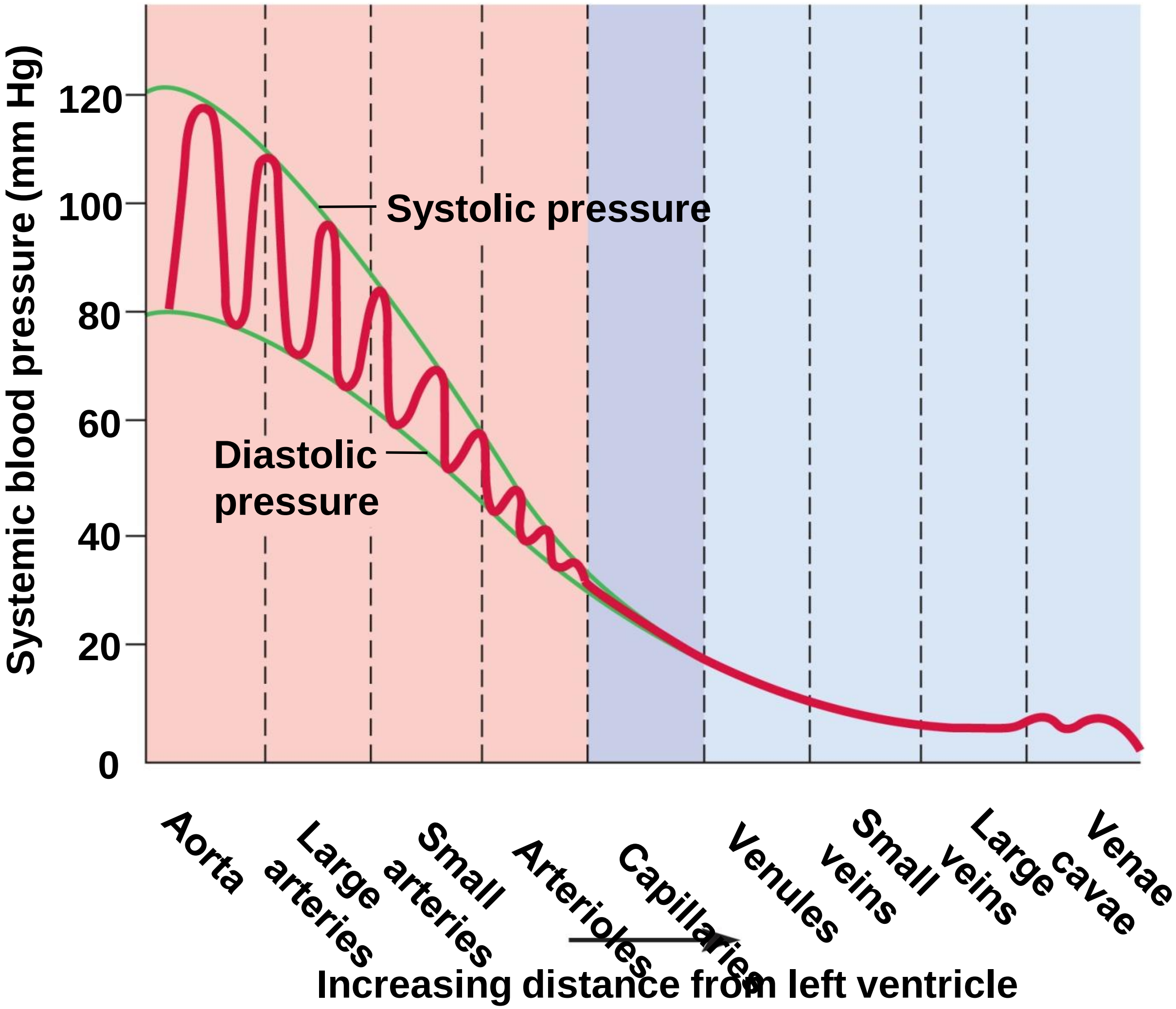

Figure 20.10

Peripheral Resistance

- **peripheral resistance** – the opposition to flow that blood encounters in vessels away from the heart
- resistance hinges on three variables
  - **blood viscosity "thickness"**
    - RBC count and albumin concentration elevate viscosity the most
    - decreased viscosity with anemia and hypoproteinemia speed flow
    - increased viscosity with polycythemia and dehydration slow flow
  - **vessel length**
    - the farther liquid travels through a tube, the more cumulative friction it encounters
    - pressure and flow decline with distance
  - **vessel radius** - most powerful influence over flow
    - only significant way of controlling peripheral resistance.
    - **vasomotion** - change in vessel radius
      - **vasoconstriction** - by muscular effort that results in smooth muscle contraction
      - **vasodilation** - by relaxation of the smooth muscle

Peripheral Resistance

- vessel radius (cont.)
  - vessel radius markedly affects **blood velocity**
  - **laminar flow** - flows in layers, faster in center
  - blood flow (F) proportional to the fourth power of radius (r), $F \propto r^4$
    - arterioles can constrict to 1/3 of fully relaxed radius
      - if r = 3 mm, F = (3^4) = 81 mm/sec; if r = 1 mm, F = 1mm/sec
      - an increase of **three times** in the radius of a vessel results in **eighty one times** the flow

APPLY WHAT YOU KNOW

- **Suppose a vessel with a radius of 1 mm had a flow of 3 mL/min., and then the vessel dilated to a radius of 5 mm. What would be the new flow rate?**

Laminar Flow and Vessel Radius

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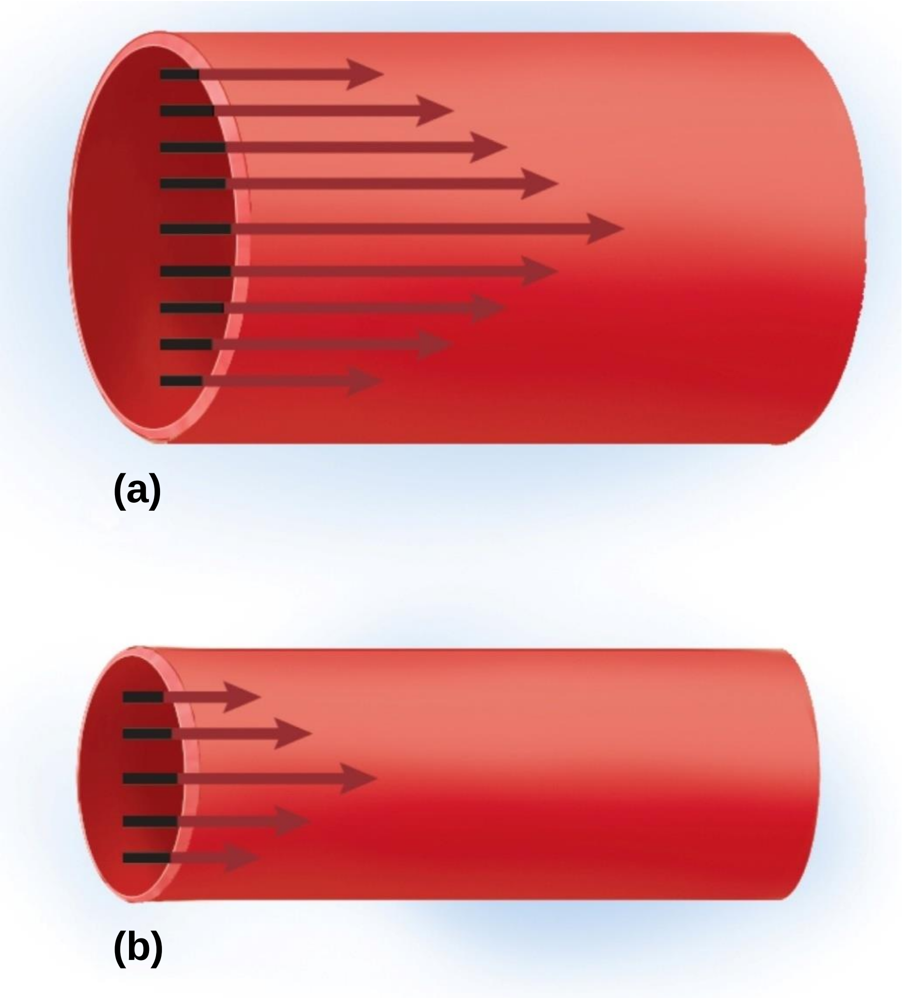

Figure 20.11

Flow at Different Points

- from **aorta** to **capillaries**, blood velocity (speed) decreases for three reasons:
  - greater distance, more friction to reduce speed
  - smaller radii of arterioles and capillaries offers more resistance
  - farther from heart, the number of vessels and their total cross-sectional area becomes greater and greater

- from **capillaries** to **vena cava**, flow increases again
  - decreased resistance going from capillaries to veins
  - large amount of blood forced into smaller channels
  - never regains velocity of large arteries

Control by Arterioles

- **arterioles** are most significant point of control over peripheral resistance and flow
  - – on proximal side of capillary beds and best positioned to regulate flow into the capillaries
  - – outnumber any other type of artery, providing the most numerous control points
  - – more muscular in proportion to their diameter
    - highly capable of vasomotion

- arterioles produce half of the total peripheral resistance

Regulation of BP and Flow

- **vasomotion** is a quick and powerful way of altering blood pressure and flow

- three ways of controlling vasomotion:
  - local control
  - neural control
  - hormonal control

Local Control of BP and Flow

- **autoregulation** – the ability of tissues to regulate their own blood supply
  - metabolic theory of autoregulation – if tissue is inadequately perfused, wastes accumulate stimulating vasodilation which increases perfusion
  - bloodstream delivers oxygen and remove metabolites
  - when wastes are removed, vessels constrict

- **vasoactive chemicals** - substances secreted by platelets, endothelial cells, and perivascular tissue stimulate vasomotion
  - histamine, bradykinin, and prostaglandins stimulate vasodilation
  - endothelial cells secrete prostacyclin and nitric oxide (vasodilators) and endothelins (vasoconstrictor)

- **reactive hyperemia**
  - if blood supply cut off then restored, flow increases above normal

- **angiogenesis** - growth of new blood vessels
  - occurs in regrowth of uterine lining, around coronary artery obstructions, in exercised muscle, and malignant tumors
  - controlled by growth factors

Neural Control of Blood Vessels

- vessels under remote control by the central and autonomic nervous systems

- **vasomotor center** of medulla oblongata exerts **sympathetic control** over blood vessels throughout the body
  - stimulates most vessels to **constrict**, but dilates vessels in skeletal and cardiac muscle to meet demands of exercise
    - **precapillary sphincters** respond only to local and hormonal control due to lack of innervation
  - vasomotor center is the integrating center for three autonomic reflexes
    - **baroreflexes**
    - **chemoreflexes**
    - **medullary ischemic reflex**

Baroreflex

- **baroreflex** – an automatic, negative feedback response to changes in blood pressure
  – increases in BP detected by **carotid sinuses**
  – signals sent to brainstem by way of **glossopharyngeal nerve**
  – inhibit the sympathetic cardiac and vasomotor neurons reducing sympathetic tone, and excite vagal fibers to the slowing of heart rate and cardiac output – thus reducing BP
  – decreases in BP have the opposite effect

- baroreflexes important in **short-term regulation** of BP but not in cases of chronic hypertension
  – adjustments for rapid changes in posture

Negative Feedback Control of BP

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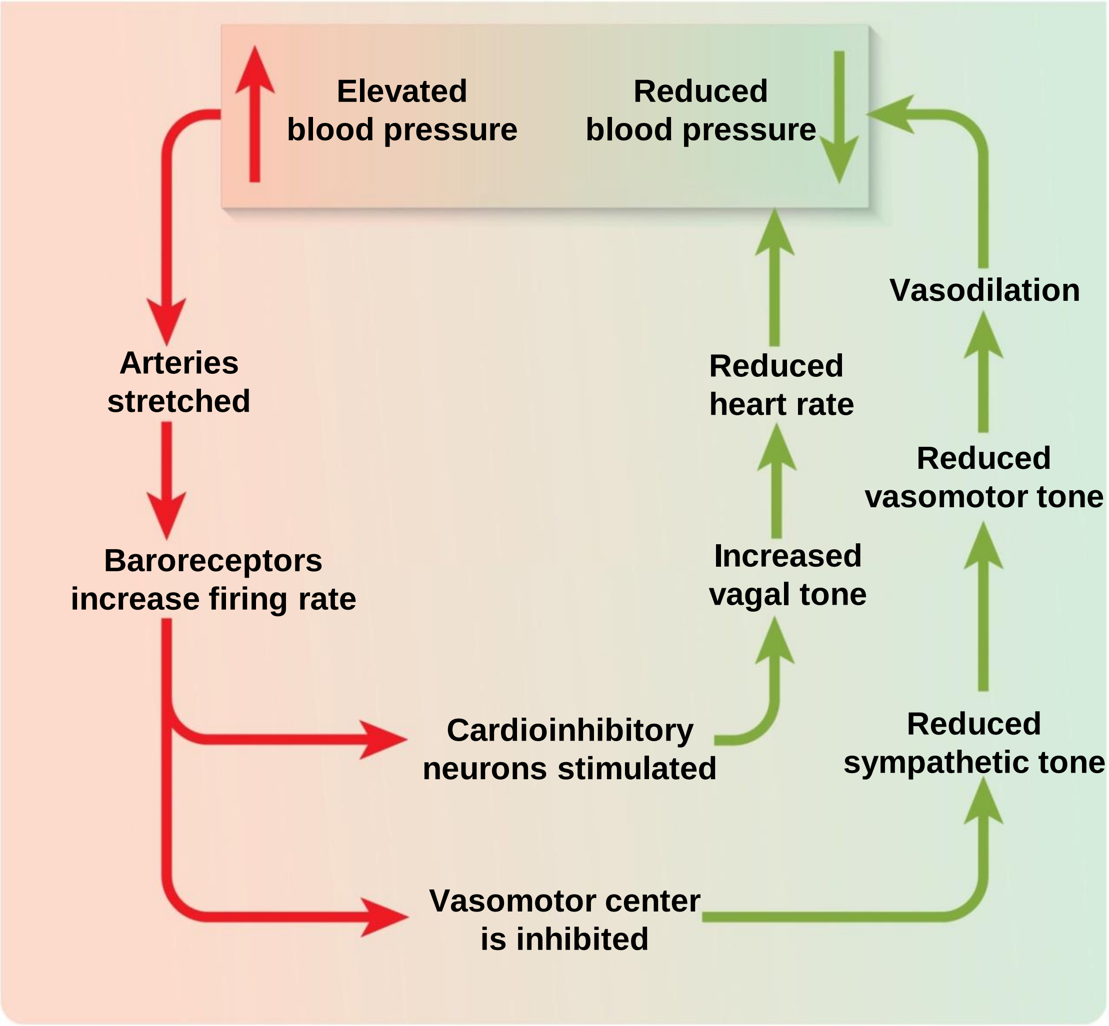

Figure 20.13

Chemoreflex

- **chemoreflex** – an automatic response to changes in blood chemistry
  - especially pH, and concentrations of O_2 and CO_2
- **chemoreceptors** called aortic bodies and carotid bodies
  - located in aortic arch, subclavian arteries, external carotid arteries
- **primary role**: adjust respiration to changes in blood chemistry
- **secondary role**: vasomotion
  - hypoxemia, hypercapnia, and acidosis stimulate chemoreceptors, acting through vasomotor center to cause widespread vasoconstriction, increasing BP, increasing lung perfusion and gas exchange
  - also stimulate breathing

Medullary Ischemic Reflex

- **medullary ischemic reflex** - automatic response to a drop in perfusion of the brain
  - medulla oblongata monitors its own blood supply
  - activates corrective reflexes when it senses ischemia (insufficient perfusion)
    - cardiac and vasomotor centers send sympathetic signals to heart and blood vessels
      - increases heart rate and contraction force
      - causes widespread vasoconstriction
      - raises BP and restores normal perfusion to the brain
- other brain centers can affect vasomotor center
  - stress, anger, arousal can also increase BP

Hormonal Control

- hormones influence blood pressure
  - some through their **vasoactive effects**
  - some by regulating **water balance**
- **angiotensin II** – potent vasoconstrictor
  - raises blood pressure
- **aldosterone**
  - promotes Na^+ and water retention by kidneys
  - increases blood volume and pressure
- **atrial natriuretic peptide** – increases urinary sodium excretion
  - reduces blood volume and promotes vasodilation
  - lowers blood pressure
- **ADH** - promotes water retention and raises BP
  - pathologically high concentrations - vasoconstrictor
- **epinephrine and norepinephrine** effects
  - most blood vessels
    - binds to α-adrenergic receptors - **vasoconstriction**
  - skeletal and cardiac muscle blood vessels
    - binds to β-adrenergic receptors - **vasodilation**

APPLY WHAT YOU KNOW

Renin inhibitors are drugs used to treat hypertension. Explain how you think they would produce the desired effect.

Two Purposes of Vasomotion

- general method of **raising or lowering BP throughout the whole body**
  - increasing BP requires medullary vasomotor center or widespread circulation of a hormone
    - important in supporting cerebral perfusion during a hemorrhage or dehydration
- method of **rerouting blood** from one region to another for perfusion of individual organs
  - either centrally or locally controlled
    - during exercise, sympathetic system reduces blood flow to kidneys and digestive tract and increases blood flow to skeletal muscles
    - metabolite accumulation in a tissue affects local circulation without affecting circulation elsewhere in the body

Routing of Blood Flow

- localized vasoconstriction
  - if a specific artery constricts, the pressure downstream drops, pressure upstream rises
  - enables routing blood to different organs as needed

- examples
  - vigorous exercise dilates arteries in lungs, heart and muscles
    - vasoconstriction occurs in kidneys and digestive tract
  - dozing in armchair after big meal
    - vasoconstriction in lower limbs raises BP above the limbs redirecting blood to intestinal arteries

Blood Flow in Response to Needs

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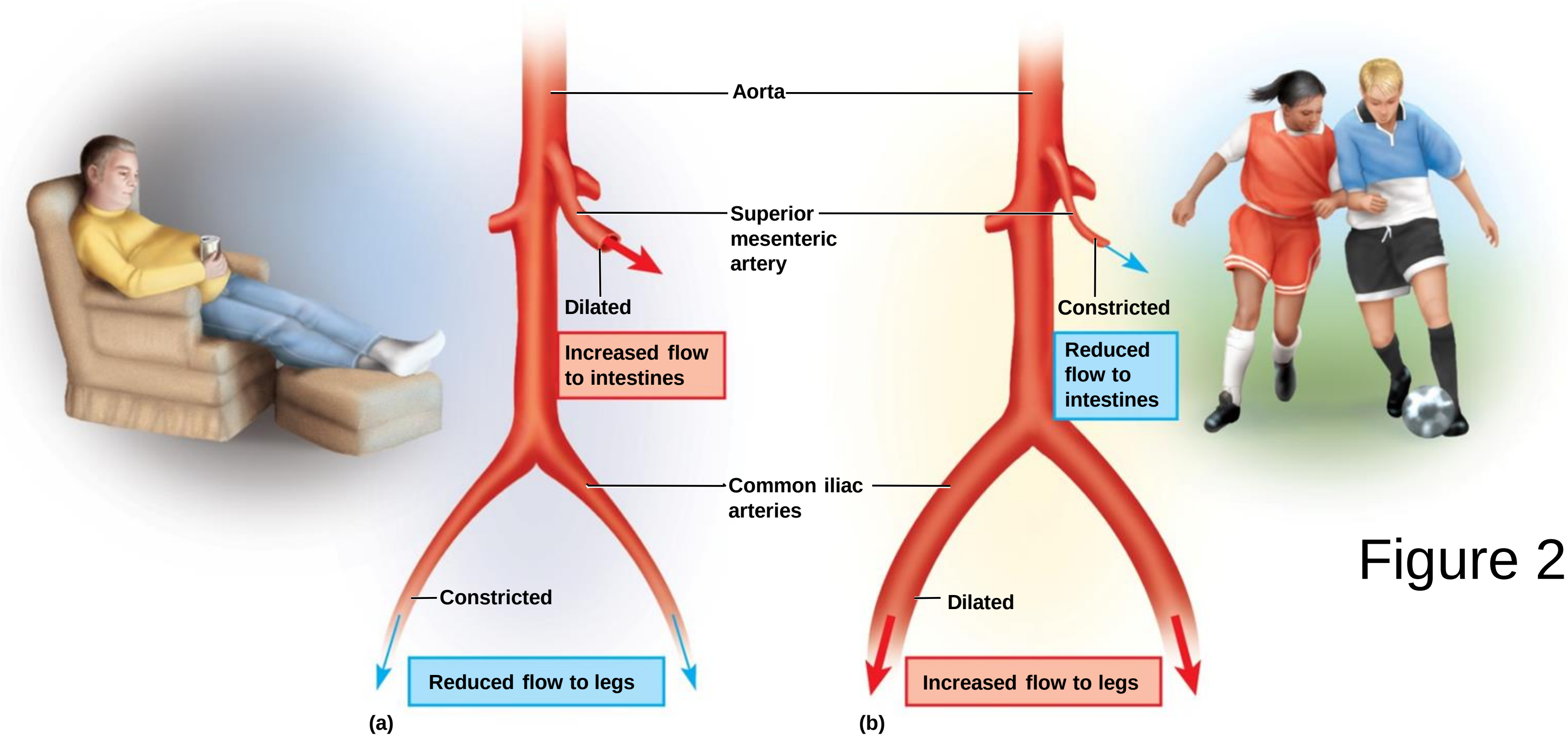

Figure 20.14

arterioles shift blood flow with changing priorities

Blood Flow Comparison

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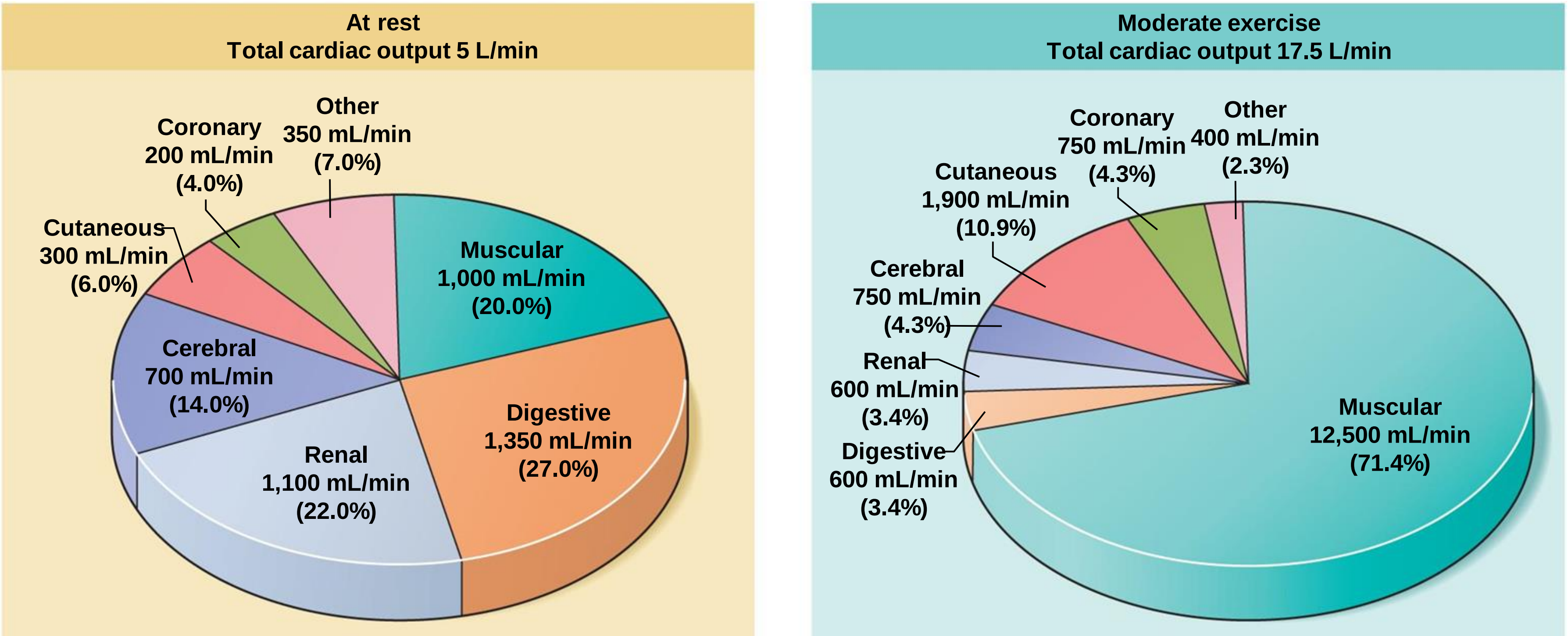

Figure 20.15

during exercise

– increased perfusion of lungs, myocardium, and skeletal muscles
– decreased perfusion of kidneys and digestive tract

A Case of Neurocardiogenic Syncope

by
David F. Dean, Department of Biology, Spring Hill College

- Case Presentation
- Allison Jacobson is a 19-year-old sophomore majoring in pre-medicine at the University of Arizona. In the past few weeks leading up to final exams, Allison has felt unusually tired despite receiving an adequate amount of sleep at night. She also has had frequent headaches, and has experienced times when her heart “felt like it was missing a beat.” Yesterday at lunch, Allison fainted while waiting in line in the cafeteria. Initially, she attributed this episode to being unusually tired and hungry, but later in the day she fainted again while waiting to mail a package at the Post Office.

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- **When Allison informed her mother about what had happened that day, her mother immediately scheduled an appointment for Allison to see the family physician. Though no abnormalities where found when he examined Allison, her physician ordered a battery of diagnostic tests, including a head-up tilt (hut) test.**

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- **Define the following terms as they relate to cardiodynamics: *stroke volume*, *end systolic volume*, and *end diastolic volume*.**
- **Define the following terms and state how each relates to systemic arterial blood pressure: *cardiac output* and *total peripheral resistance*.**

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- ***Cardiac output*** **is the volume of blood pumped from the left ventricle into the aorta and the systemic circuit in one minute. Cardiac output is determined by two factors: stroke volume and heart rate. There is a direct relationship between cardiac output and systemic arterial blood pressure.**
- ***Stroke volume*** **is the volume of blood ejected from each ventricle each time it contracts.**

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- **The *end systolic volume* is equal to the amount of blood remaining in each ventricle after ventricular contraction (systole), and the *end diastolic volume* is the amount of blood in each ventricle at the end of ventricular filling (diastole).**

- ***Total peripheral resistance* is defined as the sum of all the factors that inhibit blood flow through the arterial system. There is a direct relationship between total peripheral resistance and systemic arterial blood pressure.**

A Case of Neurocardiogenic Syncope

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- **Explain the following: the *Frank-Starling law of the heart*, the control of cardiac activity by the autonomic nervous system, and the *baroreceptor reflex* in the maintenance of systemic blood pressure.**

A Case of Neurocardiogenic Syncope

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- The *Frank-Starling law of the heart* states that an increase in venous return to the heart (i.e., increased end-diastolic volume) will increase the degree to which the ventricular myocardium is stretched and the force with which it will contract, thus increasing the stroke volume. The *Frank- Starling law of the heart* is a built-in mechanism that makes sure that cardiac output keeps up with venous return to the heart.

A Case of Neurocardiogenic Syncope

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- The *Control of cardiac activity by the autonomic nervous system:* The heart receives input from both the sympathetic and parasympathetic divisions of the autonomic nervous system. Postganglionic sympathetic neurons synapse upon the cells of the sinoatrial (SA) node and cells of the ventricular myocardium, both of which have beta-1 adrenergic receptors. The norepinephrine released by the sympathetic neurons increases both the heart rate and strength of ventricular contraction (stroke volume), thus increasing cardiac output and systemic arterial blood pressure. The parasympathetic neurons release acetylcholine which binds to muscarinic receptors on the cells of the SA node, resulting in a decrease in heart rate, cardiac output, and systemic arterial blood pressure.

A Case of Neurocardiogenic Syncope

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- The *Baroreceptors* are stretch receptors located in the walls of the carotid artery and the aorta. A decrease in systemic blood pressure is detected by these receptors as a decrease in the degree to which these elastic arteries are stretched. When stimulated by a decrease in systemic blood pressure, the baroreceptors send impulses to neurons in the cardiovascular center of the brain stem. The cardiovascular center has multiple parts— the cardioinhibitory center consists of parasympathetic neurons that slow the heart rate, and the cardioacceleratory center consists of sympathetic neurons that increase the heart rate and strength of contraction (i.e., stroke volume). There is also a vasomotor center that consists of sympathetic neurons that control the smooth muscle in the walls of arterioles. Stimulation of the vasomotor center, causing peripheral vasoconstriction and an increase in total peripheral resistance.

A Case of Neurocardiogenic Syncope

by

David F. Dean, Department of Biology, Spring Hill College

- **Explain how the baroreflex serves as an example of homeostasis and negative feedback**

A Case of Neurocardiogenic Syncope

by
David F. Dean, Department of Biology, Spring Hill College

- **Define the term *dysautonomia,* and briefly describe the condition known as *neurocardiogenic syncope* (ncs).**

A Case of Neurocardiogenic Syncope

by

David F. Dean, Department of Biology, Spring Hill College

- **Define *Dysautonomia* literally means dysfunction of the autonomic nervous system (ANS). Dysfunction of the ANS can produce malfunction of the organs that it regulates.**
- ***NCS* is sometimes referred to as neurally mediated syncope or vasovagal syncope, and is characterized by an intermittent drop in blood pressure that results in fainting (syncope).**

A Case of Neurocardiogenic Syncope

by

David F. Dean, Department of Biology, Spring Hill College

- What are the symptoms of ncs? What is the mechanism by which ncs occurs?

A Case of Neurocardiogenic Syncope

by
David F. Dean, Department of Biology, Spring Hill College

- What When a person stands up, the pull of gravity reduces the drainage of blood from the feet and legs, thus reducing venous return to the right side of the heart. According to the Frank-Starling law of the heart, decreased venous return to the heart will decrease stroke volume, and therefore, cardiac output. A decrease in cardiac output will lower systemic arterial blood pressure. Normally, the body automatically adjusts to this condition via the baroreceptor reflex, so that normal systemic BP is maintained. However, in individuals with NCS this compensatory mechanism does not always work the way it should.

A Case of Neurocardiogenic Syncope

by
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◆

The reflex control of systemic arterial blood pressure depends not only on the baroreceptor reflex, but also on other mechanoreceptors and chemoreceptors located in the cardiopulmonary region that communicate with the cardiovascular center in the brain stem. These cardiopulmonary receptors are stimulated by changes in cardiac filling pressure (i.e., end- diastolic volume) and by chemical agents. Activation of the cardiopulmonary chemoreceptors reduces heart rate, cardiac output, and systemic arterial pressure via what is known as the Bezold-Jarisch (BJ) reflex. Although its physiological importance remains debatable, the BJ reflex has been incriminated in the vasodilation and cardioinhibitory response that characterize

A Case of Neurocardiogenic Syncope

by

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- **Explain why arterial blood flow is pulsatile and venous flow is not.**

A Case of Neurocardiogenic Syncope

by

David F. Dean, Department of Biology, Spring Hill College

- **What three variables affect peripheral resistance to blood flow? Which of these is most able to change from one minute to the next?**

A Case of Neurocardiogenic Syncope

by
David F. Dean, Department of Biology, Spring Hill College

- **What are the three primary mechanisms for controlling vessel radius? Briefly explain each**

Circulatory System

-BLOOD VESSELS AND CIRCULATION

l-Farabi Kazakh National University
Higher School of Medicine

◆ PART III

LEARNING OUTCOMES

As a result of the lesson you will be able to:

- ***Describe how materials get from the blood into the surrounding tissues;***
- ***describe and calculate the forces that enable capillaries to give off and reabsorb fluid; and***
- ***describe the causes and effects of edema.***
- ***explain how blood in the veins is returned to the heart;***
- ***discuss the importance of physical activity in venous return;***
- ***discuss several causes of circulatory shock;***
- ***name and describe the stages of shock.***

Capillary Exchange

- the most important blood in the body is in the capillaries - Only 250 to 300 mL (5%)
- **capillary exchange** – two way movement of fluid across capillary walls- exchanges made between the blood and surrounding tissues
  – water, oxygen, glucose, amino acids, lipids, minerals, antibodies, hormones, wastes, carbon dioxide, ammonia

Capillary Exchange

- chemicals pass through the capillary wall by **three routes**
  - **through endothelial cell cytoplasm**
  - **intercellular clefts between endothelial cells**
  - **filtration pores (fenestrations) of the fenestrated capillaries**
- mechanisms involved
  - **diffusion**, **transcytosis**, **filtration** ,and **reabsorption**

APPLY WHAT YOU KNOW

- List the three mechanisms of capillary exchange and relate each one to the structure of capillary walls.

APPLY WHAT YOU KNOW

- the endothelial cell cytoplasm
- Intercellular clefts between the endothelial cells
- Filtration pores (fenestrations) of the fenestrated capillaries.

Capillary Exchange - Diffusion

- **diffusion —** the net movement of particles from a place of high concentration to a place of lower concentration as a result of their constant, spontaneous motion.
- **the most important form of capillary exchange**
  - glucose and oxygen being more concentrated in blood diffuse out of the blood
  - carbon dioxide and other waste being more concentrated in tissue fluid diffuse into the blood

Capillary Exchange - Diffusion

- **capillary diffusion can only occur if:**
  - the solute can **permeate** the **plasma membranes** of the endothelial cell, or
  - find **passages** large enough to pass through
    - **filtration pores and intracellular clefts**

- **lipid soluble substances**
  - steroid hormones, O_2 and CO_2 diffuse easily through **plasma membranes**

- **water soluble substances**
  - glucose and electrolytes must pass through **filtration pores and intercellular clefts**

- **large particles** - proteins, held back

Capillary Exchange - Transcytosis

[trans = across; cyt = cell; osis = process]

- endothelial cells pick up material on one side of the plasma membrane by pinocytosis [***pino*** **= drinking;** ***cyt*** **= cell;** ***osis*** **= process**] or receptor-mediated endocytosis[***endo*** **= into;** ***cyt*** **= cell; osis = process**], transport vesicles across cell, and discharge material on other side by exocytosis[***exo*** **= out of;** ***cyt*** **= cell; osis = process**]
- important for **fatty acids, albumin and some hormones (insulin)**

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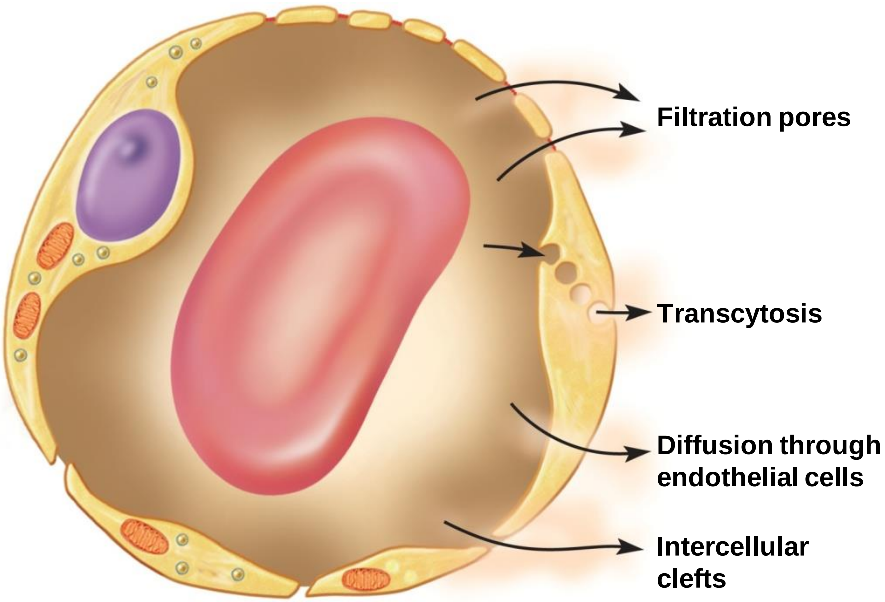
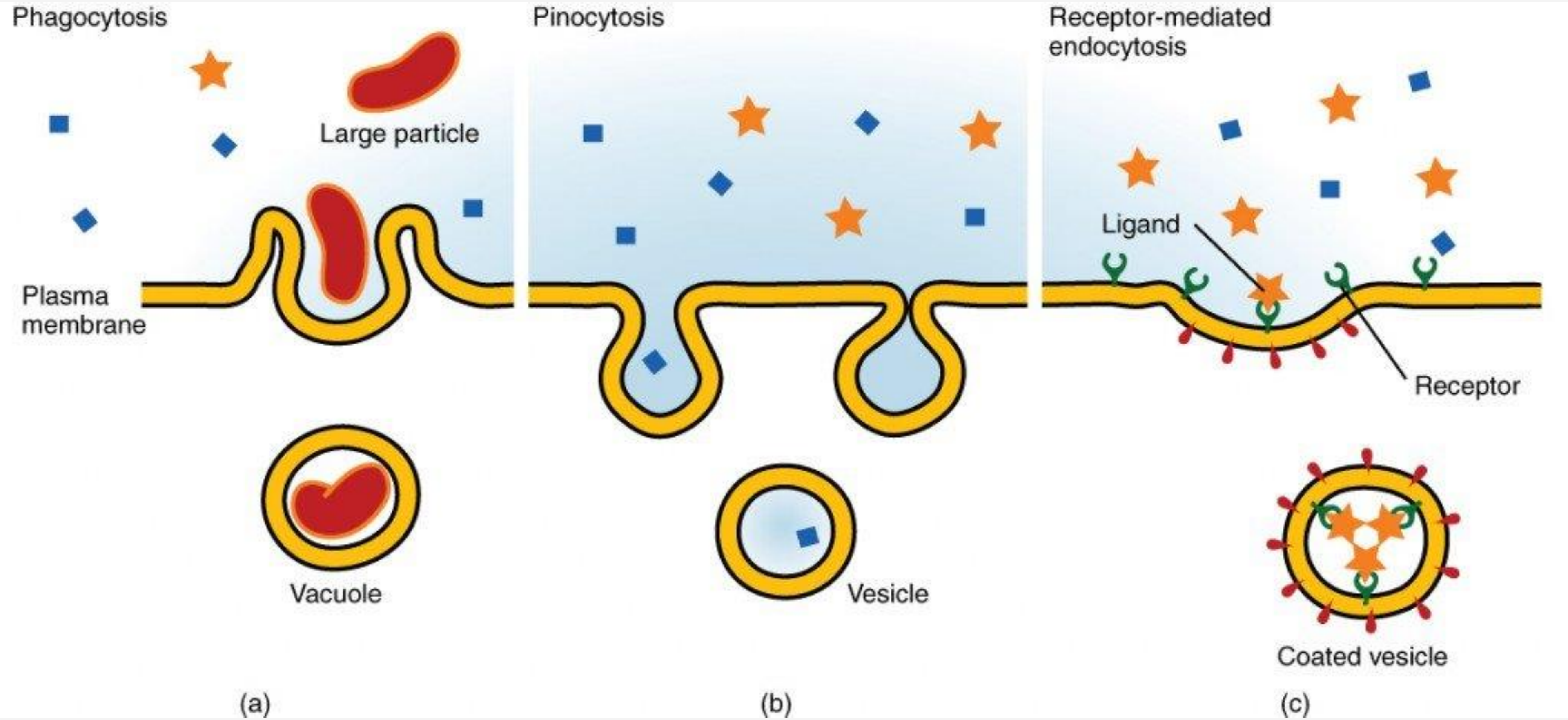
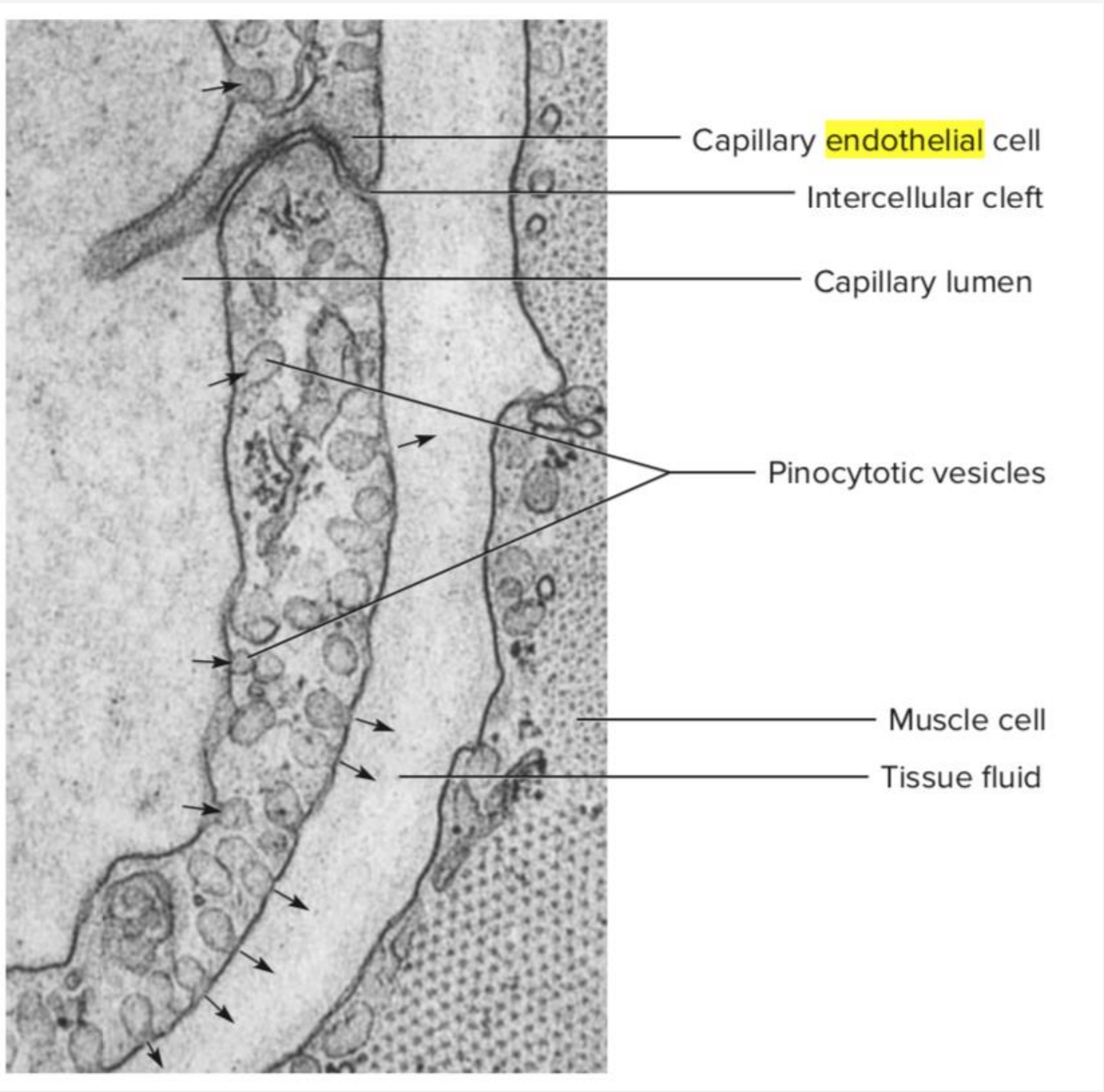


Figure 20.16

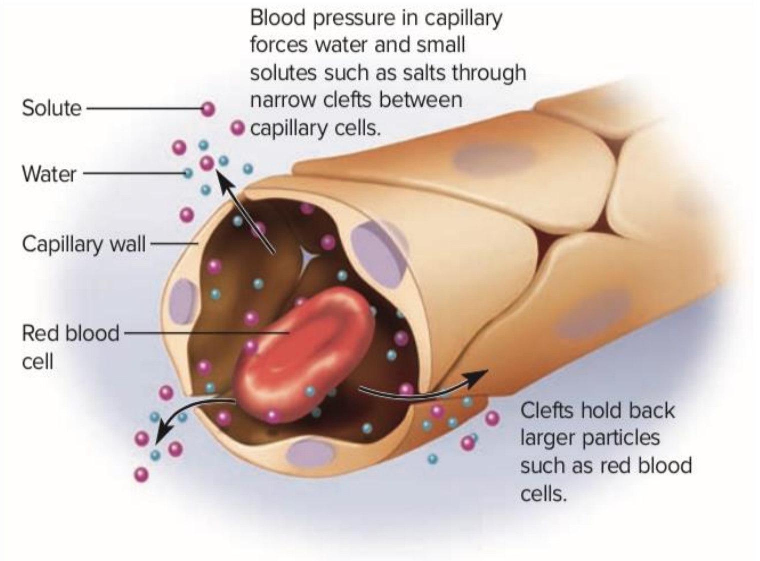

Phagocytosis
Large particle
Plasma membrane
Vacuole
(a)
Pinocytosis
Vesicle
(b)
Receptor-mediated endocytosis
Ligand
Receptor
Coated vesicle
(c)



Capillary endothelial cell
Intercellular cleft
Capillary lumen
Pinocytotic vesicles
Muscle cell
Tissue fluid

Filtration and Reabsorption

- **Filtration** is a process in which a physical pressure forces fluid through a selectively permeable membrane
- **selectively permeable membrane-** it allows some things through, such as nutrients and wastes, but usually prevents other things, such as proteins and phosphates, from entering or leaving the cell.



- filtration is seen in the blood capillaries, where blood pressure forces fluid through gaps in the capillary wall

Filtration and Reabsorption

- fluid filters out of the arterial end of the capillary and osmotically reenters at the venous end
  - delivers materials to the cell and removes metabolic wastes
- This comes about as the result of a shifting balance between **osmosis** and **hydrostatic pressure**
- **opposing forces**
  - **blood hydrostatic pressure** drives fluid out of capillary
    - high on arterial end of capillary, low on venous end
  - **colloid osmotic pressure** (COP) draws fluid into capillary
    - results from plasma proteins (albumin)- more in blood
    - **oncotic pressure** = net COP (blood COP - tissue COP)
- **hydrostatic pressure**
  - physical force exerted against a surface by a liquid
    - blood pressure is an example
- capillaries reabsorb about **85%** of the fluid they filter
- other **15%** is absorbed by the **lymphatic system** and returned to the blood

Capillary Filtration and Reabsorption

- **capillary filtration** at arterial end
- **capillary reabsorption** at venous end
- variations
  - location
    - glomeruli- devoted to filtration
    - alveolar capillary - devoted to absorption
  - activity or trauma
    - increases filtration

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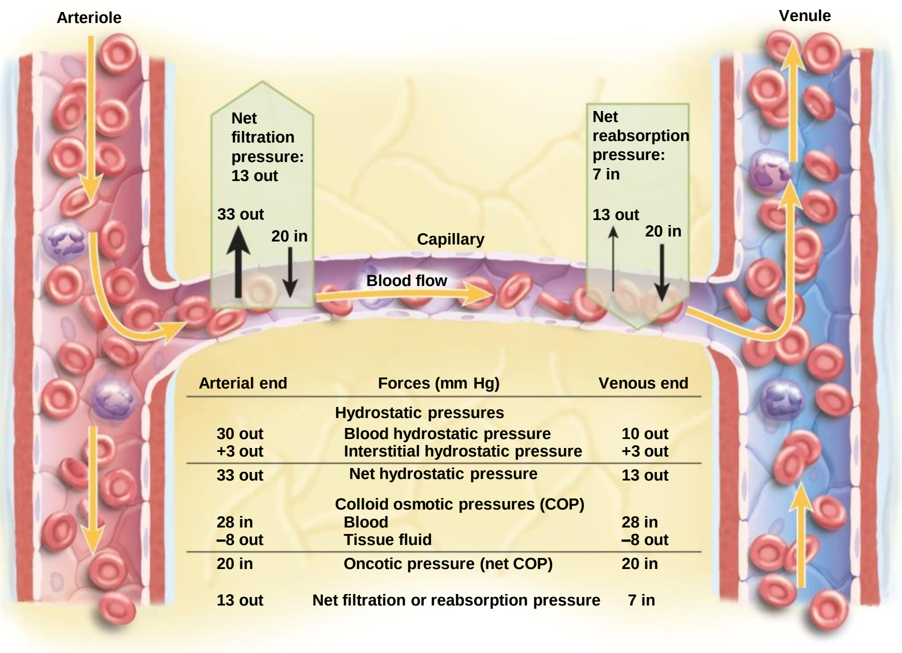

Arterial end	Forces (mm Hg)	Venous end
	Hydrostatic pressures	
30 out	Blood hydrostatic pressure	10 out
+3 out	Interstitial hydrostatic pressure	+3 out
33 out	Net hydrostatic pressure	13 out
	Colloid osmotic pressures (COP)	
28 in	Blood	28 in
–8 out	Tissue fluid	–8 out
20 in	Oncotic pressure (net COP)	20 in
13 out	Net filtration or reabsorption pressure	7 in

Capillary Filtration and Reabsorption

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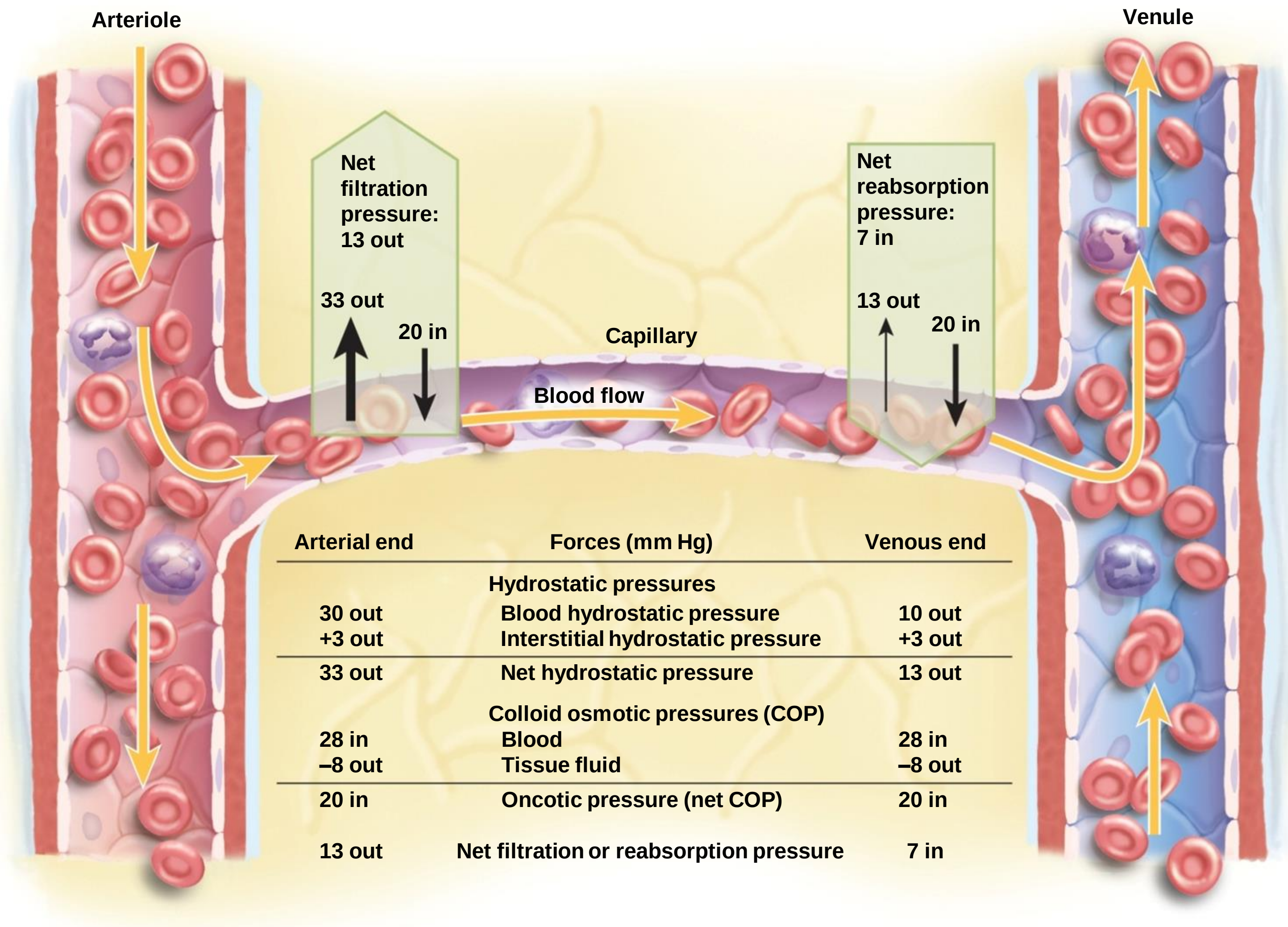

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33 out	Net hydrostatic pressure	13 out
	Colloid osmotic pressures (COP)	
28 in	Blood	28 in
–8 out	Tissue fluid	–8 out
20 in	Oncotic pressure (net COP)	20 in
13 out	Net filtration or reabsorption pressure	7 in

Figure 20.17

APPLY WHAT YOU KNOW

- What forces favor capillary filtration? What forces favor reabsorption?

APPLY WHAT YOU KNOW

- How can a capillary shift from a predominantly filtering role at one time to a predominantly reabsorbing role at another?

APPLY WHAT YOU KNOW

- **The capillary is able to shift because of the change in pressure and flow through it. Chemical influences also affect this.**

Variations in Capillary Activity

- capillaries usually reabsorb most of the fluid they filter – exception:
  - **kidney capillaries** in glomeruli do not reabsorb
  - **alveolar capillaries** in lung absorb completely to keep fluid out of air spaces

- capillary activity varies from moment to moment
  - collapsed in resting tissue, reabsorption predominates since BP is low
  - metabolically active tissue has increase in capillary flow and BP
    - increase in muscular bulk by 25% due to accumulation of fluid

APPLY WHAT YOU KNOW

- State the three fundamental causes of edema and explain why edema can be dangerous.

APPLY WHAT YOU KNOW

- 1. increased capillary filtration
- 2. reduced capillary re absorption
- 3. obstructed lymphatic drainage
- The more fluid that flows into the tissues the less oxygen delivery and waste removal there is in the tissues. This may cause the tissues to die. In the lungs the fluid could cause suffocation.

Edema

- **edema** – the accumulation of excess fluid in a tissue
  - occurs when fluid filters into a tissue faster than it is absorbed

- three primary causes
  - **increased capillary filtration**
    - kidney failure, histamine release, old age, poor venous return
  - **reduced capillary absorption**
    - hypoproteinemia, liver disease, dietary protein deficiency
  - **obstructed lymphatic drainage**
    - surgical removal of lymph nodes

Consequences of Edema

- tissue necrosis
  - oxygen delivery and waste removal impaired
- pulmonary edema
  - suffocation threat
- cerebral edema
  - headaches, nausea, seizures, and coma
- severe edema or circulatory shock
  - excess fluid in tissue spaces causes low blood volume and low blood pressure

Keeping up with the Joneses: A Case Study in Human Physiology

by
Phil Stephens
Biology Department
Villanova University, Villanova, PA

- **Part I—The Accident**
- **…..A freak accident. Dave rolled his ankle as he was rounding first base. He hit the ground and we all thought that his leg was broken, but the x-rays proved us wrong. It's just a badly sprained ankle.**
- **I've given you a prescription for a more powerful analgesic than your regular over-the-counter pain medicine," said the doctor.**
- **"Inflammation is caused by fluid moving from the blood and accumulating in the space between the cells. To minimize the inflammation of Dave's ankle, just remember PRICE—Protect, Rest, Ice, Compression, and Elevation. Call your family physician if his pain becomes severe," said the young doctor as he walked back to the examination rooms.**

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- **Define the following terms as they relate to capillary exchange: diffusion, transcytosis, filtration, reabsorption.**

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- **What two parameters are responsible for creating the movement (filtration and reabsorption) of fluid across the capillary wall?**

Filtration and Reabsorption

- This comes about as the result of a shifting balance between **osmosis** and **hydrostatic pressure**
- **opposing forces**
  – **blood hydrostatic pressure** drives fluid out of capillary
    - high on arterial end of capillary, low on venous end
  – **colloid osmotic pressure** (COP) draws fluid into capillary
    - results from plasma proteins (albumin)- more in blood
    - **oncotic pressure** = net COP (blood COP - tissue COP)

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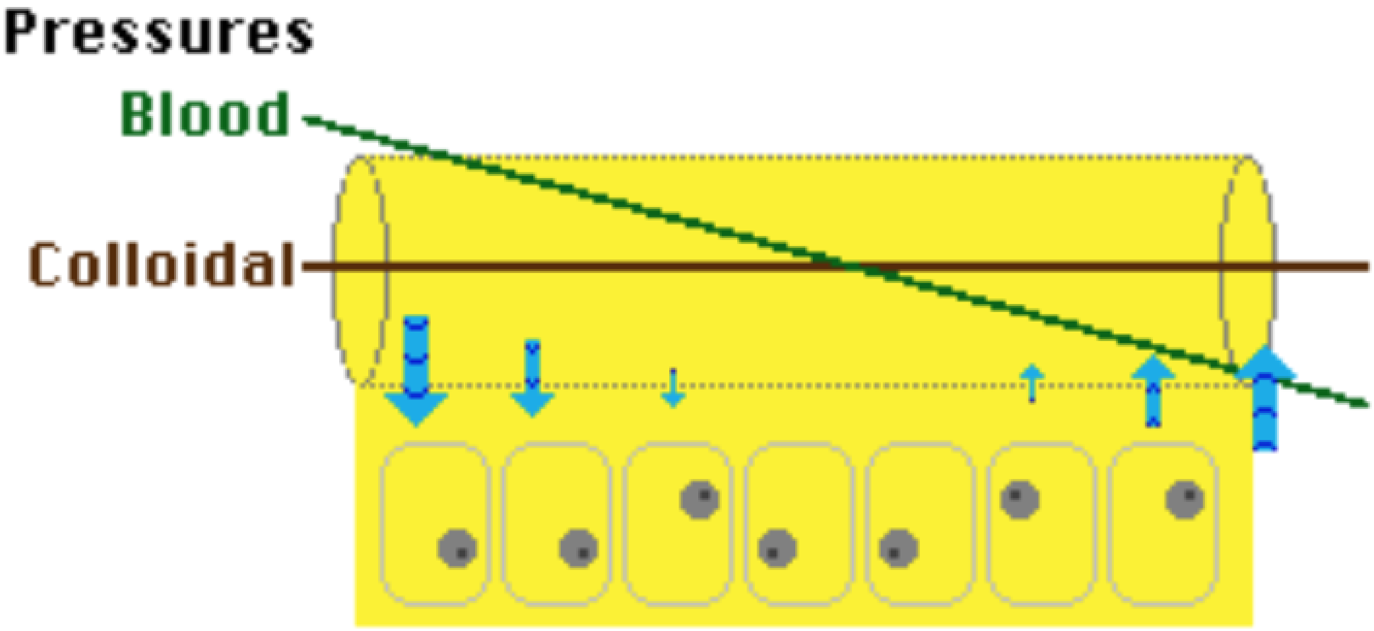
- **Draw a diagram of a capillary and label *arteriole* at one end and *venule* at the other. With pressure on the vertical axis, draw two lines to show how the two parameters (see question 1 above) vary**


Pressures
Blood
Colloidal

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- Under normal circumstances, what components of the blood cross the capillary wall?

Capillary Exchange - Diffusion

- **capillary diffusion can only occur if:**
  - the solute can **permeate** the **plasma membranes** of the endothelial cell, or
  - find **passages** large enough to pass through
    - **filtration pores and intracellular clefts**
- **lipid soluble substances**
  - steroid hormones, O_2 and CO_2 diffuse easily through **plasma membranes**
- **water soluble substances**
  - glucose and electrolytes must pass through **filtration pores and intercellular clefts**
- **large particles** - proteins, held back

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- Cytokines, like histamine and leukotrienes, are secreted by damaged cells in Dave’s ankle. How do these cytokines cause inflammation?

- Increase the size of the holes *(fenestrae)* between the endothelial cells of the capillary.

Keeping up with the Joneses: A Case Study in Human Physiology

by

Phil Stephens
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- **How does the application of ice to the ankle affect blood flow through the capillaries?**

Keeping up with the Joneses:
A Case Study in Human Physiology

by

Phil Stephens
Biology Department
Villanova University, Villanova, PA

- **How does the removal of ice from the ankle affect blood flow through the capillaries and the cytokines?**

Keeping up with the Joneses: A Case Study in Human Physiology

by

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Villanova University, Villanova, PA

- **How does compression, which is provided by an elastic (Ace) bandage wrapped around the damaged ankle, decrease inflammation?**

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Villanova University, Villanova, PA

Compression increases the pressure outside the capillary, in the interstitial fluid. Since the (transmural) blood pressure is the difference between the inside and the outside of the vessel, increasing the outside pressure functionally decreases blood pressure. Thus, there will be a decrease in the amount of filtration and an increase in reabsorption.

by
Phil Stephens
Biology Department
Villanova University, Villanova, PA

- **How does elevation of the damaged ankle decrease inflammation?**

Circulatory System

-BLOOD VESSELS AND CIRCULATION

Al-Farabi Kazakh National University
Higher School of Medicine

◆ PART IV

LEARNING OUTCOMES

As a result of the lesson you will be able to:

- ***Explain how the brain maintains stable perfusion;***
- ***discuss the causes and effects of strokes and transient ischemic attacks;***
- ***explain the mechanisms that increase muscular perfusion during exercise;***
- ***contrast the blood pressure of the pulmonary circuit with that of the systemic circuit, and explain why the difference is important in pulmonary function.***
- ***identify the principal systemic arteries and veins of the axial region;***

Special Circulatory Routes- Brain

- total blood flow to the brain fluctuates less than that of any other organ (700 mL/min)
  - **seconds** of deprivation causes loss of consciousness
  - **4-5 minutes** causes irreversible brain damage
  - blood flow can be shifted from one active brain region to another
- brain regulates its own blood flow to match changes in **BP and chemistry**
  - cerebral arteries dilate as systemic BP drops, constrict as BP rises
  - main chemical stimulus: pH
    - $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + (HCO_3)^-$
    - **hypercapnia[*capn* = smoke] -** CO_2 levels increase in brain, pH decreases, triggers vasodilation
    - **hypocapnia** – raises pH, stimulates vasoconstriction
      - occurs with hyperventilation, may lead to ischemia, dizziness, and sometimes syncope

TIAs and CVAs

- **transient ischemic attacks (TIAs)** – brief episodes of cerebral ischemia
  - caused by spasms of diseased cerebral arteries
  - dizziness, loss of vision, weakness, paralysis, headache or aphasia
  - lasts from a moment to a few hours
  - often early warning of impending stroke
- **stroke - cerebral vascular accident (CVA)**
  - sudden death of brain tissue caused by ischemia
    - atherosclerosis, thrombosis, ruptured aneurysm
  - effects range from unnoticeable to fatal
    - blindness, paralysis, loss of sensation, loss of speech common
  - recovery depends on surrounding neurons, collateral circulation

Special Circulatory Routes Skeletal Muscle

- highly variable flow depending **on state of exertion**
- **at rest:**
  - arterioles constrict
  - most capillary beds shut down
  - total flow about 1L/min
- **during exercise**:
  - arterioles dilate in response to epinephrine and sympathetic nerves
  - precapillary sphincters dilate due to muscle metabolites like lactic acid, CO_2
  - blood flow can increase 20 fold
- muscular contraction impedes flow
  - isometric contraction causes fatigue faster than intermittent isotonic contractions

Special Circulatory Routes Lungs

- The pulmonary arteries have thin distensible walls with less elastic tissue than the systemic arteries.
- low pulmonary blood pressure (25/10 mm Hg)
  - flow slower, more time for gas exchange
  - engaged in capillary fluid absorption
    - oncotic pressure overrides hydrostatic pressure
    - prevents fluid accumulation in alveolar walls and lumens
- unique response to hypoxia
  - pulmonary arteries constrict in diseased area [response to local hypoxia]
  - redirects flow to better ventilated region

Anatomy of the Pulmonary Circuit

- The pulmonary circuit begins with the **pulmonary trunk,**from the right ventricle and branches into the **right and left pulmonary arteries.**
- As it approaches the lung, the right pulmonary artery branches in two, and both branches enter the lung at a medial indentation called **the *hilum.*** The mediastinal surface exhibits a slit called the **hilum** through which the lung receives the main bronchus, blood vessels, lymphatics, and nerves. These struc- tures constitute the **root** of the lung
- The upper branch is the **superior lobar artery,** serving the superior lobe of the lung. The lower branch divides again within the lung to form the **middle lobar** and **inferior lobar arteries,** supplying the lower two lobes of that lung. The left pulmonary artery is much more variable. It gives off several superior lobar arteries to the superior lobe before entering the hilum, then enters the lung and gives off a variable number of inferior lobar arteries to the inferior lobe.

Pulmonary Circulation

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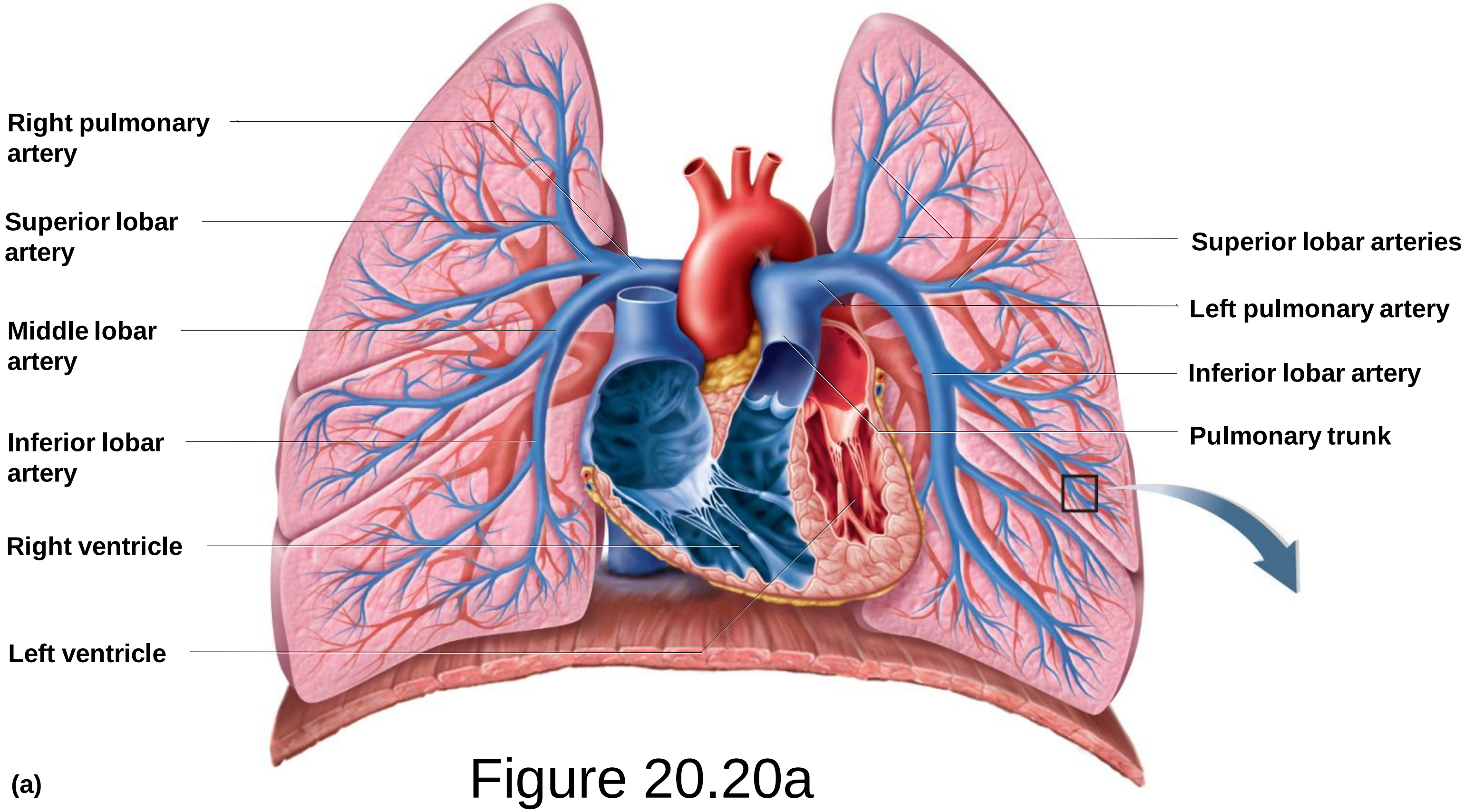

Figure 20.20a

- pulmonary trunk to pulmonary arteries to lungs
  - lobar branches for each lobe (3 right, 2 left)
- pulmonary veins return to left atrium
  - increased O_2 and reduced CO_2 levels

Pulmonary Capillaries Near Alveoli

- basketlike capillary beds surround alveoli

- exchange of gases with air and blood at alveoli

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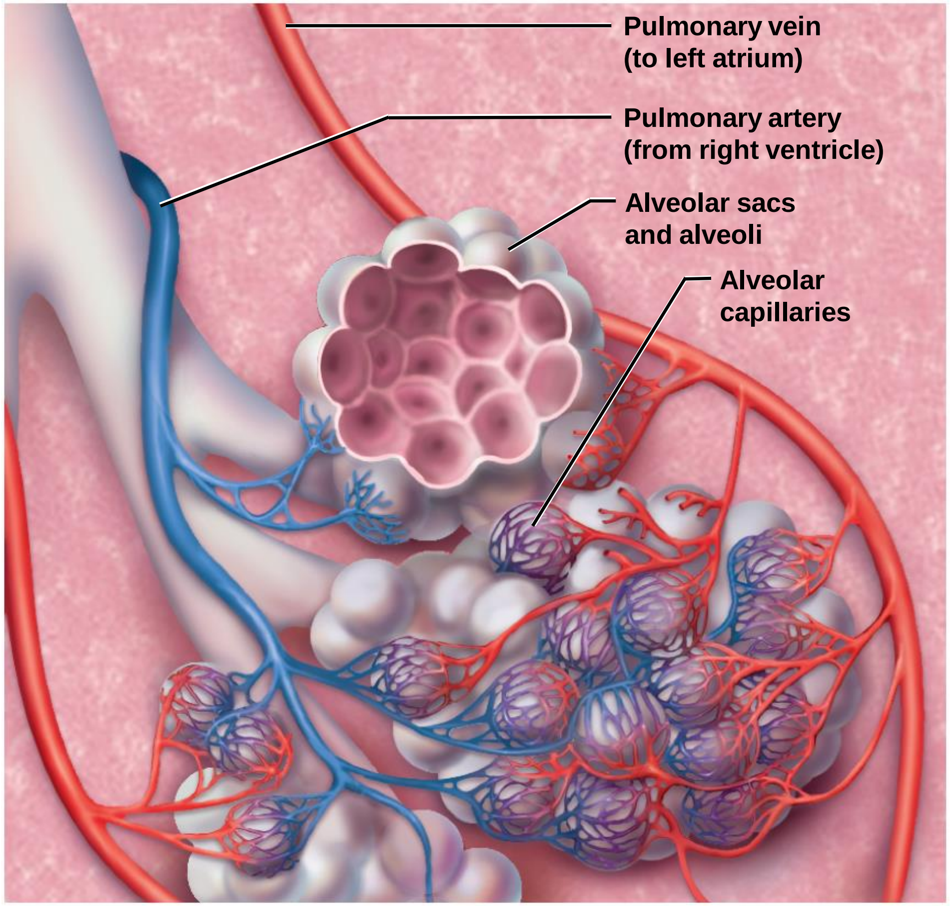

(b)

Figure 20.20b

A Case of Cerebrovascular Accident

by
David F. Dean, Department of Biology, Spring Hill College

Case Presentation

- **Samuel Dexter is a 52-year-old African-American man who is both a husband and father. He is moderately obese (bmi of 32), and has smoked two packs of cigarettes a day for the past 38 years. He awakes one morning with weakness on his right side. He is a bit confused, sees double, and his speech is slurred. When he attempts to walk to the bathroom, he stumbles a few times and falls once. His wife suspects that he has suffered a stroke and calls 911. Emergency personnel arrive within minutes of her call and transport Samuel to the emergency room of the nearest hospital.**

A Case of Cerebrovascular Accident

by
David F. Dean, Department of Biology, Spring Hill College

Case Presentation

- Upon examination by the emergency room physician, Samuel is found to have right hemiparesis and diminished pinprick and two-point discrimination on the right side of his head and arm. His deep tendon reflexes are brisk on the right and there is a positive Babinski reflex on the right. He has difficulty articulating answers to the questions he is asked, speaking only a few words and frequently responding with just a verb or a noun. His ability to respond to complicated verbal commands, whether spoken or written, is not impaired. In addition, his systemic blood pressure was found to be 160/100. A serum lipid profile was performed and the results are shown in the table below.

Table 1. Serum Lipid Profile Results	
Triglycerides	220 mg/dl
Total Cholesterol	280 mg/dl
LDL	210 mg/dl
HDL	30 mg/dl

- **Define the terms *ischemia* and *infarction*.**
- **What is a stroke? Describe the mechanism(s) by which strokes occur.**
- **Define the term *collateral blood flow*, and describe how this and other factors affect the development of stroke**

A Case of Cerebrovascular Accident

by
David F. Dean, Department of Biology, Spring Hill College

Case Presentation

- Ischemia is a reduction in blood flow to a part of the body resulting from a functional or actual obstruction of a blood vessel. Infarction is the death of cells as the result of ischemia.
- Cerebrovascular accidents (CVA), commonly called strokes, Strokes occur when there is obstruction of blood flow to a region of the brain and brain tissue dies as a result. One of the most common causes of CVA is obstruction of a cerebral artery by a fixed or mobile thrombus (i.e., thromboembolus). Other causes include compression of brain tissue by hemorrhage or edema (i.e., swelling), and progressive narrowing of cerebral arteries by arteriosclerosis.

A Case of Cerebrovascular Accident

by
David F. Dean, Department of Biology, Spring Hill College

Case Presentation

- Collateral blood flow is defined as, "Blood flow through secondary channels after obstruction of the principle channel supplying the part." When blood flow to a portion of the cerebral cortex is reduced, whether the affected portion of the cortex survives will be determined by variables such as: the degree of vascular obstruction, how quickly the obstruction occurred, the degree of available collateral circulation, and the length of time the region has been ischemic.
- The establishment of collateral blood flow is the single most important of those listed above in terms of determining the extent of tissue damage that results from local obstruction of cerebral blood flow.

Major Systemic Arteries

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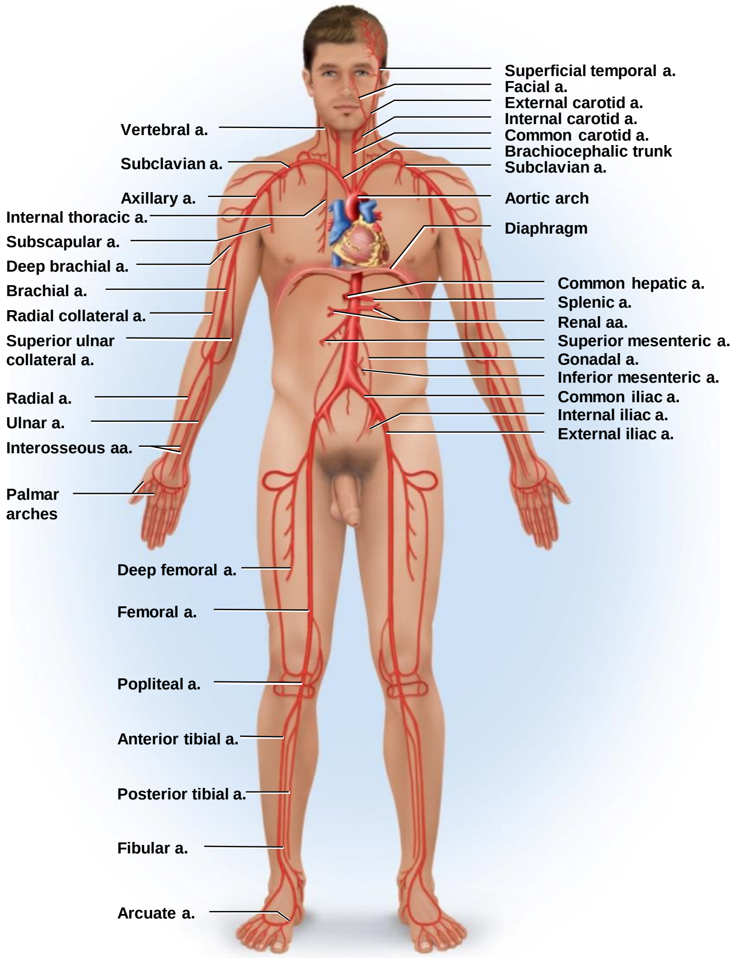

Figure 20.21

- supplies oxygen and nutrients to all organs

Major Branches of Aorta

- **ascending aorta**
  - right and left **coronary arteries** supply heart
- **aortic arch**
  - **brachiocephalic**
    - **right common carotid** supplying right side of head
    - **right subclavian** supplying right shoulder and upper limb
  - **left common carotid** supplying left side of head
  - **left subclavian** supplying left shoulder and upper limb
- **descending aorta**
  - **thoracic aorta** above diaphragm
  - **abdominal aorta** below diaphragm

Major Branches of the Aorta

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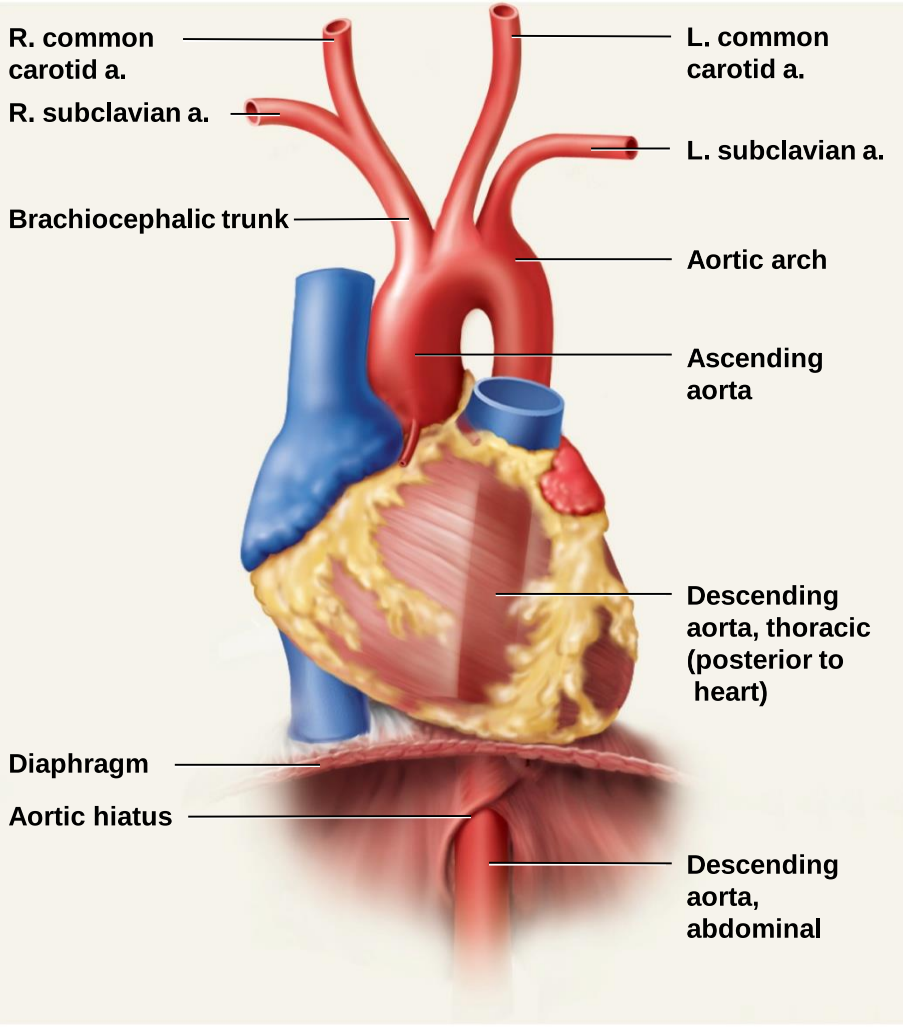

Figure 20.23

Arteries of the Head and Neck

- The head and neck receive blood from four pairs of arteries

  1. **The common carotid arteries.** Shortly after leaving the aortic arch, the brachiocephalic trunk divides into the ***right subclavian artery*** and ***right common carotid artery***. A little farther along the aortic arch, the ***left common carotid artery*** arises independently. The common carotids pass up the anterolateral region of the neck, alongside the trachea

Continuation of the Common Carotid Arteries

- Near the laryngeal prominence (“Adam’s apple”), each common carotid branches into an ***external and internal carotid artery.*** 1. The **external carotid artery** ascends the side of the head external to the cranium and supplies most external head structures except the orbits. It gives rise to the following arteries in ascending order:
- a. the **superior thyroid artery** to the thyroid gland and larynx;
- b. the **lingual artery** to the tongue;
- c. the **facial artery** to the skin and muscles of the face;
- d. the **occipital artery** to the posterior scalp;
- e. the **maxillary artery** to the teeth, maxilla, oral cavity, and external ear;
- f. the **superficial temporalartery** to the chewing muscles, nasa lcavity, lateral aspect of the face, most of the scalp, and the duramater.

Continuation of the Common Carotid Arteries

- Near the laryngeal prominence (“Adam’s apple”), each common carotid branches into an *external* and *internal carotid artery.*
-

  2. **The internal carotid artery** passes medial to the angle of the mandible and enters the cranial cavity through the carotid canal of the temporal bone. It supplies the orbits and about 80% of the cerebrum. After entering the cranial cavity, each internal carotid gives rise to the following branches:
- a. the **ophthalmic artery** to the orbit, nose, and forehead;
- b. the **anterior cerebral artery** to the medial aspect of the cerebral hemisphere;
- c. the **middle cerebral artery,** which travels in the lateral sulcus of the cerebrum, supplies the insula, and then issues numerous branches to the lateral region of the frontal, temporal, and parietal lobes of the brain.

Arteries of the Head and Neck

- 2. **The vertebral arteries**. These arise from the right and left subclavian arteries and travel up the neck through the transverse foramina of vertebrae C1 through C6. They enter the cranial cavity through the foramen magnum.
- **Continuation of the Vertebral Arteries**
- The vertebral arteries give rise to small branches that supply the spinal cord and its meninges, the cervical vertebrae, and deep muscles of the neck.
- They then enter the foramen magnum, supply the cranial bones and meninges, and converge to form a single **basilar artery** along the anterior aspect of the brainstem.
- Branches of the basilar artery supply the cerebellum, pons, and inner ear. At the pons-midbrain junction, the basilar artery divides and flows into the *cerebral arterial circle*.

Arteries of the Head and Neck

- 3. ***The thyrocervical trunks*.** These tiny arteries arise from the subclavian arteries lateral to the vertebral arteries; they supply the thyroid gland and some scapular muscles.
- 4. ***The costocervical trunks****.* These arteries arise from the subclavian arteries a little farther laterally. They supply the deep neck muscles and some of the intercostal muscles of the superior rib cage.

Arteries of the Head and Neck

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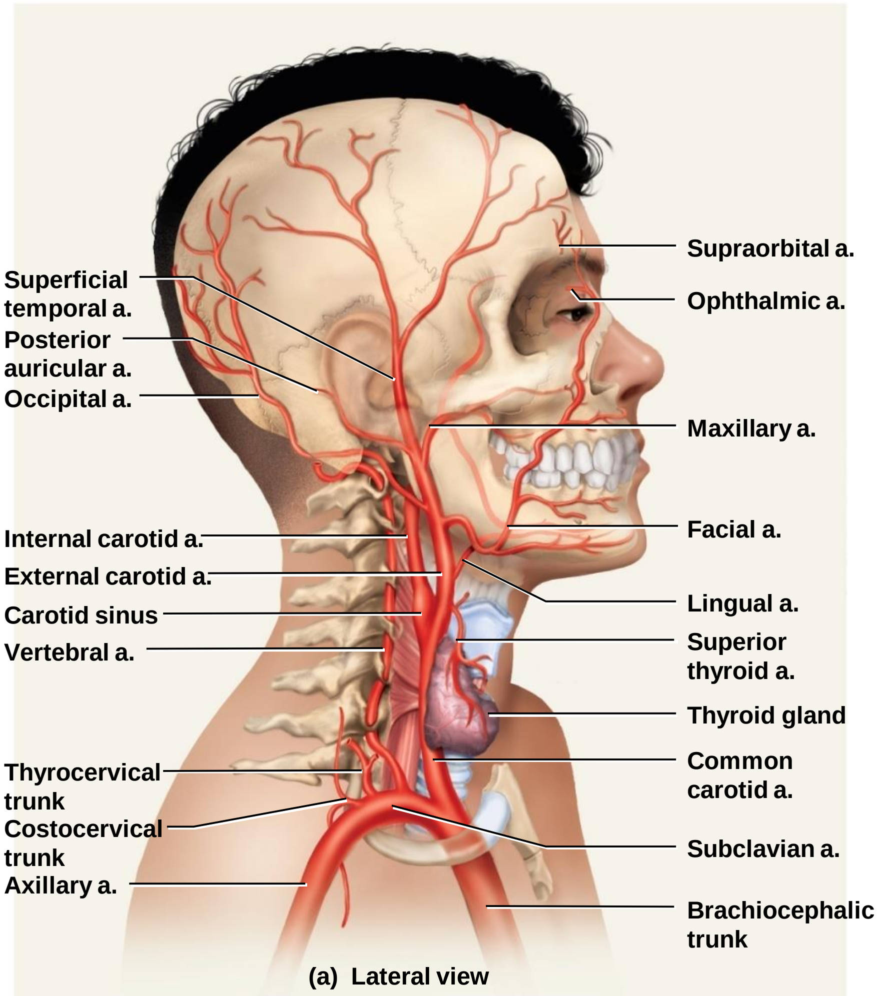

(a) Lateral view

Figure 20.24a

- common carotid divides into internal and external carotids
  - external carotid supplies most external head structures

Circulatory System

-BLOOD VESSELS AND CIRCULATION

Al-Farabi Kazakh National University Higher School of Medicine

◆ PART V

LEARNING OUTCOMES

As a result of the lesson you will be able to:

- ***identify the principal systemic arteries and veins of the axial region;***
- ***trace the flow of blood from the heart to any major organ of the axial region and back to the heart.***

Major Branches of the Aorta

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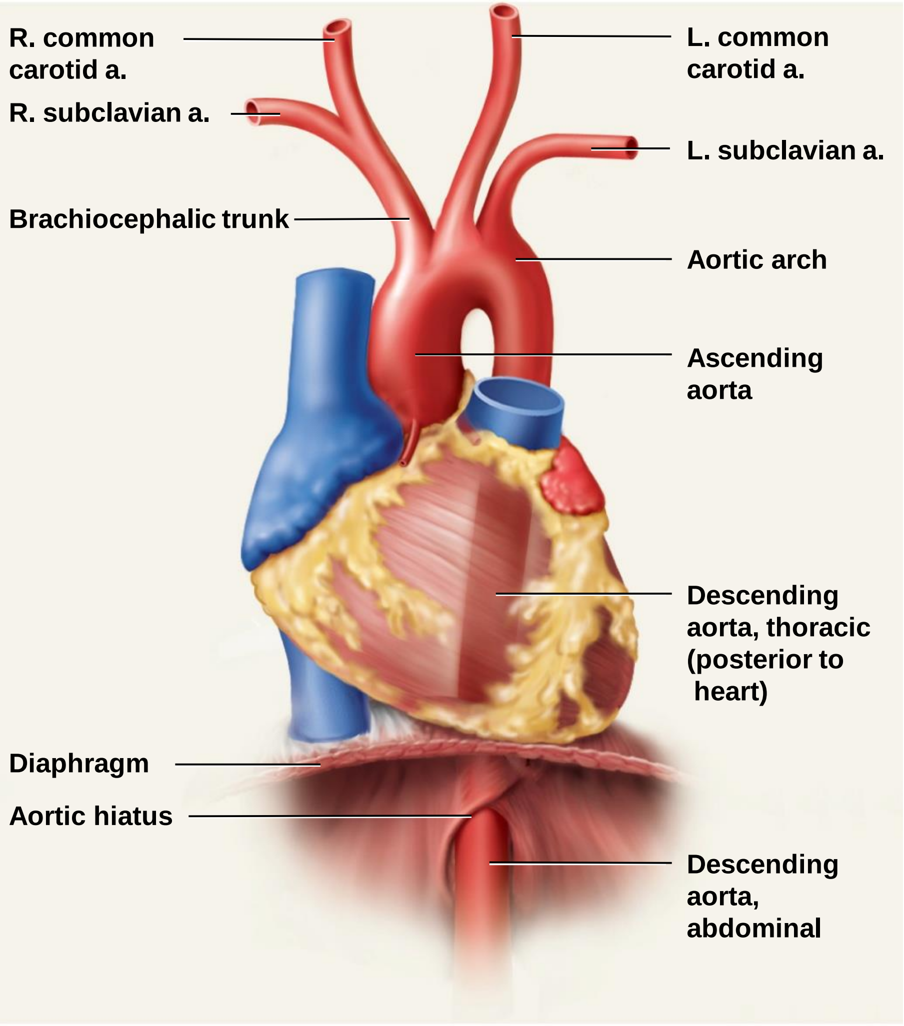

Figure 20.23

Arterial Supply of Brain

- paired **vertebral arteries** combine to form **basilar artery** on pons
- **Circle of Willis** on base of brain formed from *anastomosis of basilar and internal carotid arteries*
- supplies brain, internal ear and orbital structures
  - anterior, middle and posterior cerebral
  - superior, anterior and posterior cerebellar

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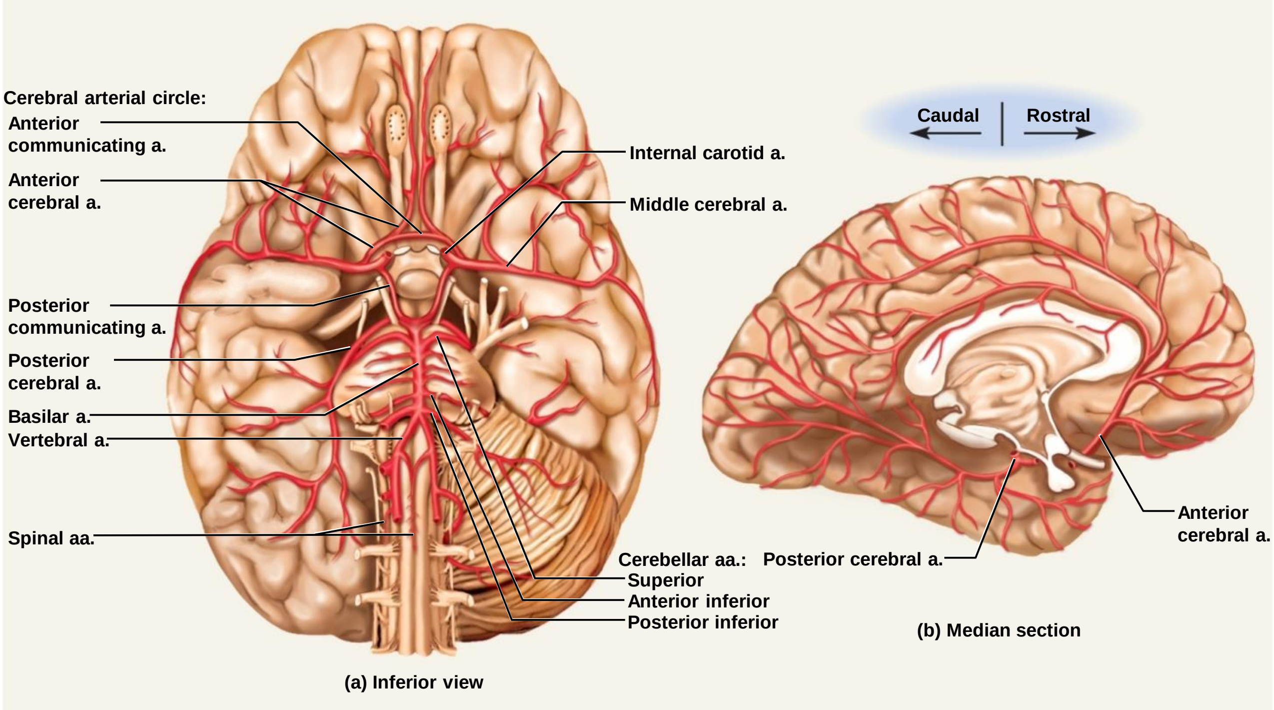

Figure 20.25 a-b

Arteries of the Head and Neck

- 1. Two **posterior cerebral arteries** arise from the *basilar artery* and sweep posteriorly to the rear of the brain, serving the inferior and medial regions of the temporal and occipital lobes as well as the midbrain and thalamus. 2. Two **anterior cerebral arteries** arise from the *internal carotids,* travel anteriorly, and then arch posteriorly over the corpus callosum as far as the posterior limit of the parietal lobe. They give off extensive branches to the frontal and parietal lobes.
- 3. The single **anterior communicating artery** is a short *anastomosis between the right and left anterior cerebral arteries.*
- 4. The two **posterior communicating arteries** are small *anastomoses between the posterior cerebral and internal carotid arteries*.

Major Systemic Arteries

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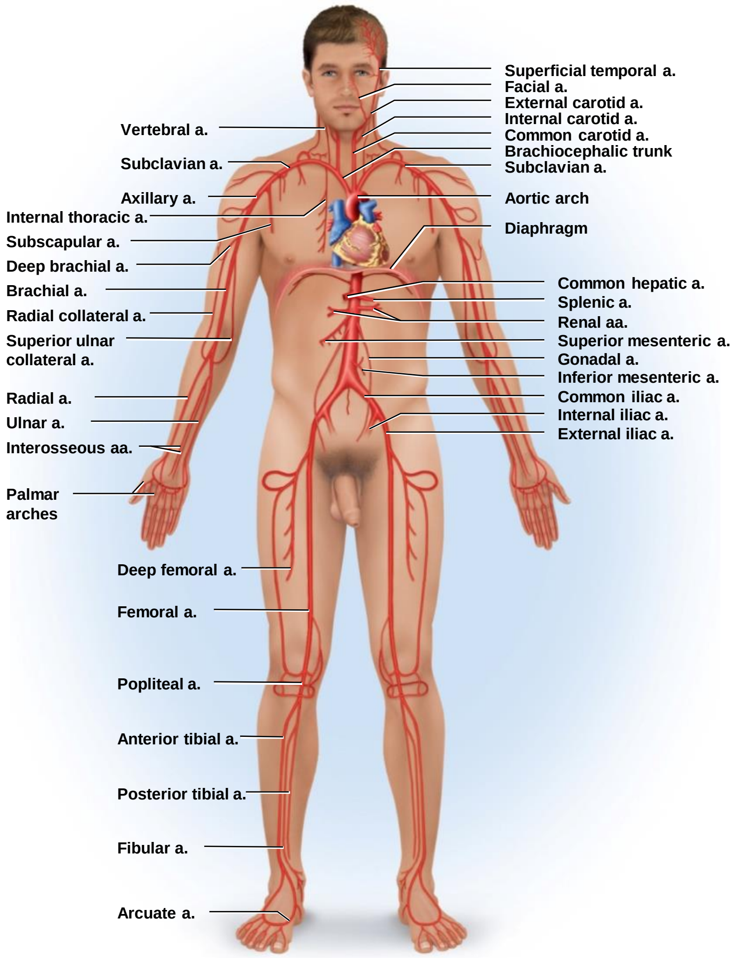

Figure 20.21

- supplies oxygen and nutrients to all organs

Major Systemic Veins

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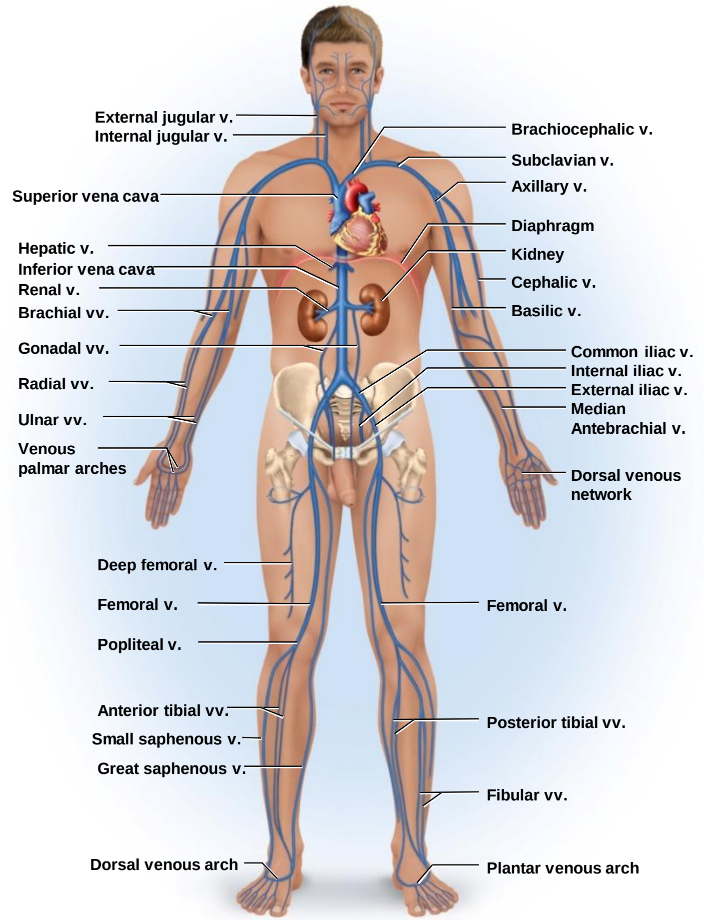

Figure 20.22

- deep veins run parallel to arteries while superficial veins have many anastomoses

Deep Veins of Head and Neck

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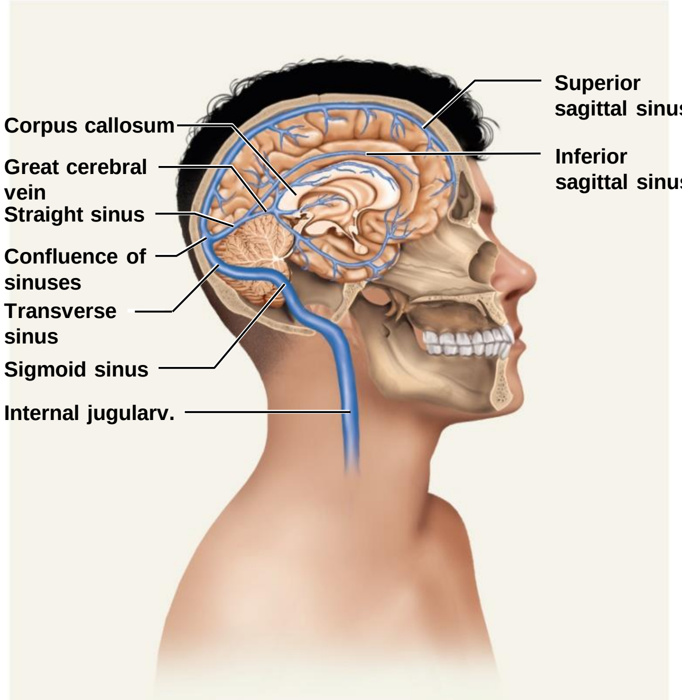
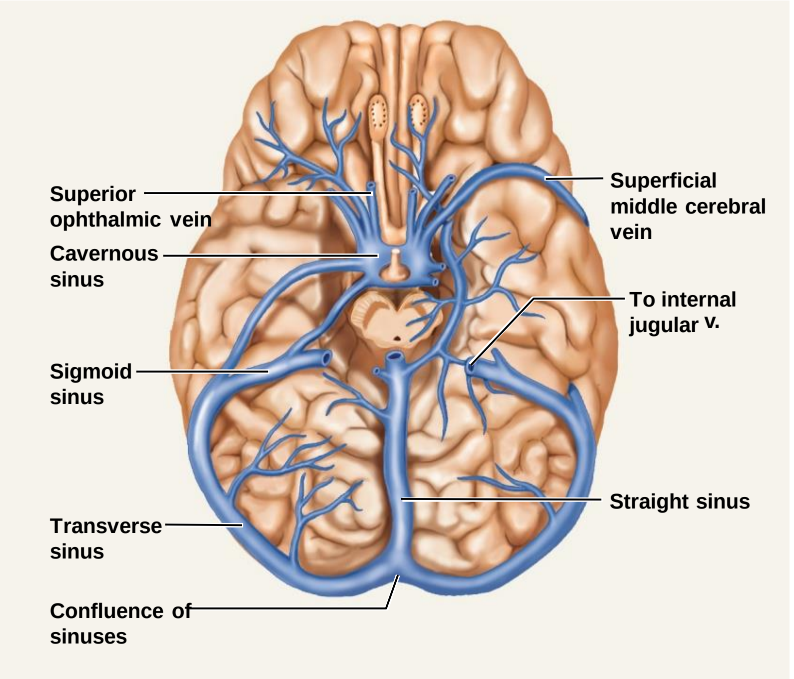


(a) Dural venous sinuses, medial view



(b) Dural venous sinuses, inferior view

Figure 20.26 a-b

- large, thin-walled **dural sinuses** form in between layers of dura mater
- drain blood from brain to internal jugular vein

Superficial Veins of Head and Neck

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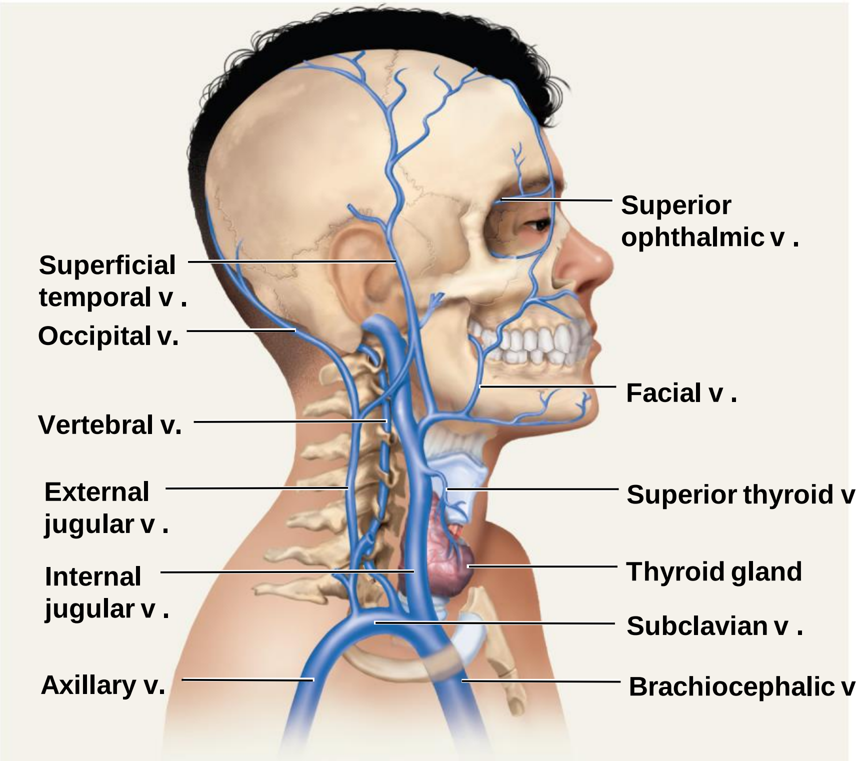

(c) Superficial veins of the head and neck

Figure 20.26c

- **internal jugular vein** receives most of the blood from the brain
- branches of **external jugular vein** drain the external structures of the head
- upper limb is drained by **subclavian vein**

Arteries of the Thorax

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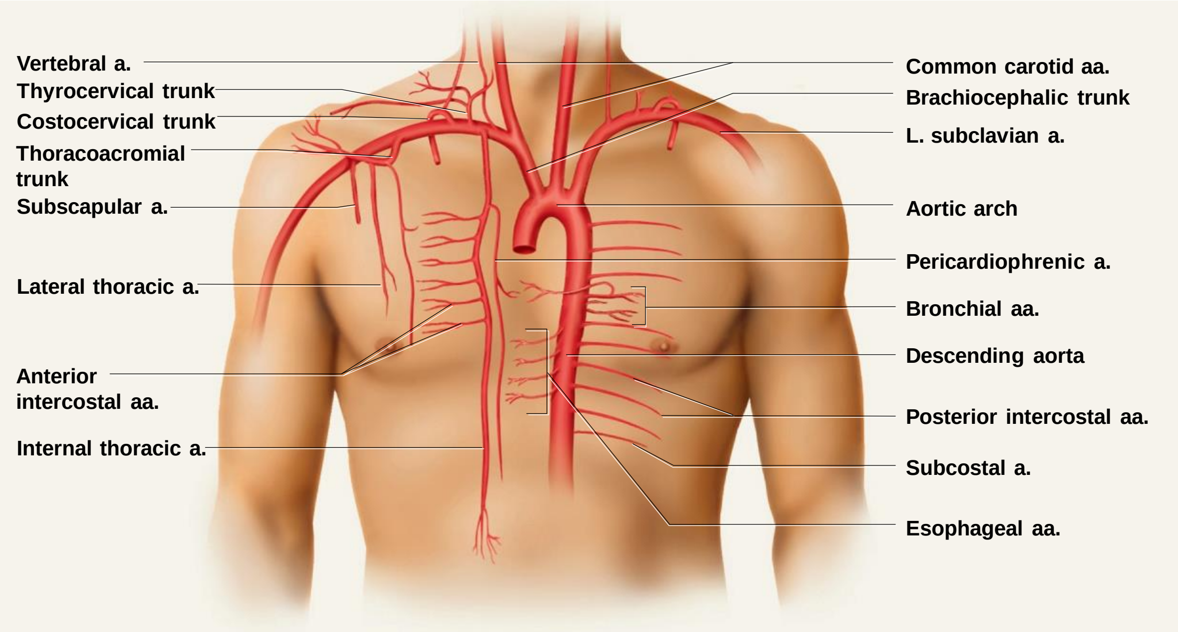


(a) Major arteries

Figure 20.27a

- thoracic aorta supplies viscera and body wall
  - bronchial, esophageal, and mediastinal branches
  - posterior intercostal and phrenic arteries
- internal thoracic, anterior intercostal, and pericardiophrenic arise from subclavian artery

Arteries of the Thorax

- **Visceral Branches of the Thoracic Aorta**

  - **Bronchial arteries.** The right bronchial artery usually arises from one of the left bronchial arteries or from a *posterior intercostal artery.* The bronchial arteries supply the visceral pleura, pericardium, and esophagus, and enter the lungs to supply the bronchi, bronchioles, and larger pulmonary blood vessels.
  - **Esophageal arteries.** Four or five unpaired esophageal arteries arise from the anterior surface of the aorta and supply the esophagus.
  - **Mediastinal arteries**. supply structures of the posterior mediastinum.

- **Parietal Branches of the Thoracic Aorta**
  - **Posterior intercostal arteries**. supply the intercostal, pectoralis, serratus anterior, and some abdominal muscles, as well as the vertebrae, spinal cord, meninges, breasts, skin, and subcutaneous tissue.
  - **subcostal arteries**. supply the posterior intercostal tissues, vertebrae, spinal cord, and deep muscles of the back.
  - **superior phrenic arteries**. supply the superior and posterior regions of the diaphragm.

Arteries of the Thorax

- **Branches of the Subclavian and Axillary Arteries**

▪ The **internal thoracic (mammary) artery** supplies the breast and anterior thoracic wall and issues the following branches:

a. The **pericardiophrenic artery** supplies the pericardium and diaphragm.

b. The **anterior intercostal arteries** arise from the thoracic artery as it descends alongside the sternum. They travel between the ribs, supply the ribs and intercostal muscles, and anastomose with the posterior intercostal arteries. Each of these sends one branch along the lower margin of the rib above and another, parallel branch along the upper margin of the rib below.

▪ The **thoracoacromial trunk** provides branches to the superior shoulder and pectoral regions.

▪ The **lateral thoracic artery** supplies the pectoral, serratus anterior, and subscapularis muscles. It also issues branches to the breast and is larger in females than in males.

▪ The **subscapular artery** is the largest branch of the axillary artery. It supplies the scapula and the latissimus dorsi, serratus anterior, teres major, deltoid, triceps brachii, and intercostal muscles.

Veins of the Thorax

- **Tributaries of the Superior Vena Cava**

  - The **subclavian vein** *drains the upper limb*.. It receives the ***external jugular and vertebral veins***, then ends (changes name) where it receives the internal jugular vein.
  - The **brachiocephalic vein** is formed by ***union of the subclavian and internal jugular veins***. The right brachiocephalic is very short, about 2.5 cm, and the left is about 6 cm long. They receive tributaries from the vertebrae, thyroid gland, and upper thoracic wall and breast.
  - The **superior vena cava** is formed by the ***union of the right and left brachiocephalic veins.*** Its main tributary is the ***azygos vein.*** It drains all structures superior to the diaphragm except the pulmonary circuit and coronary circulation.

Veins of the Thorax

- **The Azygos System**

■ **The right ascending lumbar vein** ***drains the right abdominal wall***

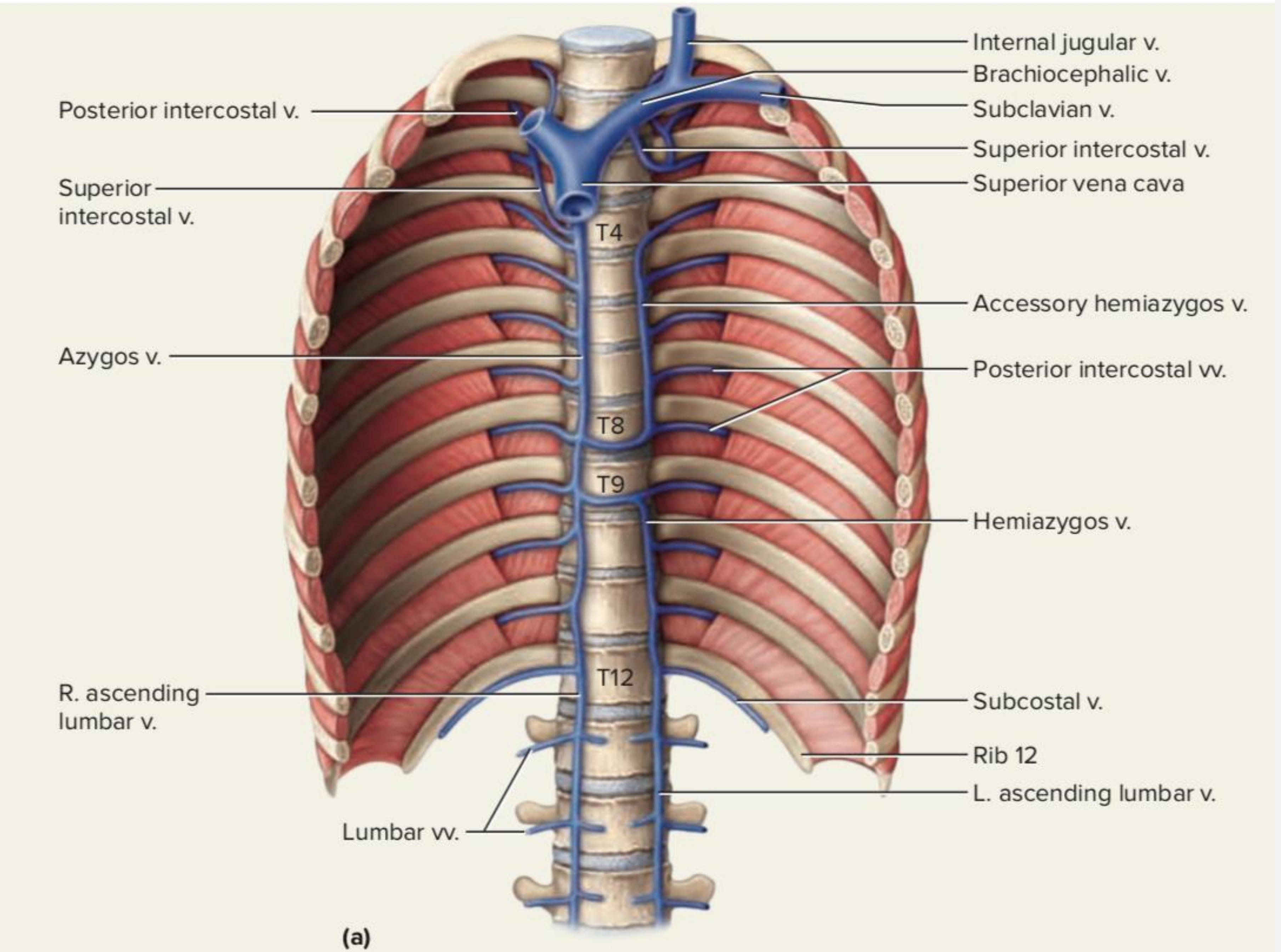
■ **The right posterior intercostal veins** ***drain the intercostal spaces***.

■ **The right esophageal, mediastinal, pericardial, and bronchial veins** drain their respective organs into the azygos vein.

■ **The hemiazygos vein** **receives the *lower three posterior intercostal veins, esophageal veins, and mediastinal veins.*** At the level of vertebra T9, it crosses to the right and empties into the azygos vein.

■ **The accessory hemiazygos vein** receives drainage from ***posterior intercostal veins 4 through 8 and sometimes the left bronchial veins.***

■ **The left posterior intercostal veins The first** one usually *drains directly into the left brachiocephalic vein*. **The second and third** unite to form the ***left superior intercostal vein***, which empties into the left brachiocephalic vein.



Internal jugular v.
Brachiocephalic v.
Subclavian v.
Superior intercostal v.
Superior vena cava
Posterior intercostal v.
Superior intercostal v.
T4
Accessory hemiazygos v.
Azygos v.
Posterior intercostal vv.
T8
T9
Hemiazygos v.
T12
R. ascending lumbar v.
Subcostal v.
Rib 12
L. ascending lumbar v.
Lumbar vv.

(a)

Arteries of the Abdominal and Pelvic Region

- **Major Branches of the Abdominal Aorta**

■ The **inferior phrenic arteries** supply the inferior surface of the diaphragm.

■ The **celiac trunk** supplies the upper abdominal viscera

■ The **superior mesenteric artery** supplies the intestines.

■ The **middle suprarenal arteries** supply the adrenal glands.

■ The **renal arteries** supply the kidneys.

■ The **ovarian arteries** of the female and **testicular arteries** of the male (collectively called the **gonadal arteries**) descend along the posterior body wall to the female pelvic cavity or male scrotum, and supply the gonads.

■ The **inferior mesenteric artery** supplies the distal end of the large intestine.

■ The **lumbar arteries** arise from the lower aorta in four pairs. They supply the posterior abdominal wall (muscles, joints, and skin) and the spinal cord and other tissues in the vertebral canal.

■ The **median sacral artery,** a tiny median artery at the inferior end of the aorta, supplies the sacrum and coccyx.

■ The **common iliac arteries** arise as the aorta forks at its inferior end.

Major Branches of Abdominal Aorta

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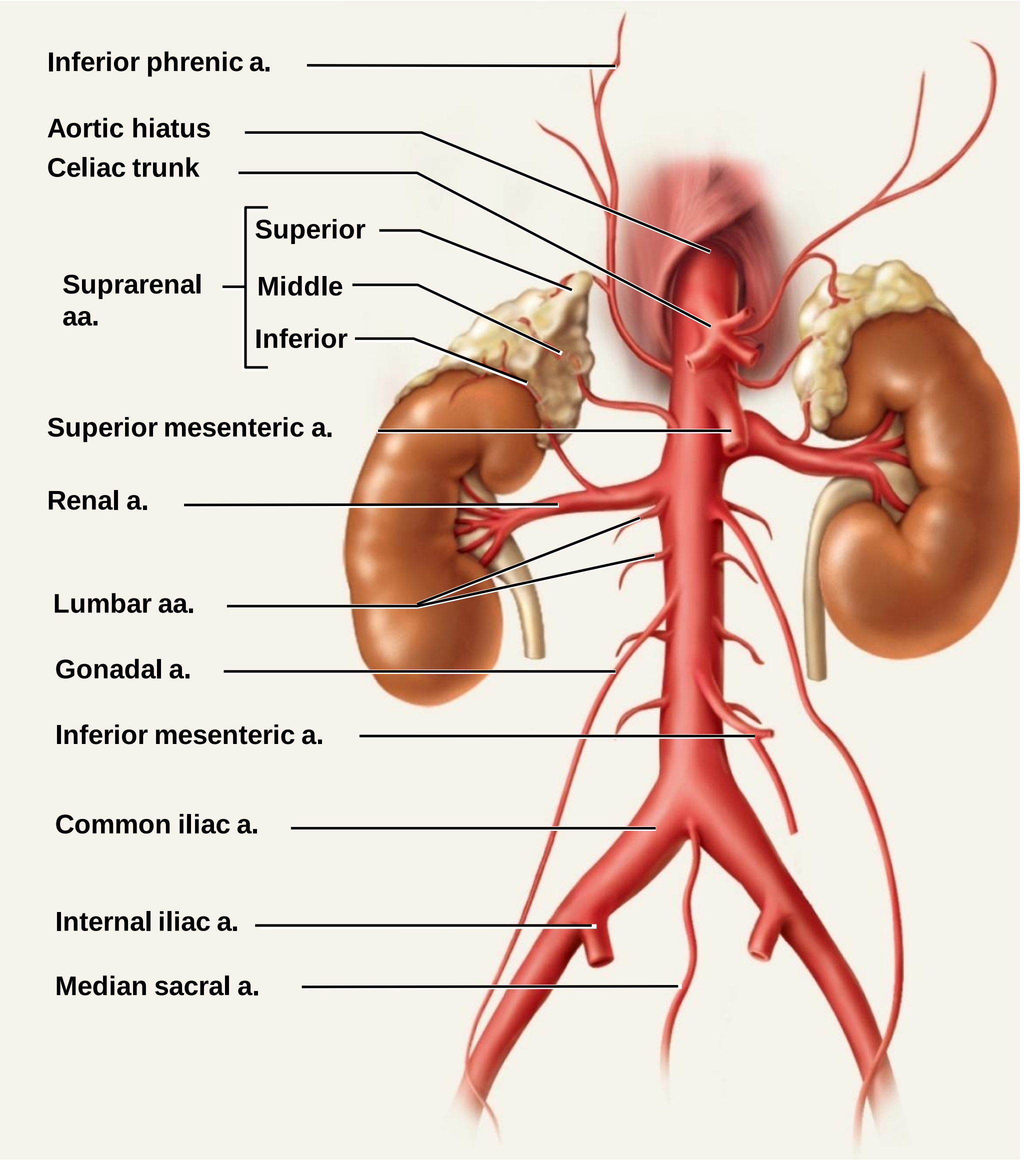


Figure 20.29

Arteries of the Abdominal and Pelvic Region

- **Branches of the Celiac Trunk**

■ The **common hepatic artery**.

○ a. The **gastroduodenal artery** gives off the **right gastro-omental (gastroepiploic) artery** to the stomach. It then continues as the **pancreaticoduodenal artery**, which splits into two branches that pass around the anterior and posterior sides of the head of the pancreas. These anastomose with the two branches of the *inferior pancreaticoduodenal artery*.

○ b. The **hepatic artery proper** ascends toward the liver. It gives off the **right gastric artery,** then branches into **right** and **left hepatic arteries.** The right hepatic artery issues a **cystic artery** to the gallbladder, then the two hepatic arteries enter the liver from below.

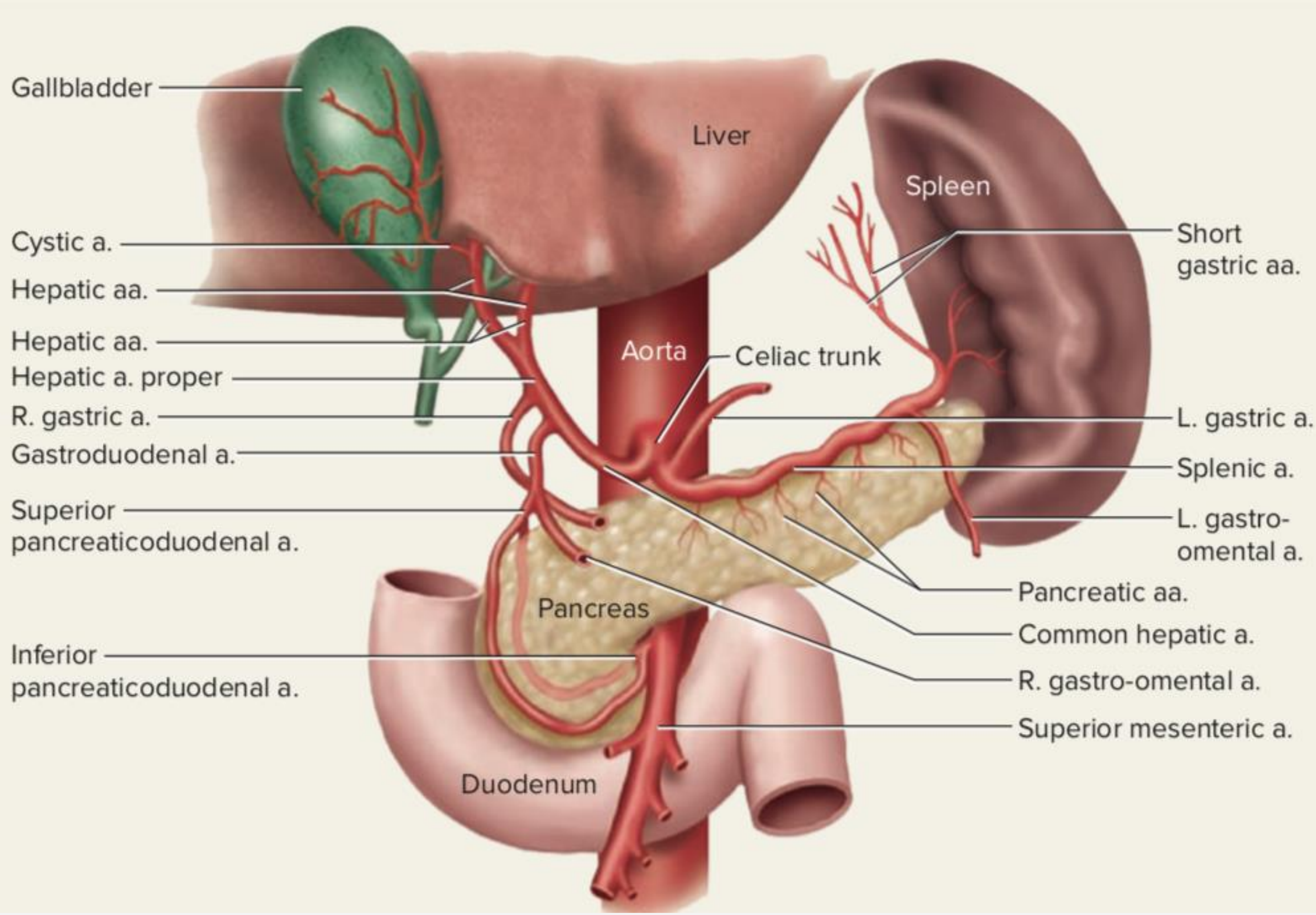
■ The **left gastric artery** supplies the stomach and lower esophagus, arcs around the *lesser curvature* (superomedial margin) of the stomach, and anastomoses with the right gastric artery. Thus, the right and left gastric arteries approach from opposite directions and supply this margin of the stomach. The left gastric also has branches to the lower esophagus, and the right gastric also supplies the duodenum.

■ The **splenic artery** supplies blood to the spleen, but gives off the following branches on the way there:

○ Several small **pancreatic arteries** supply the pancreas.

○ The **left gastro-omental (gastroepiploic) artery** arcs around the *greater curvature* (inferolateral margin) of the stomach and anastomoses with the right gastro-omental artery. furnish blood to both the stomach and omentum.

○ The **short gastric arteries** supply the upper portion (fundus) of the stomach.


Gallbladder
Liver
Spleen
Cystic a.
Hepatic aa.
Hepatic aa.
Hepatic a. proper
R. gastric a.
Gastroduodenal a.
Superior pancreaticoduodenal a.
Aorta
Celiac trunk
Short gastric aa.
L. gastric a.
Splenic a.
L. gastro-omental a.
Pancreatic aa.
Common hepatic a.
R. gastro-omental a.
Superior mesenteric a.
Pancreas
Inferior pancreaticoduodenal a.
Duodenum

Celiac Trunk Branches

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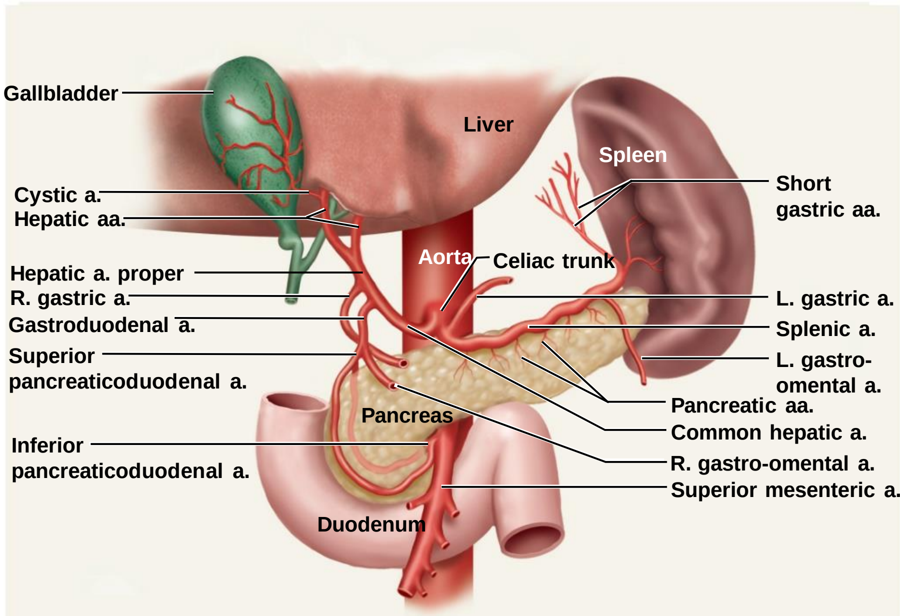
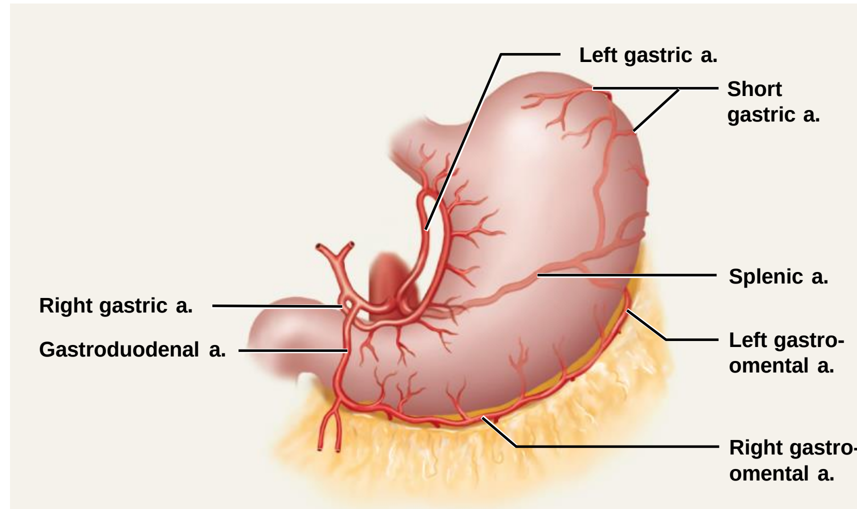


(a) Branches of the celiac trunk



(b) Celiac circulation to the stomach

Figure 20.30 a-b

- branches of **celiac trunk** supply upper abdominal viscera - stomach, spleen, liver, and pancreas

Arteries of the Abdominal and Pelvic Region

- **Mesenteric Circulation**

superior mesenteric artery:

- **1. The inferior pancreaticoduodenal artery,** branches to pass around the anterior and posterior sides of the pancreas and anastomose with the two branches of the superior pancreaticoduodenal artery.
- **2. Twelve to 15 jejunal and ileal arteries** form a fanlike array that supplies nearly all of the small intestine
- **3. The ileocolic artery** supplies the ileum, appendix, and parts of the large intestine.
- **4. The right colic artery** also supplies the ascending colon.
- **5. The middle colic artery** supplies most of the transverse colon.
- **The inferior mesenteric artery**:
  - **1. The left colic artery supplies the transverse and descending colon.**
  - **2. The sigmoid arteries supply the descending and sigmoid colon.**
  - 3. The **superior rectal artery** supplies the rectum.

Mesenteric Arteries

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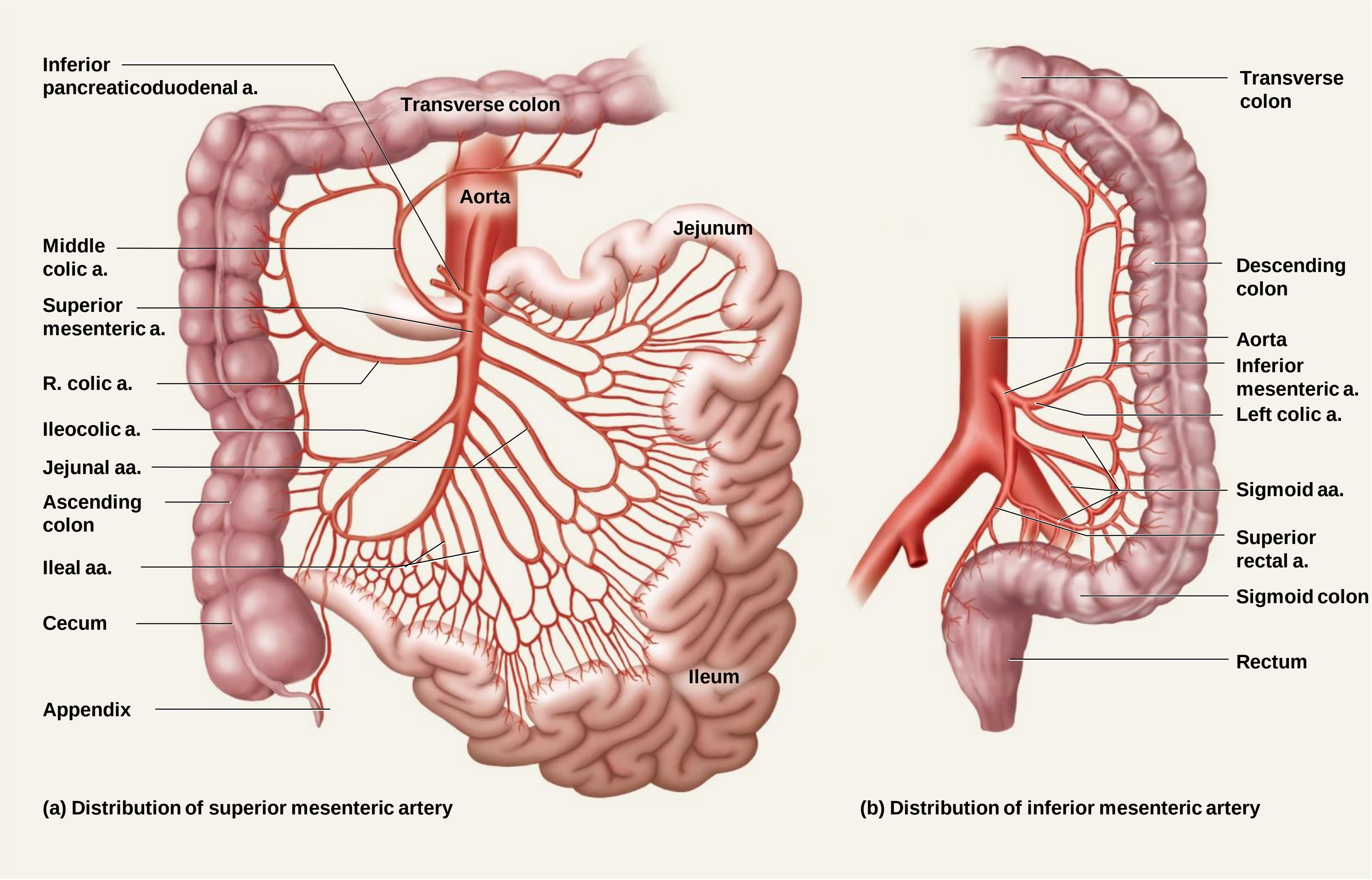

Figure 20.31 a-b

Arteries of the Pelvic Region

- **The internal iliac artery** supplies mainly the pelvic wall and viscera**.**divides into anterior and posterior trunks.
- **The anterior trunk produces the following branches:**

■ **1. The superior vesical artery** supplies the urinary bladder and distal end of the ureter.

■ **2.** In men, **the inferior vesical artery** supplies the bladder, ureter, prostate gland, and seminal vesicle. In women, the corresponding vessel is **the vaginal artery,** which supplies the vagina and part of the bladder and rectum.

■ **3. The middle rectal artery** supplies the rectum.

■ **4. The obturator artery** exits the pelvic cavity through the obturator foramen and supplies the adductor muscles of the medial thigh.

■ 5. **The internal pudendalartery** supplies the blood for vascular engorgement during sexual arousal.

■ **6.** In women, **the uterine artery** is the main blood supply to the uterus and supplies some blood to the vagina. **It enlarges substantially in pregnancy. It passes up the uterine margin, then turns laterally at the uterine tube and anastomoses with the *ovarian artery,*** thus supplying blood to the ovary as well**.**

■ **7. The inferior gluteal artery** supplies the gluteal muscles and hip joint.

Arteries of the Pelvic Region

- **The internal iliac artery**.
- **The posterior trunk produces the following branches:**
- **1. The iliolumbar artery** supplies the lumbar body wall and pelvic bones.
- **2. The lateral sacral arteries** lead to tissues of the sacral canal, skin, and muscles posterior to the sacrum. There are usually two of these, superior and inferior.
- **3. The superior gluteal artery** supplies the skin and muscles of the gluteal region and the muscle and bone tissues of the pelvic wall.

Veins of the Abdominal and Pelvic Region

- **Tributaries of the Inferior Vena Cava**

- ■ **The inferior vena cava (IVC) is the body's largest blood vessel, picks up blood from numerous tributaries in the following ascending order**
- ○ **The internal iliac veins** drain the gluteal muscles; the medial aspect of the thigh, the urinary bladder, rectum, prostate, and ductus deferens of the male; and the uterus and vagina of the female. They unite with the ***external iliac veins,*** which drain the lower limb**.**
- ○ Four pairs of **lumbar veins** empty into the IVC, as well as into the ascending lumbar veins
- ○ **The ovarian veins of the female and testicular veins of the male (collectively called the gonadal veins)** drain the gonads.
- ○ **The renal veins** drain the kidneys into the IVC.
- ○ **The suprarenal veins** drain the adrenal (suprarenal) glands.
- ○ **The inferior phrenic veins** drain the inferior aspect of the diaphragm.
- ○ **Three hepatic veins** drain the liver, extending a short distance from its superior surface to the IVC.

Inferior Vena Cava and Branches

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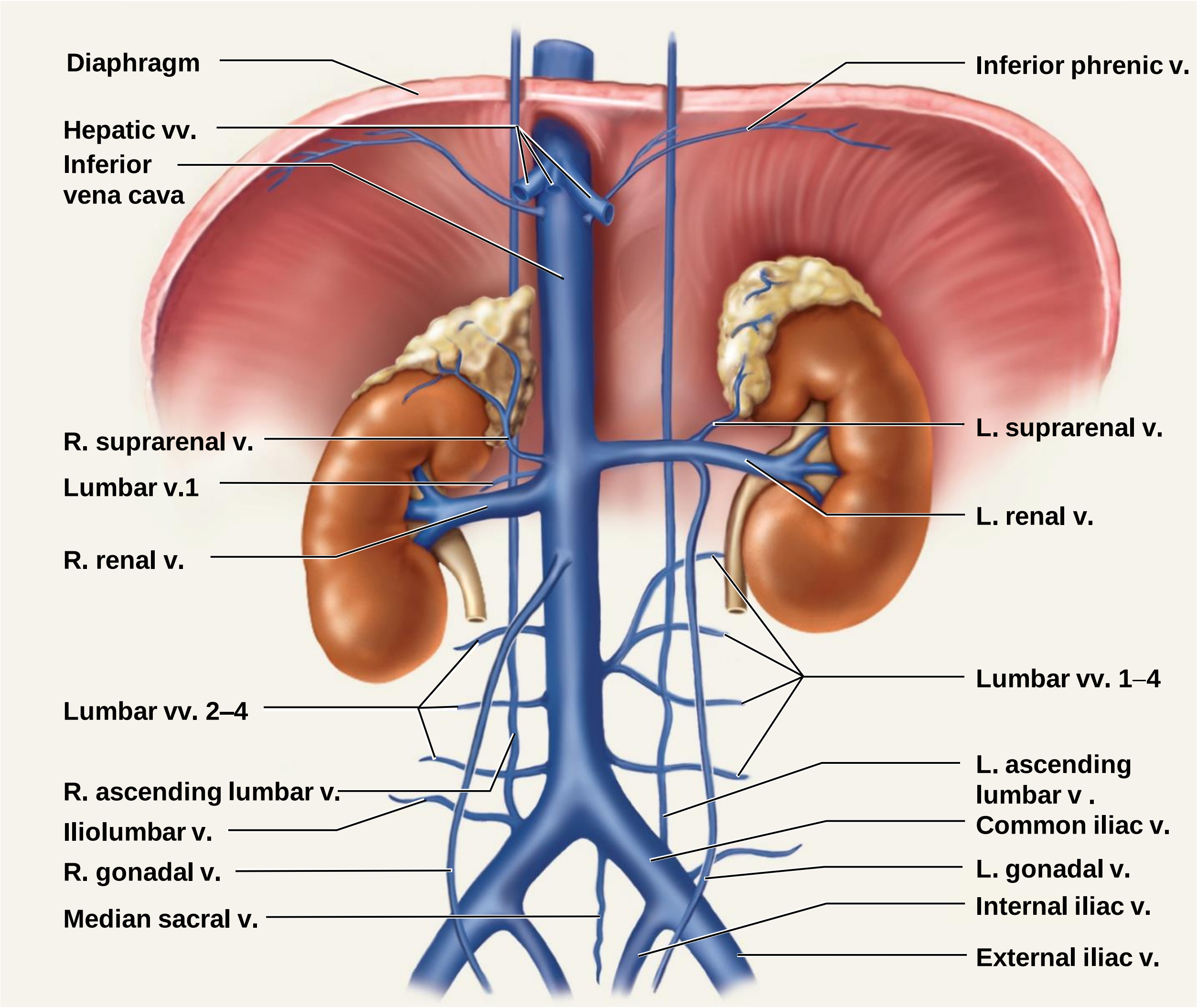


Figure 20.32

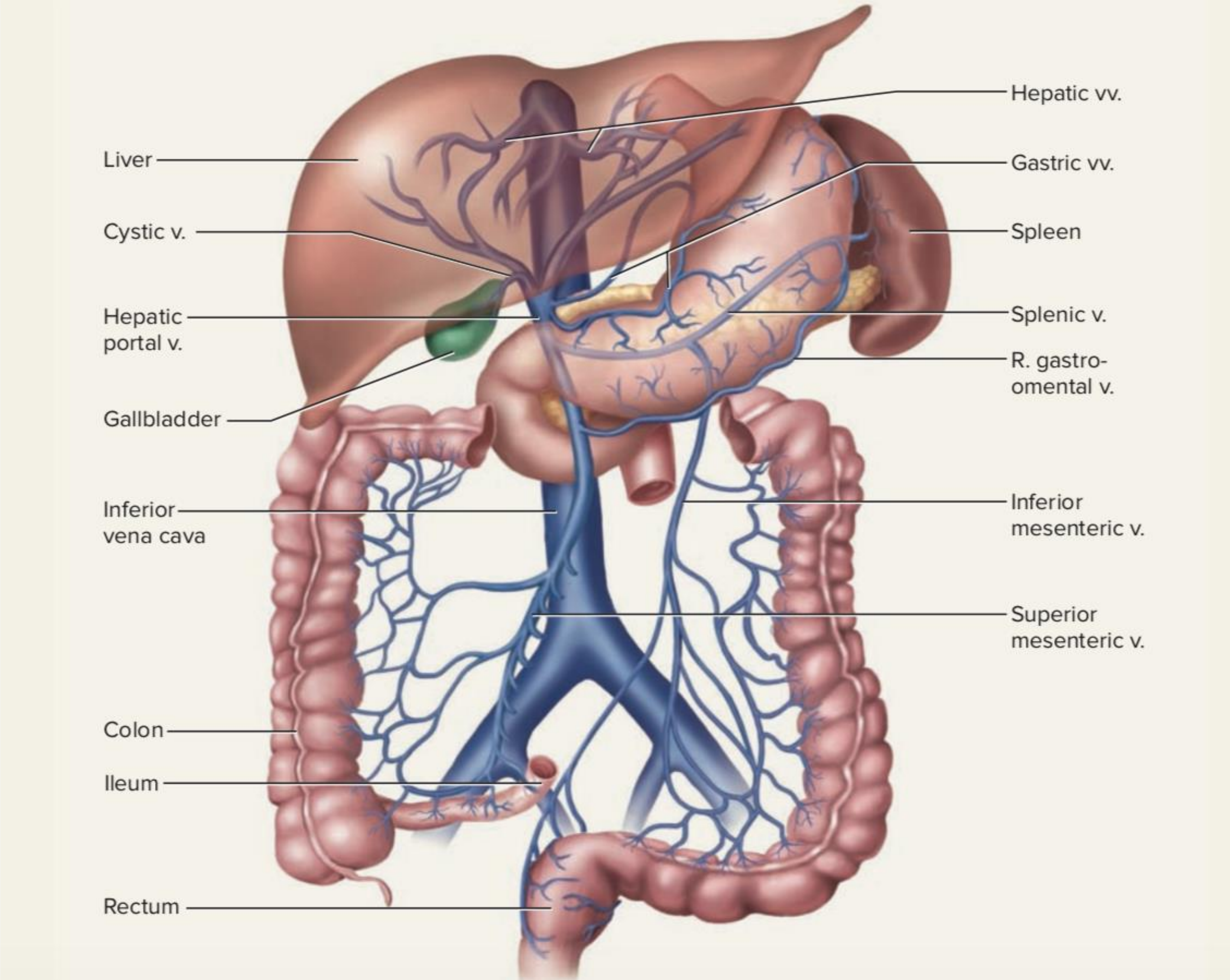
Veins of the Abdominal and Pelvic Region

- **Veins of the Abdominal Wall**

  - **ascending lumbar veins** receives blood from the common iliac veins below and from the aforementioned lumbar veins of the posterior body wall

- **The Hepatic Portal System**

  - **The hepatic portal system** receives all of the blood draining from the abdominal digestive tract, as well as from the pancreas, gallbladder, and spleen.**principal veins are as follows:**
    - **The inferior mesenteric vein** receives blood from the rectum and distal part of the colon.
    - **The superior mesenteric vein** receives blood from the entire small intestine, ascending colon, transverse colon, and stomach.
    - **The splenic vein** drains the spleen and travels across the abdominal cavity toward the liver**.**
    - **The hepatic portal vein**
    - **The left and right gastric veins** form an arc along the lesser curvature of the stomach and empty into the hepatic portal vein.

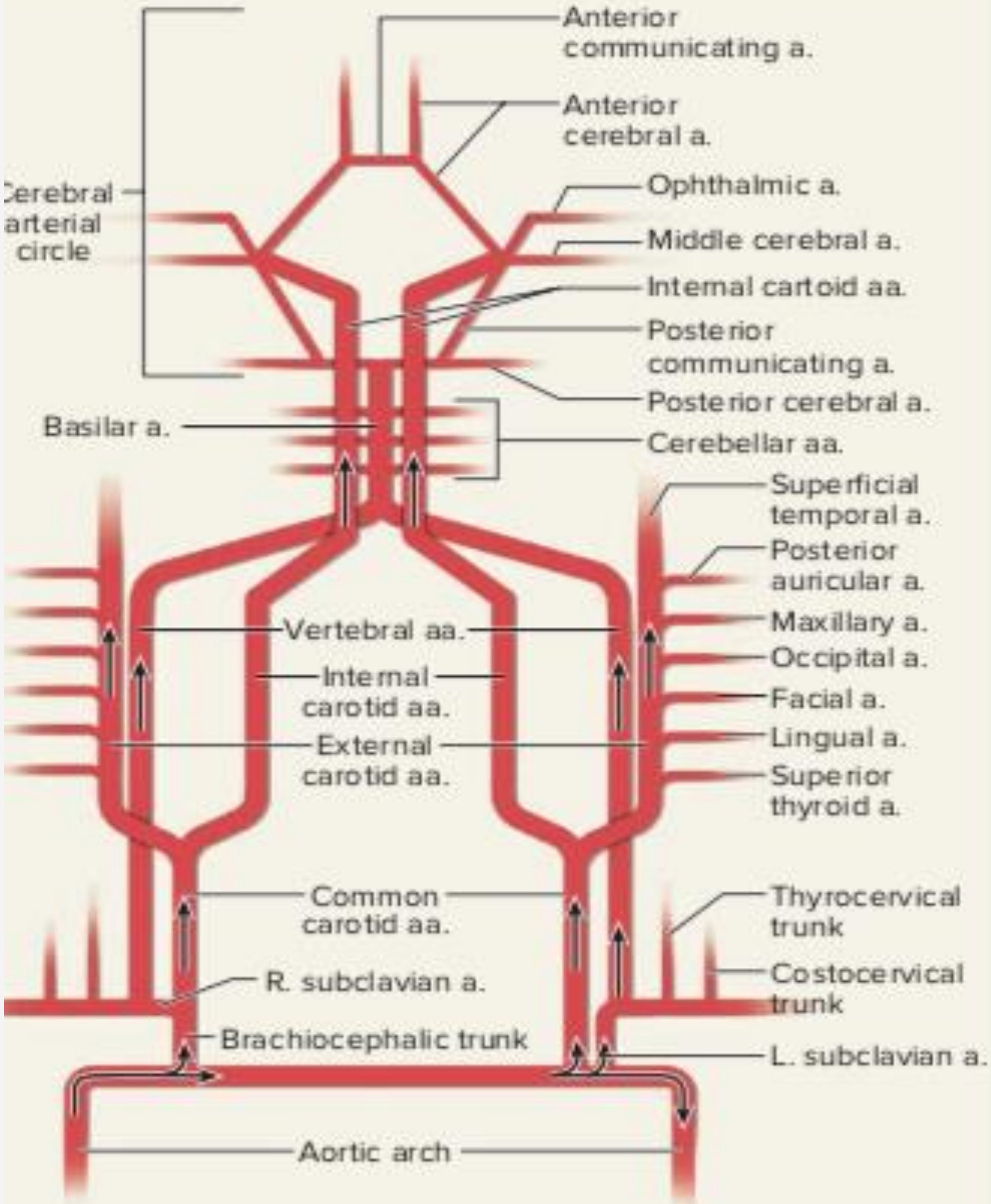

Hepatic vv.
Liver
Gastric vv.
Cystic v.
Spleen
Hepatic
portal v.
Splenic v.
R. gastro-
omental v.
Gallbladder
Inferior
vena cava
Inferior
mesenteric v.
Superior
mesenteric v.
Colon
Ileum
Rectum

Circulatory System

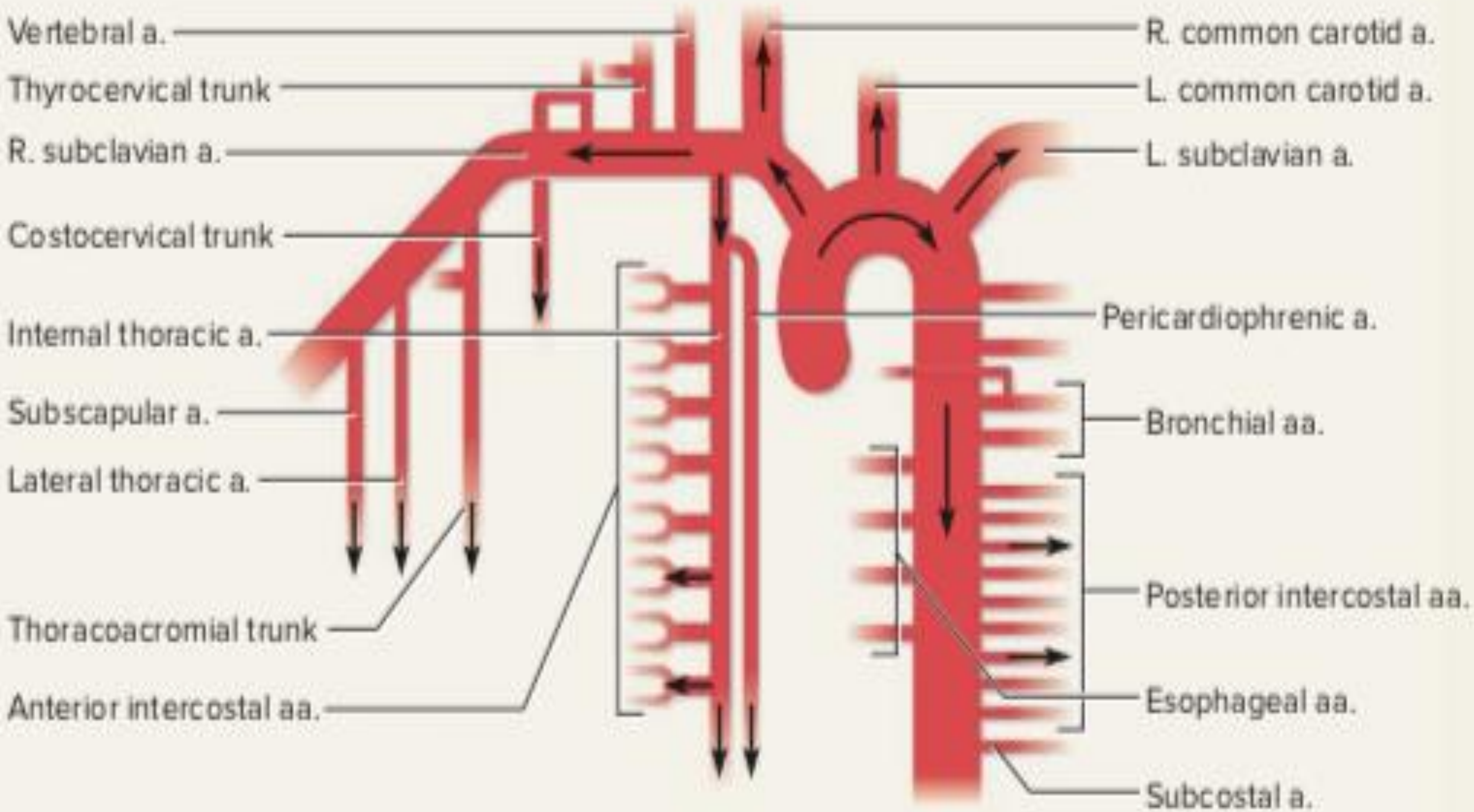
-BLOOD VESSELS AND CIRCULATION

Al-Farabi Kazakh National University Higher School of Medicine

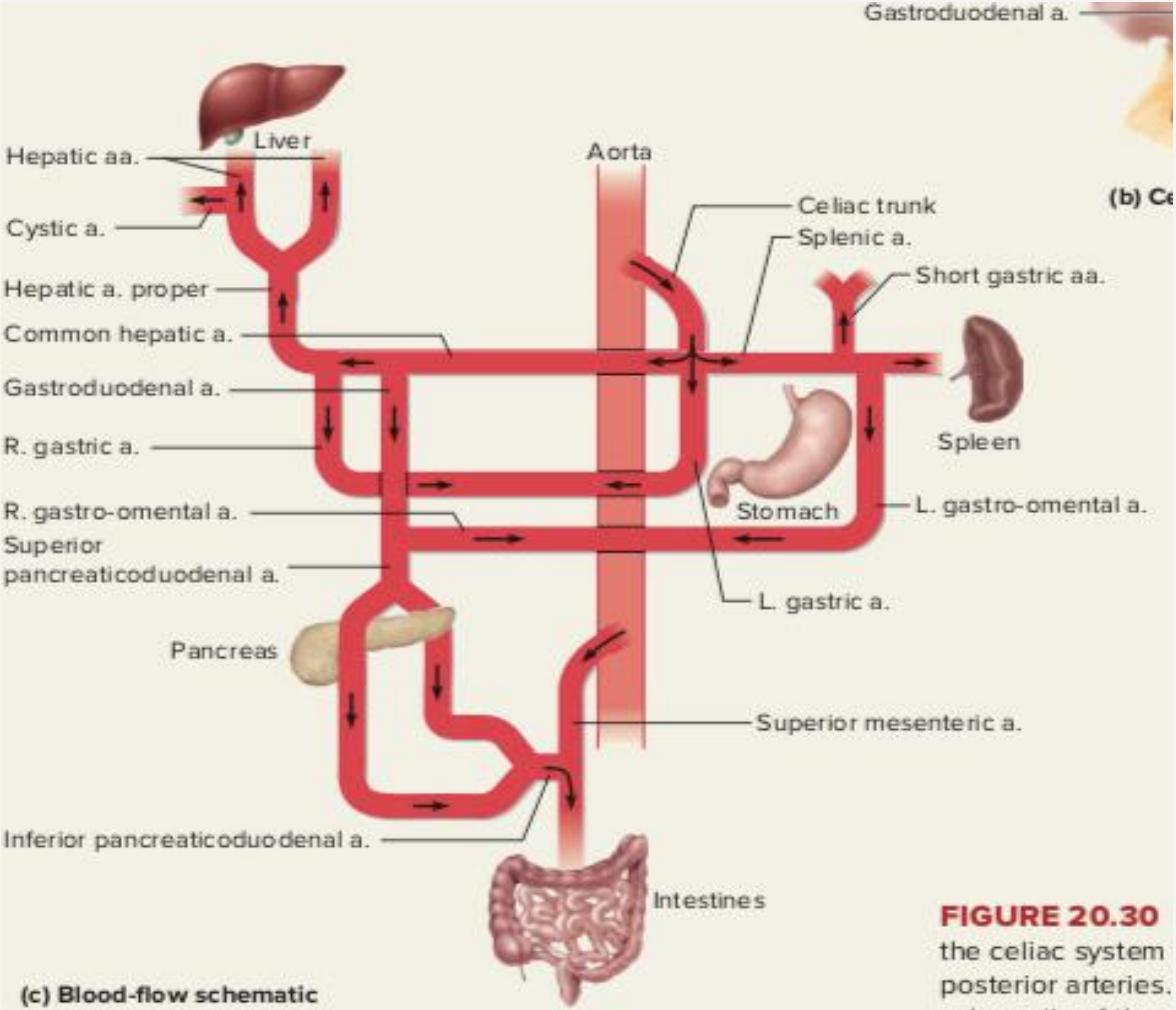
◆ PART VI



(b) Anterior view, blood-flow schematic



(b) Blood-flow schematic



(c) Blood-flow schematic

FIGURE 20.30
the celiac system
posterior arteries.
schematic of the c

Mesenteric Arteries

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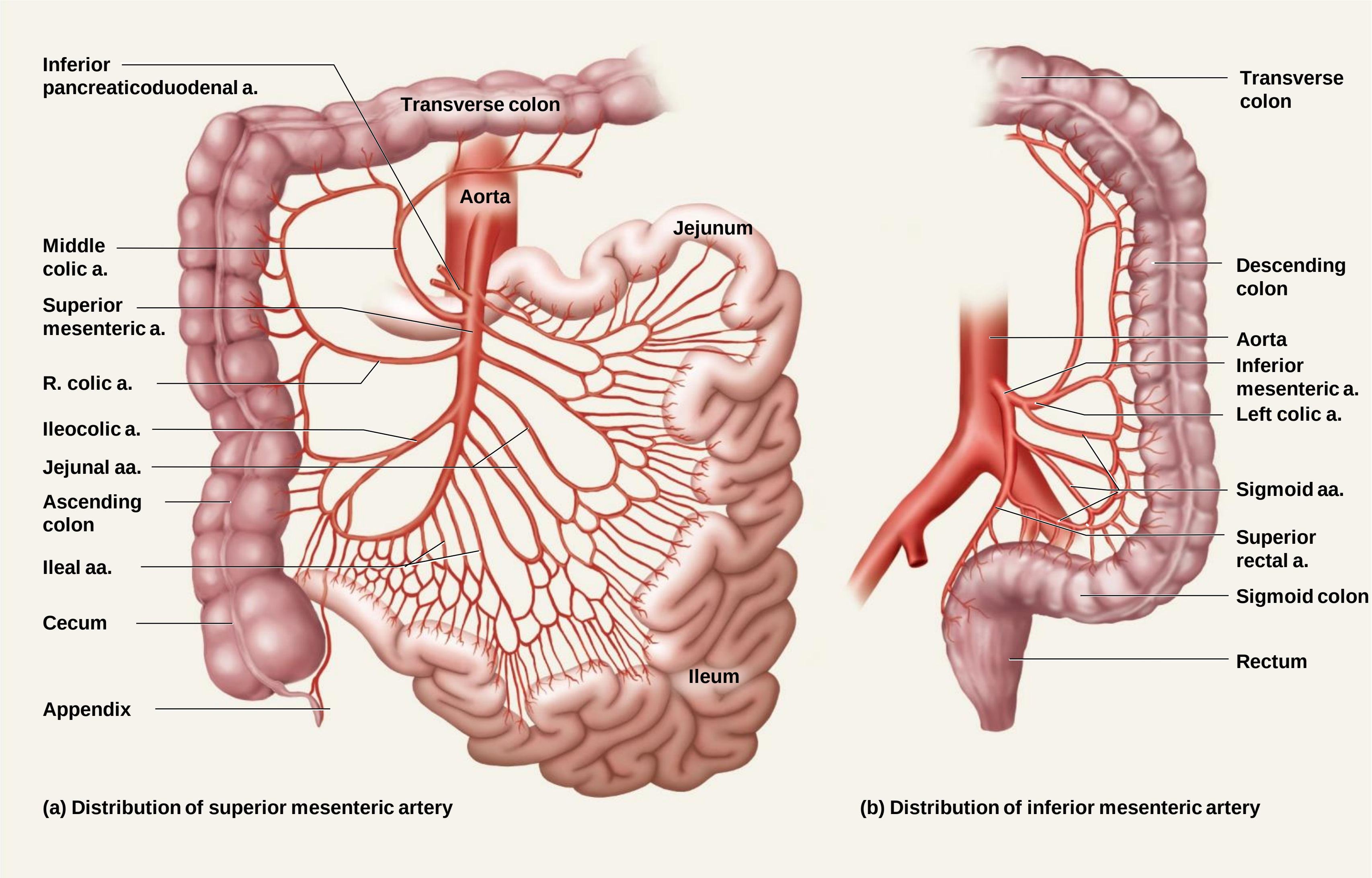
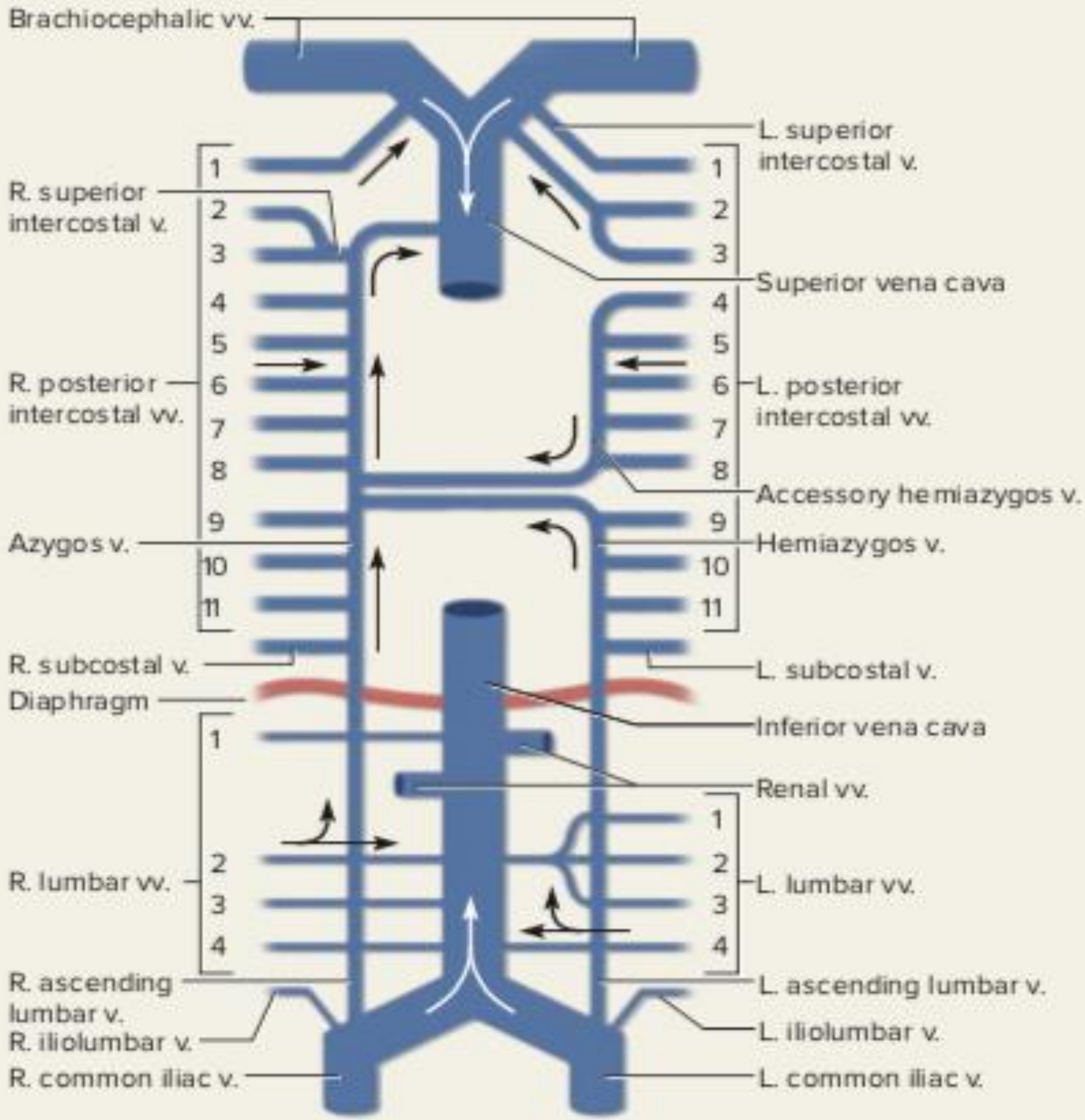
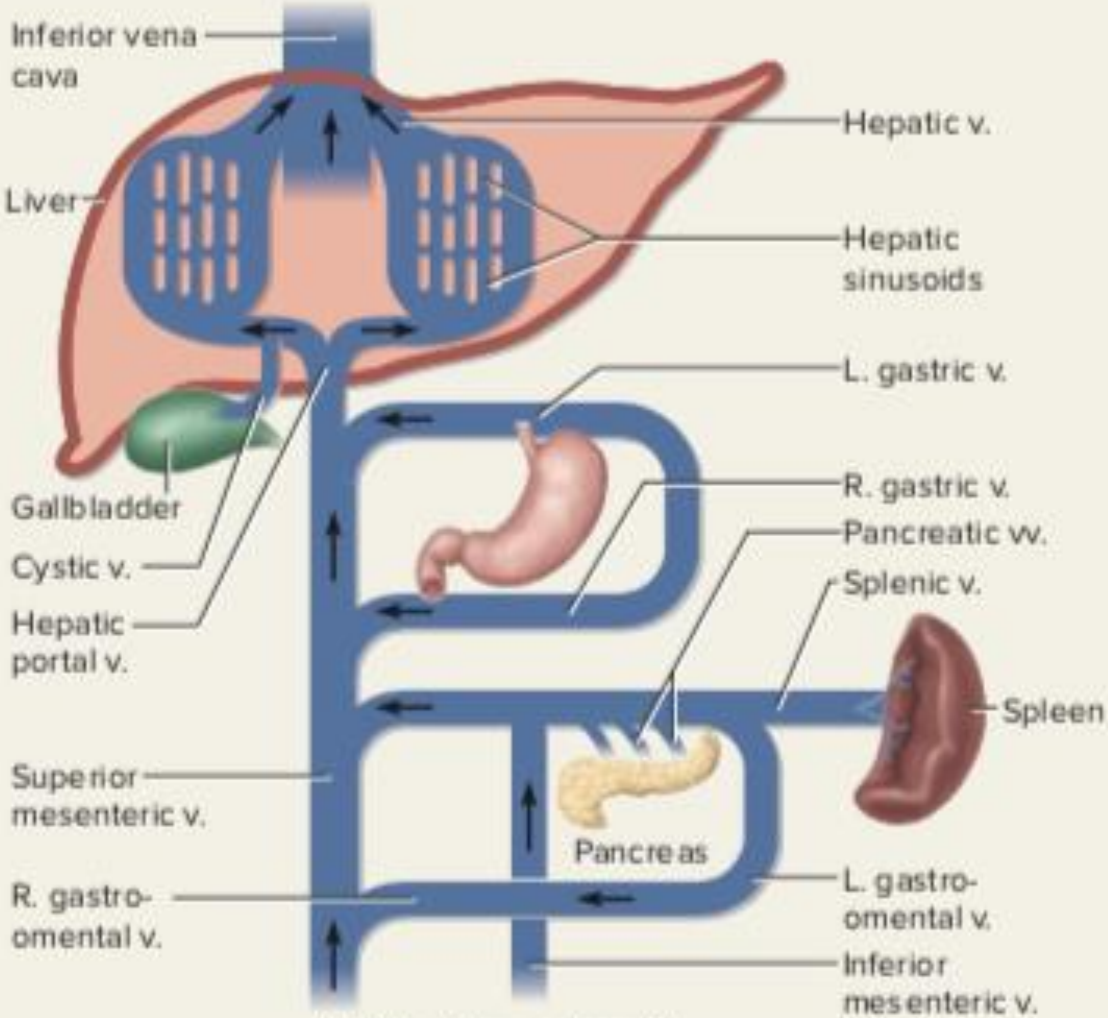


Figure 20.31 a-b



Brachiocephalic vv.
L. superior intercostal v.
R. superior intercostal v.
Superior vena cava
R. posterior intercostal vv.
L. posterior intercostal vv.
Accessory hemiazygos v.
Azygos v.
Hemiazygos v.
R. subcostal v.
L. subcostal v.
Diaphragm
Inferior vena cava
Renal vv.
R. lumbar vv.
L. lumbar vv.
R. ascending lumbar v.
L. ascending lumbar v.
L. iliolumbar v.
R. iliolumbar v.
R. common iliac v.
L. common iliac v.
1
2
3
4
5
6
7
8
9
10
11

(b)



(b) Blood-flow schematic

LEARNING OUTCOMES

As a result of the lesson you will be able to:

- ***identify the principal systemic arteries and veins of the limbs;***
- ***trace the flow of blood from the heart to any region of the upper or lower limb and back to the heart.***

The Shoulder and Arm (Brachium)

- right subclavian artery; the left subclavian artery
- axillary artery
- circumflex humeral arteries
- brachial artery
- deep brachial artery
- radial collateral artery
- superior ulnar collateral artery

The Forearm, Wrist, and Hand

- radial artery
- ulnar artery
- interosseous 24 arteries -**anterior interosseous artery and posterior interosseous artery**
- palmar arches -**deep palmar arch** and the **superficial palmar arch**

Arteries of the Upper Limb

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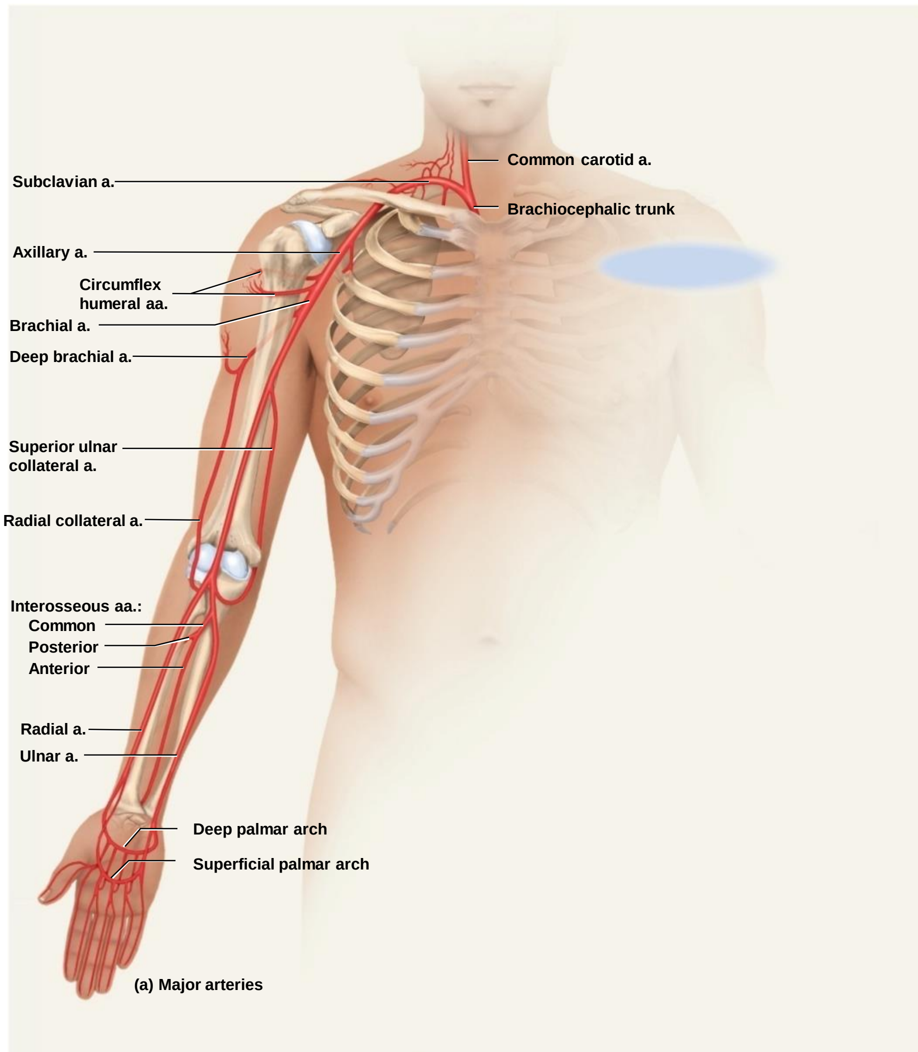
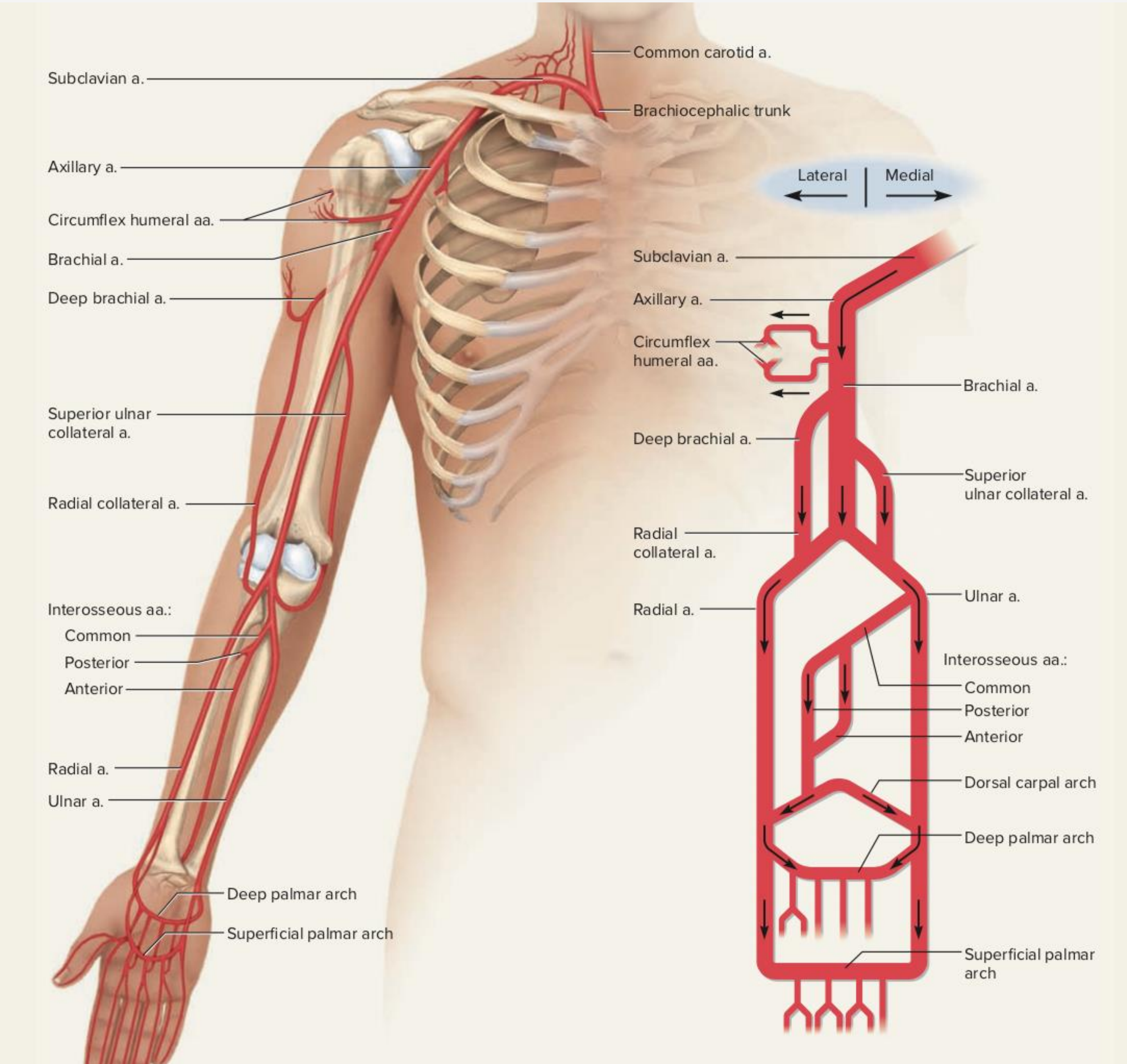


Figure 20.34a

- subclavian passes between clavicle and 1st rib
- vessel changes names as passes to different regions
  - **subclavian** to **axillary** to **brachial** to **radial** and **ulnar**
  - **brachial** used for BP and **radial** artery for pulse



(a) Major arteries

(b) Blood-flow schematic

Veins of the Upper Limb

- I. Superficial Veins
- dorsal venous network
- cephalic[25] vein
- basilic[26] vein
- median cubital vein
- median antebrachial vein drains a network of blood vessels in the hand called the **superficial palmar venous network.**
- Deep Veins
- . The **deep** and **superficial venous palmar arches** receive blood from the fingers and palmar region. They are anastomoses that join the radial and ulnar veins.
- 2. Two **radial veins** give rise to one of the brachial veins described shortly.
- 3. Two **ulnar veins** unite near the elbow to form the other brachial vein.
- 4. The two **brachial veins** continue up the brachium, converge into a single vein just before the axillary region.
- 5. The **axillary vein** forms by the union of the brachial and basilic veins. At the lateral margin of the first rib, it changes name to the subclavian vein.
- 6. The **subclavian vein** meets the internal jugular vein of the neck. There it becomes the brachiocephalic vein. The right and left brachiocephalics converge and form the superior vena cava, which empties into the right atrium of the heart.

Superficial and Deep Veins of Upper Limb

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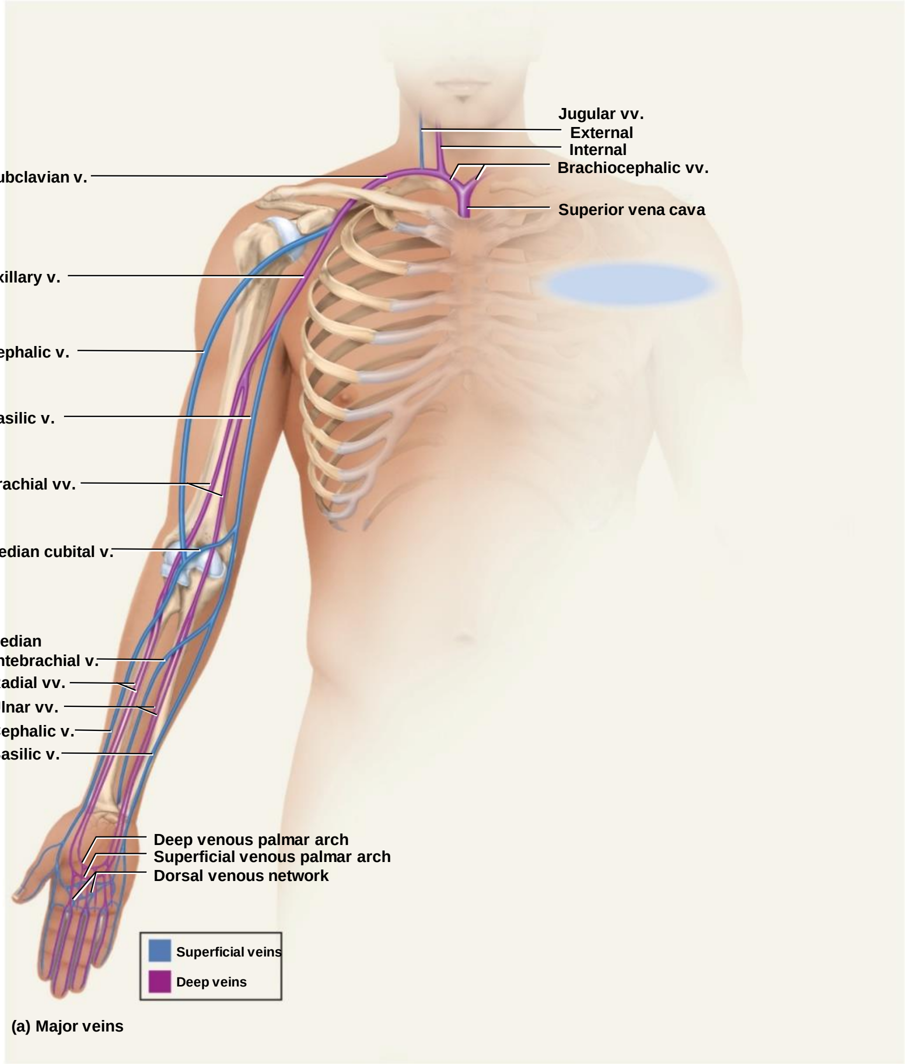
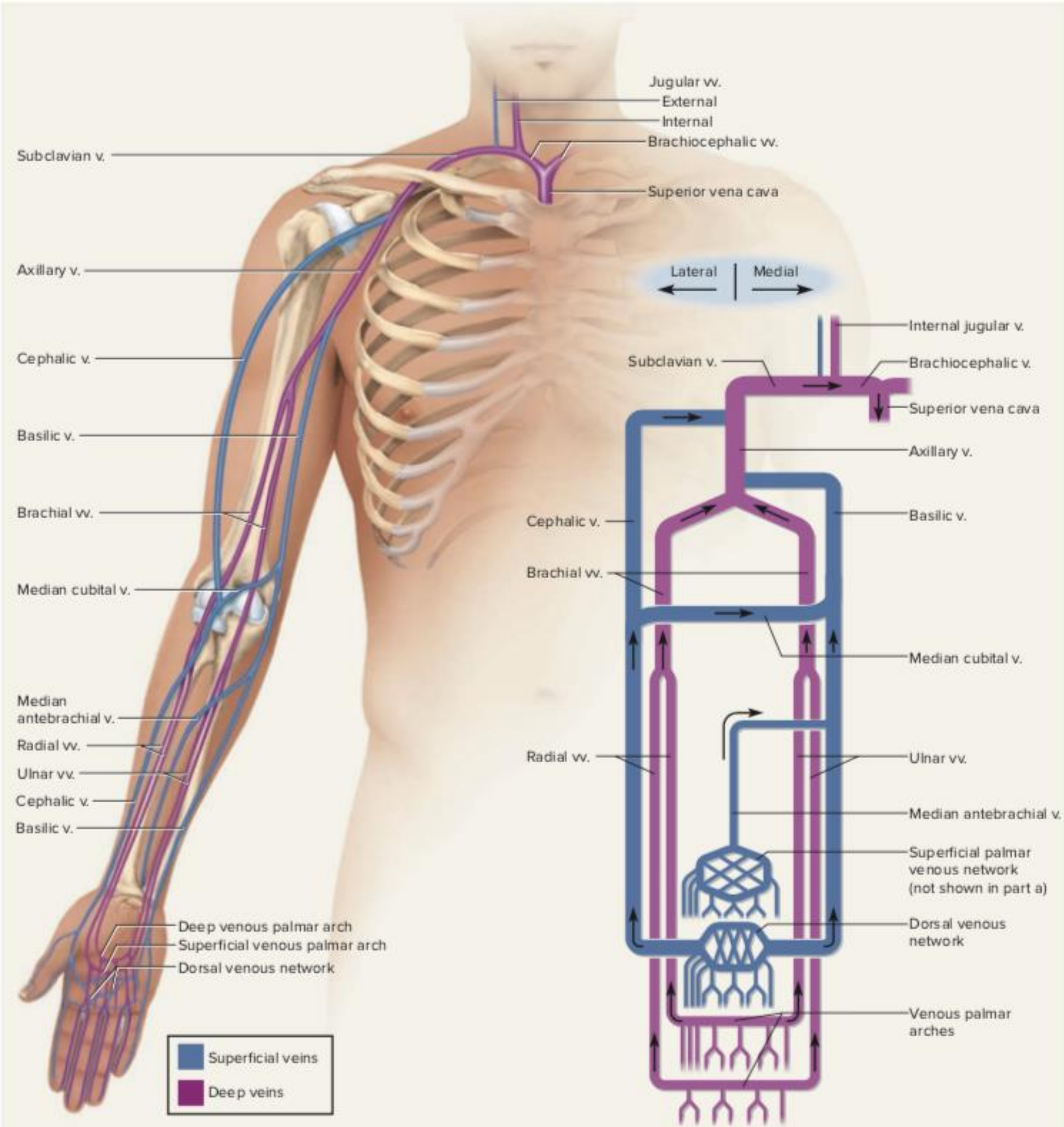


Figure 20.35a



(a) Major veins

(b) Blood-flow schematic

Arteries of the Lower Limb

- I. Arteries from the Pelvic Region to the Knee
  - The **external iliac artery** sends small branches to the skin and muscles of the abdominal wall and pelvis.
  - The **femoral artery**
- a. The **deep femoral artery** arises from the lateral side of the femoral, within the triangle. It is the largest branch and is the major arterial supply to the thigh muscles.
- b.Two **circumflex femoral arteries** arise from the deep femoral, encircle the head of the femur, and anastomose laterally. They supply mainly the femur, hip joint, and hamstring muscles.
  - The **popliteal artery** in the popliteal fossa at the rear of the knee. it gives off anastomoses called **geniculararteries** that supply the knee joint.

Arteries the Leg and Foot

- The **anterior tibial artery** arises from the popliteal artery, it travels lateral to the tibia and supplies the extensor muscles. Upon reaching the ankle
- a. The **dorsal pedal artery** traverses the ankle and upper medial surface of the foot and gives rise to the arcuate artery.
- b. The **arcuate artery** sweeps across the foot from medial to lateral and gives rise to vessels that supply the toes.
- The **posterior tibial artery** supplying flexor muscles along the way. Inferiorly, gives rise to the following:
- a. The **medial** and **lateral plantar arteries** The medial plantar artery supplies mainly the great toe. The lateral plantar artery sweeps across the sole of the foot and becomes the deep plantar arch.
- b. The **deep plantar arch** gives off another set of arteries to the toes.
- The **fibular (peroneal) artery** supplying lateral muscles of the leg along the way, and ends in a network of arteries in the heel.

Arteries of the Lower Limb

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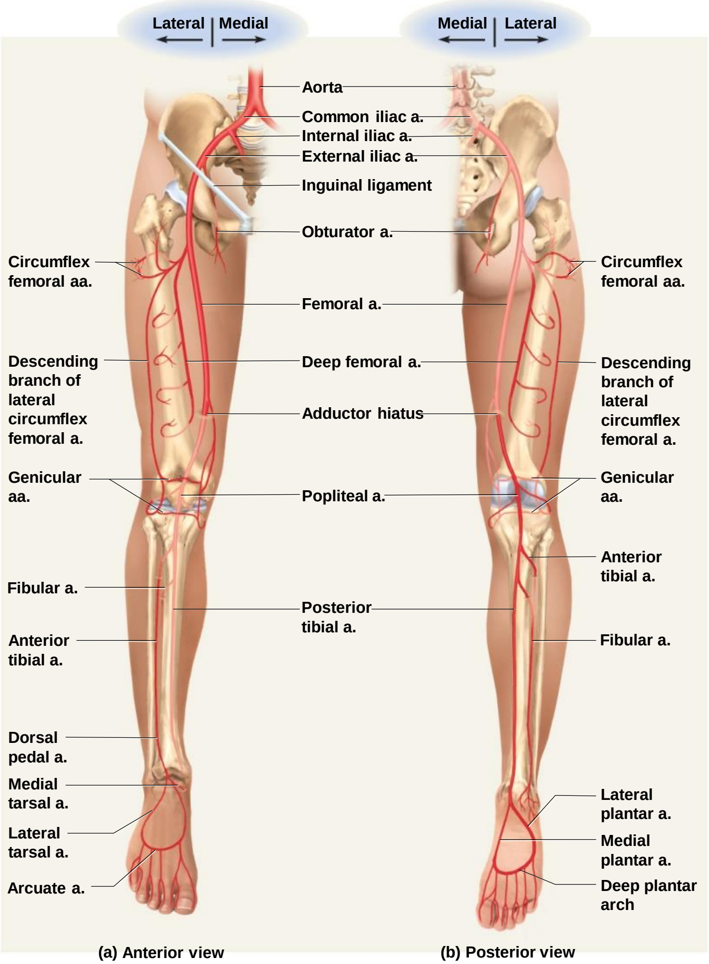
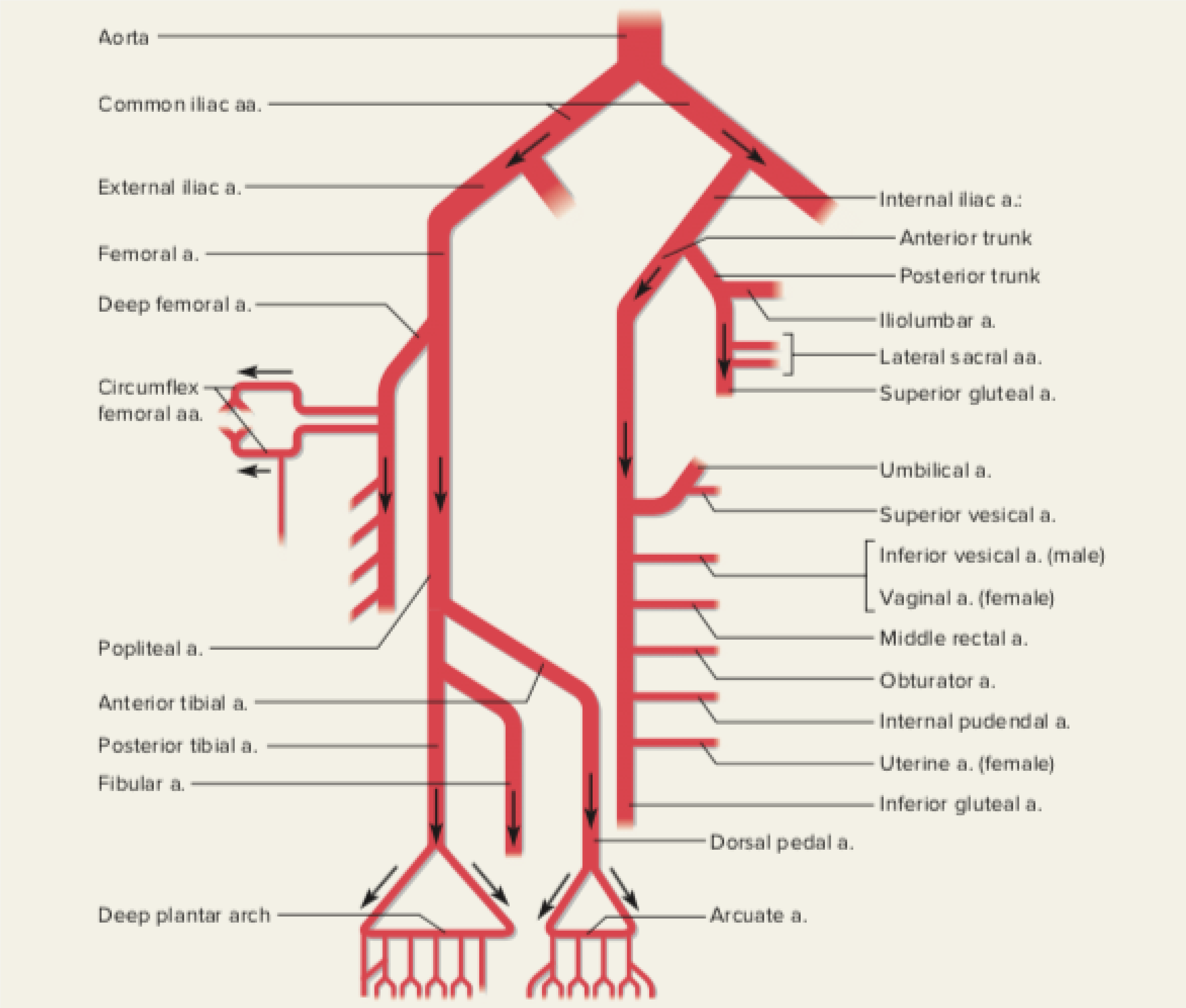


Figure 20.36 a-b

- branches to the lower limb arise from external iliac branch of the common iliac artery



Aorta
Common iliac aa.
External iliac a.
Femoral a.
Deep femoral a.
Circumflex femoral aa.
Popliteal a.
Anterior tibial a.
Posterior tibial a.
Fibular a.
Deep plantar arch
Internal iliac a.:
Anterior trunk
Posterior trunk
Iliolumbar a.
Lateral sacral aa.
Superior gluteal a.
Umbilical a.
Superior vesical a.
Inferior vesical a. (male)
Vaginal a. (female)
Middle rectal a.
Obturator a.
Internal pudendal a.
Uterine a. (female)
Inferior gluteal a.
Dorsal pedal a.
Arcuate a.

Veins of the Lower Limb

- The Superficial Veins
- The **dorsal venous arch** collects blood from the toes and more proximal part of the foot, and has numerous anastomoses similar to the dorsal venous network of the hand.
- The **small (short) saphenousvein** arises from the lateral side of the arch and passes up that side of the leg as far as the knee. There, it drains into the popliteal vein.
- The **great (long) saphenous vein,** the longest vein in the body, arises from the medial side of the arch and travels all the way up the leg and thigh to the inguinal region. It empties into the femoral vein slightly inferior to the inguinal ligament. It is commonly used as a site for the long-term administration of intravenous fluids; it is a relatively accessible vein in infants and in patients in shock whose veins have collapsed. Portions of this vein are commonly used as grafts in coronary bypass surgery. The great and small saphenous veins are among the most common sites of varicose veins.

Veins of the Lower Limb

- Deep Veins
- The **deep plantar venous arch** (fig. 20.39b) receives blood from the toes and gives rise to **lateral** and **medial plantar veins** on the respective sides. T
- The two **posterior tibial veins**
- The two **fibular (peroneal) veins** ascend the back of the leg and similarly converge like a Y.
- The **popliteal vein** begins near the knee by convergence of these two inverted Ys. It passes through the popliteal fossa at the back of the knee.
- The two **anterior tibial veins**
- The **femoral vein** is a continuation of the popliteal vein into the thigh. It drains blood from the deep thigh muscles and femur.
- The **deep femoral vein** drains the femur and muscles of the thigh supplied by the deep femoral artery. The **external iliac vein** is formed by the union of the femoral and great saphenous veins near the inguinal ligament.
- The **internal iliac vein** Its tributaries drain the gluteal muscles; the medial aspect of the thigh; the urinary bladder, rectum, prostate, and ductus deferens in the male; and the uterus and vagina in the female
- The **common iliac vein** is formed by the union of the external and internal iliac veins. The right and left common iliacs then unite to form the inferior vena cava.

Superficial and Deep Veins of Lower Limb

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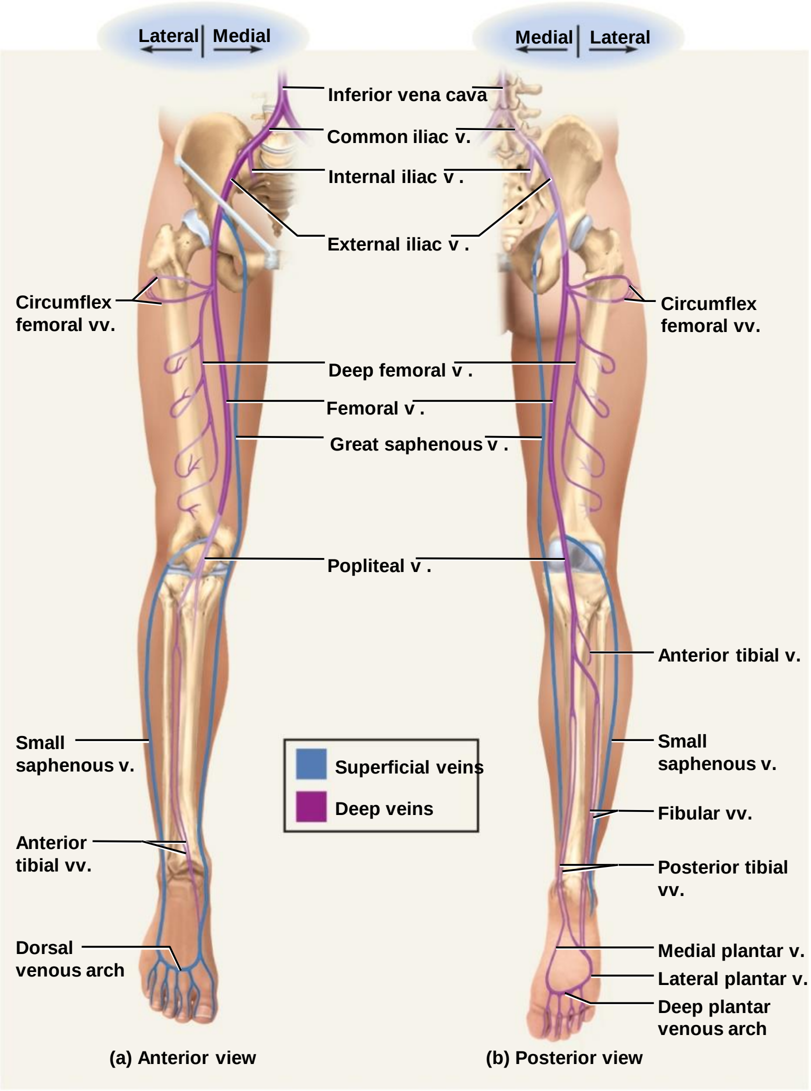
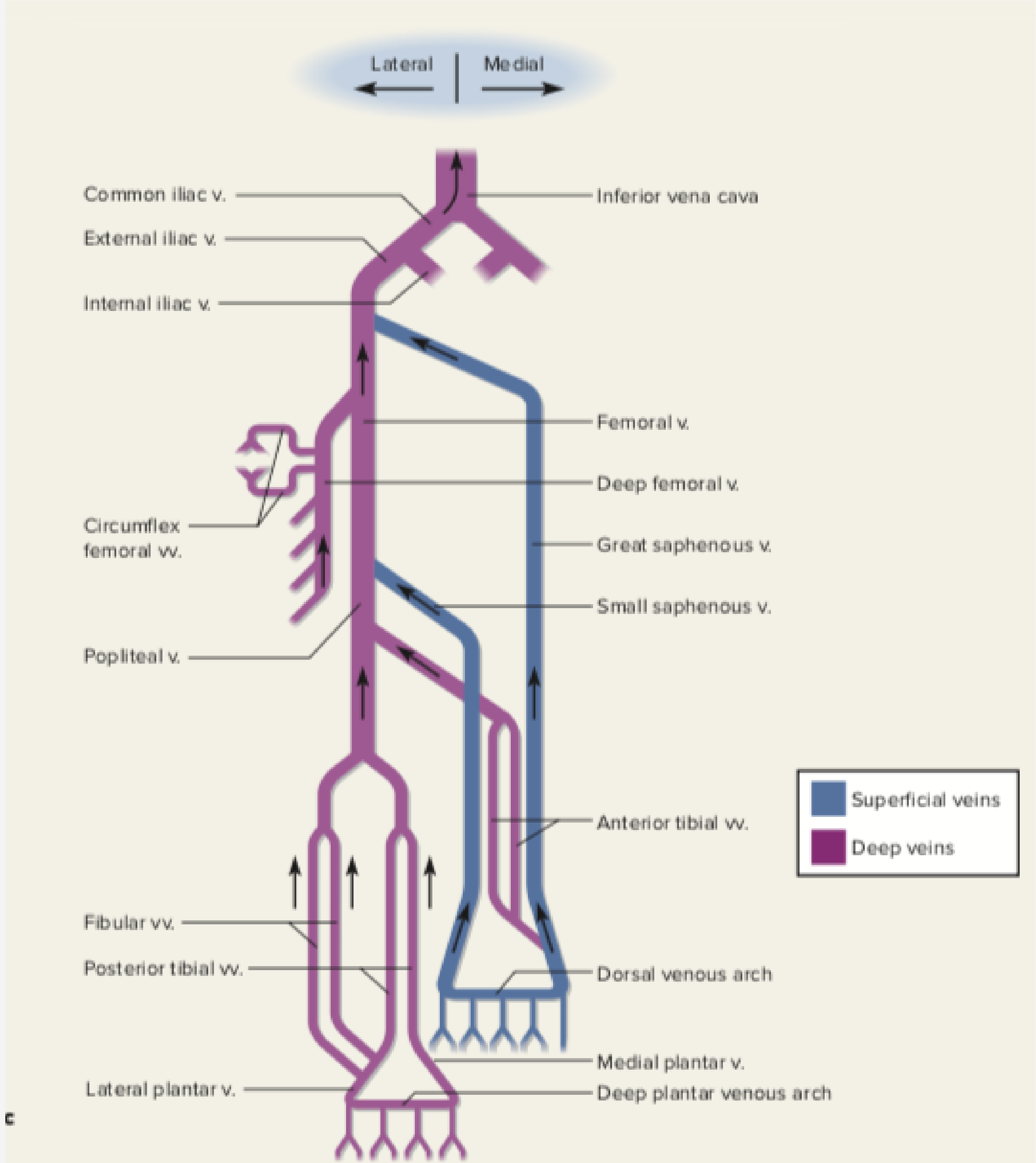


Figure 20.38 a-b



Lateral
Medial
Common iliac v.
External iliac v.
Internal iliac v.
Inferior vena cava
Femoral v.
Deep femoral v.
Circumflex femoral vv.
Great saphenous v.
Small saphenous v.
Popliteal v.
Anterior tibial vv.
Superficial veins
Deep veins
Fibular vv.
Posterior tibial vv.
Dorsal venous arch
Medial plantar v.
Lateral plantar v.
Deep plantar venous arch
c